# EFFECT OF COATED EXPANDED POLYSTYRENE (CEPS) BEADS AGGREGATES ON THE PROPERTIES OF HOLLOW CONCRETE BLOCK

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By

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I hereby declare that all corrections and comments made by the supervisor(s) and examiner have been taken into consideration and rectified accordingly.

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# ABSTRAK

Industri pembinaan kian makmur, sentiasa berkembang dan dijangka mendominasi keseluruhan ekonomi dunia. Tidak disangkal lagi, permintaan bahan pembinaan akan meningkat. Oleh disebabkan permintaan bahan sumber yang semakin meningkat, inovasi baru ataupun alternatif diperlukan untuk mennyelesaikan permintaan tinggi untuk kerja-kerja pembinaan pada masa akan datang. Oleh yang demikian, pengunaan bahan pembinaan semulajadi tidak lagi relevan dan bahan yang boleh diperbaharui ataupun bahan buangan seperti polistirena patut dipilih sebagai alternatif. Polistirena adalah bahan plastik yang versatil, digunakan untuk pelbagai kegunaan di seluruh dunia. Walau bagaimanapun, bahan ini tidak boleh dibiodegradasi, jadi ianya perlu dikitar semula untuk kesejahteraan persekitaran masa akan datang. Polistirena bermanfaat untuk digunakan sebagai alternatif dalam industri pembinaan disebabkan oleh sifat penebat haba dan bunyi dan ringan mereka. Dalam kajian ini. 'Expanded Polystyrene' (EPS) yang bersalut telah digunakan sebagai pengganti aggregat halus (separuh) di dalam konkrit blok berlubang. Salutan pada EPS tersebut meningkatkan ikatan antara campuran simen dengan EPS. Konkrit blok berlubang disediakan dengan campuran mortar kering menggunakan mesin pemampat hidraulik.beberepa ujian seperti kekuatan mampatan, penyerapan air, ketumpatan dan kadar serap permulaan dijalankan untuk mengetahui ciri-ciri blok konkrit. Perbandingan antara konkrit blok dengan CEPS dan konkrit blok biasa telah dibuat. Konkrit blok CEPS mempunyai ketumpatan yang lebih rendah, kekuatan mampatan yang lebih rendah dan kadar penyerapan air yang lebih tinggi berbanding konkrit blok biasa. Oleh itu, konkrit blok CEPS sesuai digunakan untuk pembinaan ringan dan untuk kegunaan yang bukan menahan beban. Bahan tambah dan reka bentuk bancuhan yang lain perlu digunakan sekiranya ingin menggunakan blok ini sebagai unit penahan beban.

# ABSTRACT

The construction industry is prospering and expected to continue growing and expected to dominate the overall world economy. Indeed, the construction materials demand will increase undoubtedly. Due to the increasing demand of the resources, brand new innovation or alternatives is needed to overcome the high demand of the construction activities in the future. Therefore the usage of natural materials for construction materials no longer relevant and renewable or waste materials such as polystyrene should be chosen as an alternative. Polystyrene is a versatile plastic materials that is widely used for variety of applications around the world. However, this materials is non bio-degradable so it needs to be recycled in order to have sustainable environment. Polystyrene is advantageous to be used as an alternative in construction industry because of their thermal and sound insulation properties and also their lightweight characteristic. In this study, coated expanded polystyrene (EPS) have been used as partial replacement of fine aggregates in the hollow concrete block. The coating of the EPS help to increase the bond between cement paste and EPS. The hollow concrete block samples are prepared with dry mortar mixture with hydraulic compression machine. Several tests incudes compressive strength, water absorption, density, and initial rate of suction have been conducted to know their properties. Comparison of the properties of samples with and without CEPS have been made. CEPS block samples show less density, more water absorption and lower strength compared to the conventional block samples. Therefore, CEPS block are suitable to be used for lightweight construction and non-load bearing application. If they were to be used as load bearing unit, admixtures and different mix design need to be used to achieve better properties.

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| | |
|---|---|
| EPS | Expanded Polystyrene |
| CEPS | Coated Expanded Polystyrene |
| CMU | Concrete Masonry Unit |
| BS | British Standard |
| MS | Malaysian Standard |
| ASTM | American Society of Testing and Materials |
| ISO | International Organization for Standardization |
| OPC | Ordinary Portland Cement |
| IRA | Initial Rate of Suction |

# CHAPTER 1

# INTRODUCTION

## 1.1 Background

The construction industry is booming and expected to continue growing and expected to dominate the overall economy. Indeed, the construction materials demand will increase undoubtedly. Due to the increasing demand of the resources, brand new innovation is needed to overcome the high demand of the construction activities.

Construction materials can be categorized into two types which are natural and synthetic materials. Natural materials are those that are minimally or unprocessed materials while synthetic materials are materials that have been industrialized. The most common construction materials that have been sought of throughout the decades are cements and aggregates. These materials can produce various concrete products including concrete block. Concrete block is the common building materials that have been widely used in construction industry.

Generally, concrete block comprised of Portland cements, aggregates and water and it is widely known that aggregates is the basic materials needed in every construction activities. The use of aggregates in the concrete block contribute the most to the weight of the block. Thus, the heavyweight aggregates need to be replaced with another materials that have the same properties as natural aggregates. Therefore, in order to pursue sustainable construction industry, another study in order to continue developing innovative and environment friendly concrete block should be done.

Ferrandiz-Mas et al., (2014) states that, Expended Polystyrene Beads (EPS) is one of the solution to replace natural aggregates in construction industry and it is an environmentally friendly materials. Expanded polystyrene (EPS) is a stable with low density, non-absorbent, hydrophobic, closed cell nature consisting of discrete air voids in a polymer matrix. (D.Saradhi, 2005). EPS is commonly used in a variety of applications because of its features of lightweight, good thermal insulation, moisture resistance, durability, acoustic absorption and low thermal conductivity.

However, due to hydrophobic characteristic of EPS which also have closed cell structures, it will not mixed well with cement paste will lead to segregation. To address the segregation issues of the mortar containing EPS, the EPS need to be treated in order to promote enhancement of stickiness to the cement paste. The treated EPS, which the EPS have been coated with chemical coater (hydrophilic- type) that is also known as cementitious layer increase the affinity of EPS beads to water (Ravindrarajah and Tuck, 1994). Thus, enhance the bonding between cement paste and the EPS beads and eliminate segregation issues.

Primarily, a lot of study have been conducted on concrete block. However, very little study on concrete block incorporating EPS beads have been done despite the tremendous amount of studies regarding concrete with EPS beads. Thus, this research is expected to be an alternative solutions to address the issues of attaining sustainable construction industries.

## 1.2 Problem Statement

Concrete block is a concrete product that made of Portland cement, aggregates (sand or fine aggregates) and also known as mortar. Concrete block also referred as concrete masonry units (CMU) and produced in standard size rectangular block that widely used in building construction. Concrete block is one of the most sought out building materials. However, conventional or common concrete block are usually heavy due to the contribution of weight from aggregates.

On the other hand, Expanding Polystyrene (EPS), a plastic material derived from crude oil and used in variety of application in the industries including concrete products. EPS is a low density, inert hydrocarbon thermoplastic that used extensively in packaging and thermal insulation. Due to high volume of waste EPS and the environmental issues associated with EPS, it is important to develop new beneficial reuse application of this materials that exploit their lightweight properties.

Thus, with the incorporation of EPS in the concrete block, a lightweight block can be achieved due to the properties of EPS that act as sand replacement which is lighter than natural sand.

## 1.3 Objective

1. To investigate the effect of CEPS beads aggregates to the properties of hollow concrete block.
2. To evaluate and compare the properties of hollow concrete block incorporating CEPS beads with conventional hollow concrete block.

## 1.4 Scope of Work

This study will be focusing on assessment of CEPS beads as replacement of natural fine aggregates in the hollow concrete block. The conventional hollow concrete block was designed with a proportion of 1:6 (cement: sand). This conventional hollow concrete block will be treated as controlled sample and will be compared to the concrete block with CEPS. The performance of the mechanical properties of each sample will assessed through various testing and the result will be compared and discussed in the last chapter.

## 1.5 Layout of Dissertation

This dissertation consist of five different chapter:

a) Chapter 1

Chapter 1 first introduce the research with background of study, and problem statement that have been identified to fully understand the reason and relevancy of the study being conducted. Next, the objectives of the research which the research is aimed to achieve is stated and also scope of work that involved the explanation of the flow and procedure of work during throughout the research.

b) Chapter 2

Chapter 2 presents the literature review in conjunction with the research title. Previous works that incorporated the use of EPS beads as sand replacement have been reviewed and summarized. A brief overview of literature review is also included.

c) Chapter 3

Chapter 3 explain the methodology undertaken to achieve the objectives of the research. Further explanation regarding the methods, tests conducted and standard reference used can be viewed in this chapter to facilitate understanding of the execution of the project.

d) Chapter 4

Chapter 4 will compiled all the research results for each test that have been conducted and the result was discussed. The discussion will show either the objective of the research is accomplished or the research have produce substantial result to facilitate future research or to be used in real project.

e) Chapter 5

Lastly, Chapter 5 will summarized the findings in the research and conclude it. There are also recommendations that can be useful for future research.

# CHAPTER 2

# LITERATURE REVIEW

## 2.1 Overview

The construction industry is one of the most booming industry among all the industry in the world and will continue to evolve. Thus it is important that sustainability of the construction industry is a necessity which needs to be considered. Therefore sustainable initiative needs to be implemented in order to preserve for future materials demand. Instead of using natural sand, which contributes a lot to the weight of any concrete product especially for concrete block, a lightweight materials needs to be used to replace the natural sand in which a sustainable lightweight concrete block can be produced. Expanded Polystyrene (EPS) aggregates is one of the potential choices to be incorporated in construction industry. The presented literature review in this chapter intend to cover the objective of this study. Most of the previous research focuses on the use of expanded polystyrene for production of lightweight concrete. However, very little information that are available in the literature for its production as final building product (masonry unit). This chapter addresses previous research related to hollow concrete block, mortar, lightweight aggregates, EPS beads aggregates, coated EPS (CEPS) beads aggregates, and CEPS mortar and EPS block.

## 2.2 Hollow Concrete Block

Primarily, concrete block is used as a building material in the construction industry and also known as concrete masonry unit (CMU). Concrete block is only one of the various precast concrete production. The term precast is used because the concrete products are formed and hardened before they are brought to the construction site. According to Elgaali and Elchalakani (n.d), in comparison to conventional bricks, hollow block are better due to uniform quality, higher durability, faster construction and less labour requirement. Most of the hollow concrete blocks have one or more hollow cavities, and their sides may be cast smooth or may come with a design. As for the usage, hollow concrete blocks are stacked one at a time and held together with fresh concrete mortar to the desired length and height of the wall.

Hollow block has a standard size of 390 x 190 x 190 mm. however the size vary according to the manufacturer. Typically, 25% to 50% of the hollow block size are voids. In the manufacturing process, each typical hollow block is estimated to consume 2.0 kg of cement, 9.0 kg of sand, 11.0 kg of aggregate, and 0.80 kg of water. Thus, the manufacturing industry of concrete block consumed millions of metric tons of natural aggregate and fresh water around the world annually. Alternative materials (aggregates)

have been anticipated to provide a good alternative to the huge consumption these natural materials (Elgaali and Elchalakani, n.d).

In general, the concrete mixture used for concrete blocks has a higher percentage of sand and a lower percentage of gravel or maybe no gravel at all and water that also known as mortar mixture. The mixture is different compared to conventional concrete mixtures used for general construction purposes. The mixture to produce a concrete block usually is a very dry, stiff mixture that will hold its shape when it is removed from the block mould (John, 1991).

## 2.3 Mortar

Mortar is one of the most seek material in Malaysia for a variety of non-structural work including bricklaying, floor rendering, screed and wall finishing. Mortar is made up of the mixture of cement, water and fine aggregates which is natural aggregates or local mining sand. Currently, the conventional mortar that contributed to heavy weight on structural member is commonly used for bricklaying and floor rendering.

Modernization of new technology offers new innovation to transform conventional mortar into the new, modified mortar. This newly modified mortar is known as lightweight mortar which has the same strength but different characteristic which contribute to a smaller cross-section of load bearing element and reduction in the size of foundation (Babu et al., 2006).

According to Tamut et al., (2014), lightweight mortar are advantageous to be used in construction due to lighter weight contribution , reduced self-weight of the structure and also increase thermal resistance. Uses of lightweight aggregates in the mortar mixture normally contribute to the achievement of a lightweight mortar.

## 2.4 Lightweight Aggregates

Xu et al. (2012) stated that, compared to conventional mixture, lightweight concrete or mortar shows some excellent characteristics such as lower density, higher specific strength, better thermal insulation and greater energy absorption which can be obtained by replacing typical natural aggregate either totally or partially with lightweight aggregates.

Generally, lightweight mortar has a bulk density of less than 15 kN/$m^3$ and the values will be varied upon the different type of aggregates used. There is various type of lightweight aggregates that can be used in the construction industry. Lightweight aggregate are broadly classified into two types which are natural such as pumice, diatomite, volcanic cinders, etc. and artificial such as perlite, clay, sintered fly ash, expanded shale, etc.

Expanded polystyrene (EPS) is a type of artificial lightweight aggregate with the density of only 10–30 kg/$m^3$ (Miled et al., 2004). Kaya and Kar (2014) also mentioned that EPS aggregates is a lightweight material that comprises 98% of air and 2% of polystyrene. However, due to the ultra-lightweight density of EPS, the lightweight aggregate concrete is prone to segregation during casting. Thus, many researchers have studied to overcome this drawback.

## 2.5 EPS Beads Aggregates

Expanded polystyrene (EPS) possesses various special characteristics such as lightweight, good thermal insulation, moisture resistance, durability, acoustic absorption and low thermal conductivity. Thus, EPS demand in the industry is increasing continuously as they are being used for a variety of application including building constructions. However, waste EPS has caused lots of environmental pollutions since it cannot be decomposed in nature. Therefore, utilization of waste EPS in concrete technology is a common scenario. (Kan et al., 2009).

EPS is a stable with low density, non-absorbent, hydrophobic, closed cell nature consisting of discrete air voids in a polymer matrix. (D.Saradhi, 2005). The closed cell structure prevents water absorption and it is also a highly compressible material. EPS beads are a stable material with the presence of any chemicals. However, it can be dissolved by the presence of concentrated acids, organic solvents and saturated aliphatic compound.

EPS aggregates are known as resin before being expanded by the steaming process and use of expanding agent. The resin are heated in a special machine that known as pre-expanders with steam at the temperature that range between 80°C to 100°C. The

density of the polystyrene will be reduced from 630 kg/$m^3$ to 10 – 35 kg/$m^3$. During pre-expansion the compact beads were converted onto cellular plastic beads with the small closed cell that contains high air voids (Miled et al., 2004). .

EPS' hydrophobic characteristic because of their close cell structure consisting of 98% of air and 2% of polystyrene will produce low-density mortar for the concrete block. This will lead to producing a lightweight concrete block since there is more air voids compared to the ordinary concrete block. However, the ultra-lightweight properties and hydrophobic nature of this EPS, segregation in lightweight concrete or lightweight mortar are bound to happen. Many research are done to address this segregation problem. One of them is coating the EPS beads with coating material that can promote adhesion between water, cements and EPS.

## 2.6 Coated EPS Beads Aggregates

EPS beads aggregates have a hydrophobic characteristic that will repel water, thus due to this characteristic uses of this material in the mortar mixture of the concrete block will lead to segregation issues with the cement paste. Therefore, to address the segregation issues, a bonding agent such as epoxy resin or aqueous dispersions of polyvinyl propionate need to be used to coat the EPS aggregate in order to enhance the bond between EPS aggregates and cement paste in the mortar mixture (Tang et al., 2008).

First, the virgin EPS beads will be transferred into a silo for the coating process. The coating material is an aqueous surfactant solution that contains substantive cationic surfactant, substituted or ethoxylated quaternary ammonium compound (that contain $C_{10}$ to $C_{18}$ alkyl substituent) or ethoxylated primary or secondary amine (that contain $C_{10}$ to $C_{18}$ alkyl substituent) and non – ionic surfactant such as ethoxylated primary or secondary alcohol or a nonylphenol – ethylene oxide condensate.

The EPS beads then are coated using the coating machine. The EPS beads that have been coated with the hydrophilic surfactant will have greater bonding strength with cement paste in the mortar mixture. The illustration of the coating process of the polystyrene resin is shown in **Figure 2.1**.

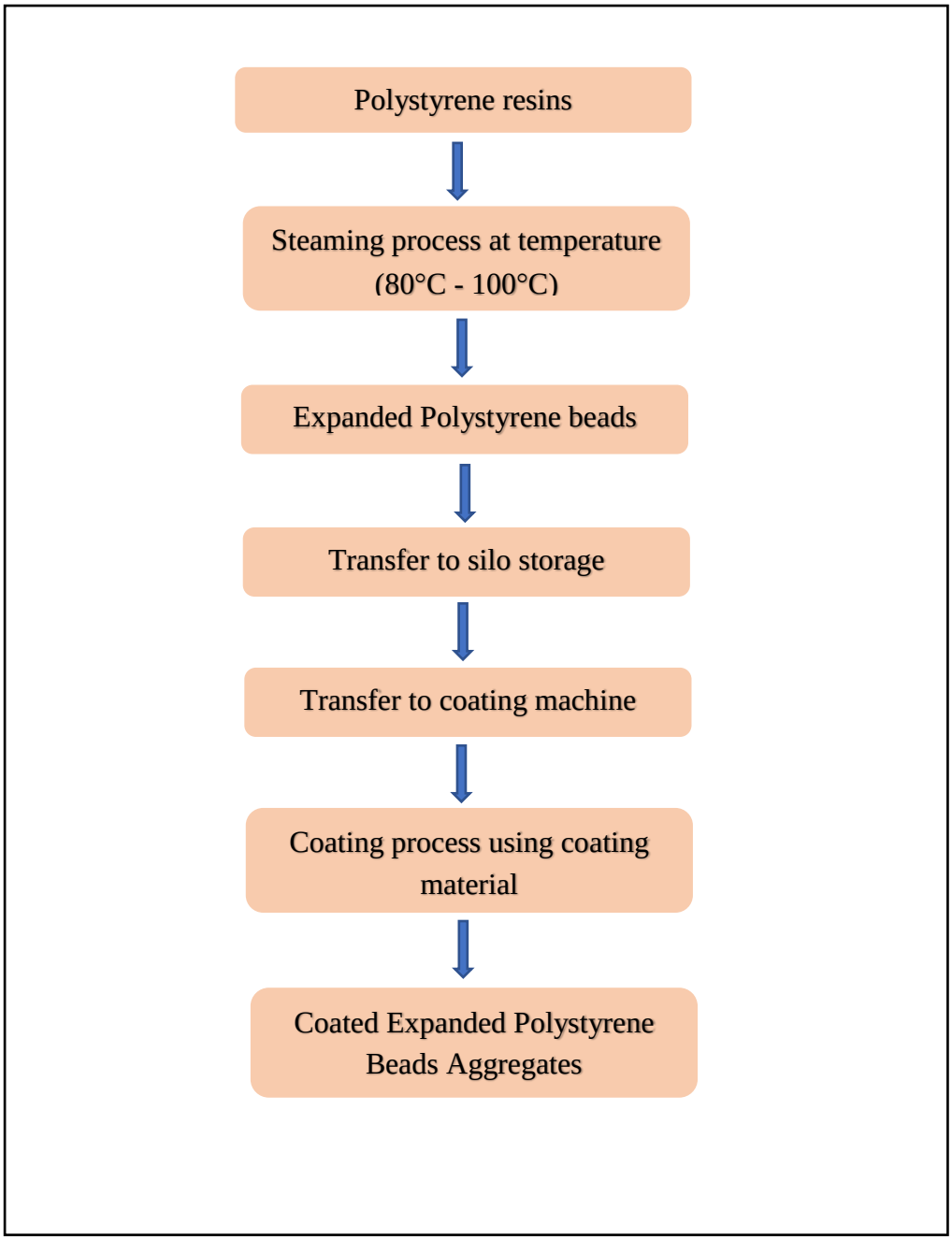
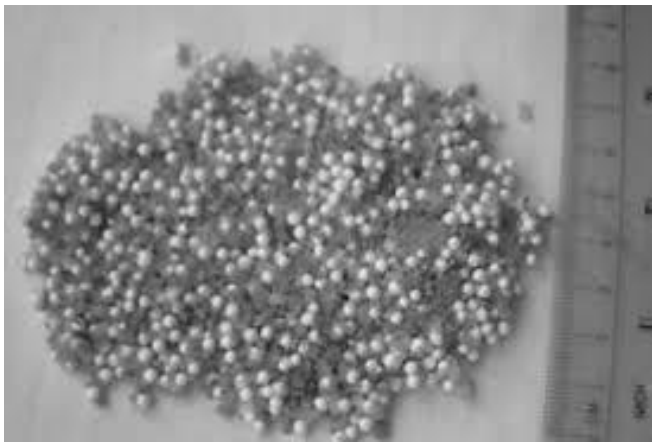



**Figure 2.1** Flow chart of EPS beads treatment (Chen and Liu, 2004).

## 2.7 CEPS Mortar



Mortar is made up of the mixture of cement, water and fine aggregates which is natural aggregates or local mining sand. Generally, conventional mortar contributed most to the heavy weight of structural member. In addition, since the aggregates demand continue to increase, the sustainability of the materials are alarming. Therefore, numerous efforts have been done through the years in order to achieve a good performance lightweight mortar.

Typically, lightweight concrete or mortar are used for both non-structural and structural uses (Sussman and Baumann, 1972). Lightweight concrete or mortar manufactured with EPS have been used as covering panelling, curtain walls, coating systems for composite flooring and also concrete blocks according to Cook (1983). Concrete or mortar that made up of lightweight aggregates have shown an equal if not better durability, even when exposed to severe conditions (Zhang and Gjorv, 1991).

EPS as a lightweight aggregate has been widely used in the concrete production for the construction industry. However, no bibliographic references have been located to prove the existence of scientific studies regarding EPS use in brickwork and special mortars production. On the other hand, there are commercialized mortars with more than 3 mm pearls EPS additions for some specific uses (Ferrandiz-Mas et al., 2014)

Expanded polystyrene foam (EPS) is a thermoplastic polymer closed cell structure. It is a biologically inert and nontoxic. EPS has interesting properties such as low density, thermal insulation, hydrophobicity and chemical resistance when exposed to acids and alkalis. EPS is granulated into small particles that can be considered as non-absorbent and lightweight polymeric aggregate. Replacement of natural aggregates with coated EPS (CEPS) beads aggregates which produce CEPS mortar reduce the water absorption to 82.05% compared to the conventional mortar.

Thus, the replacement provides waterproofing characteristic to the CEPS mortar (Ewadh and Basri, 2012). Positive effect is shown when incorporating CEPS beads aggregates in the mortar as the density and thermal conductivity are reduced and excellent sound insulation effect.

## 2.8 EPS blocks

Hago, et al. (2002; 2004) and Al-Jabri, et al. (2005) developed a comprehensive study of the structural and thermal properties of lightweight aggregate concrete hollow blocks. They developed a comparative study between hollow blocks made for normal weight concrete using vermiculite and EPS lightweight concretes to optimize strength and thermal insulation. The water to the cement ratio used in EPS concrete was kept at 0.6 and the OPC volume was kept constant. The vermiculite concrete mixes density ranged

between 2242 and 1405 kg/m3, while the EPS concrete density ranged between 1555 and 850 kg/$m^3$.

The compressive strength and thermal conductivity tests were conducted on all the mixes of the hollow blocks made with vermiculite concrete and EPS concrete cube. An optimum mixture of 1320 kg/m3 density are selected which produced 5.52 MPa cube compressive strength, and hollow blocks of 12.77 kg weight, 798 kg/m3 gross density, 3.53 MPa block compressive strength, 2.24 MPa masonry column compressive strength, and k-value corresponding to 0.60 W/m.K. The results then were compared against the properties of ordinary hollow block concrete. As conclusion, EPS beads concrete produced an optimum lightweight concrete hollow blocks of low thermal conductivity and suitable strength for non-load bearing applications.

## 2.9 Summary

This chapter highlights the advantages of incorporating EPS beads aggregates in the production of concrete product**,** especially for a hollow concrete block. Alternatives should be taken to reduce the use of natural aggregates as it will impair the sustainability of future construction industry. EPS beads aggregates as replacement of natural aggregates are beneficial to the economy and environment. They are artificial lightweight materials that renewable, compared to natural aggregates and show the positive effect which is lower density and better thermal conductivity. However, although the potential of EPS beads aggregates to be natural aggregates replacement sound promising, EPS beads aggregate hydrophobic characteristic need to be treated first to prevent segregation in the mixture. Until now, very little attempt to utilize CEPS beads aggregates in the final building product, concrete block itself. Therefore, this research is conducted to

investigate the potential of CEPS beads aggregates as replacement of natural aggregates on the mechanical properties in the hollow concrete block.

# CHAPTER 3

# METHODOLOGY

## 3.1 Overview

This chapter describe the methods to achieve the objective of the research as stated in Chapter 1. The preparation of the sample step by step will be discussed further in this chapter. Then, the testing procedure also will be discussed in accordance to related guideline including American Society for Testing and Materials (ASTM), British Standard (BS), Malaysian Standard (MS) and International Organization of Standardization (ISO) test procedures.

## 3.2 Experimental design

Figure 3.1 below show the flow chart of research methodology. The flow chart describe overall stages of research work throughout the study.

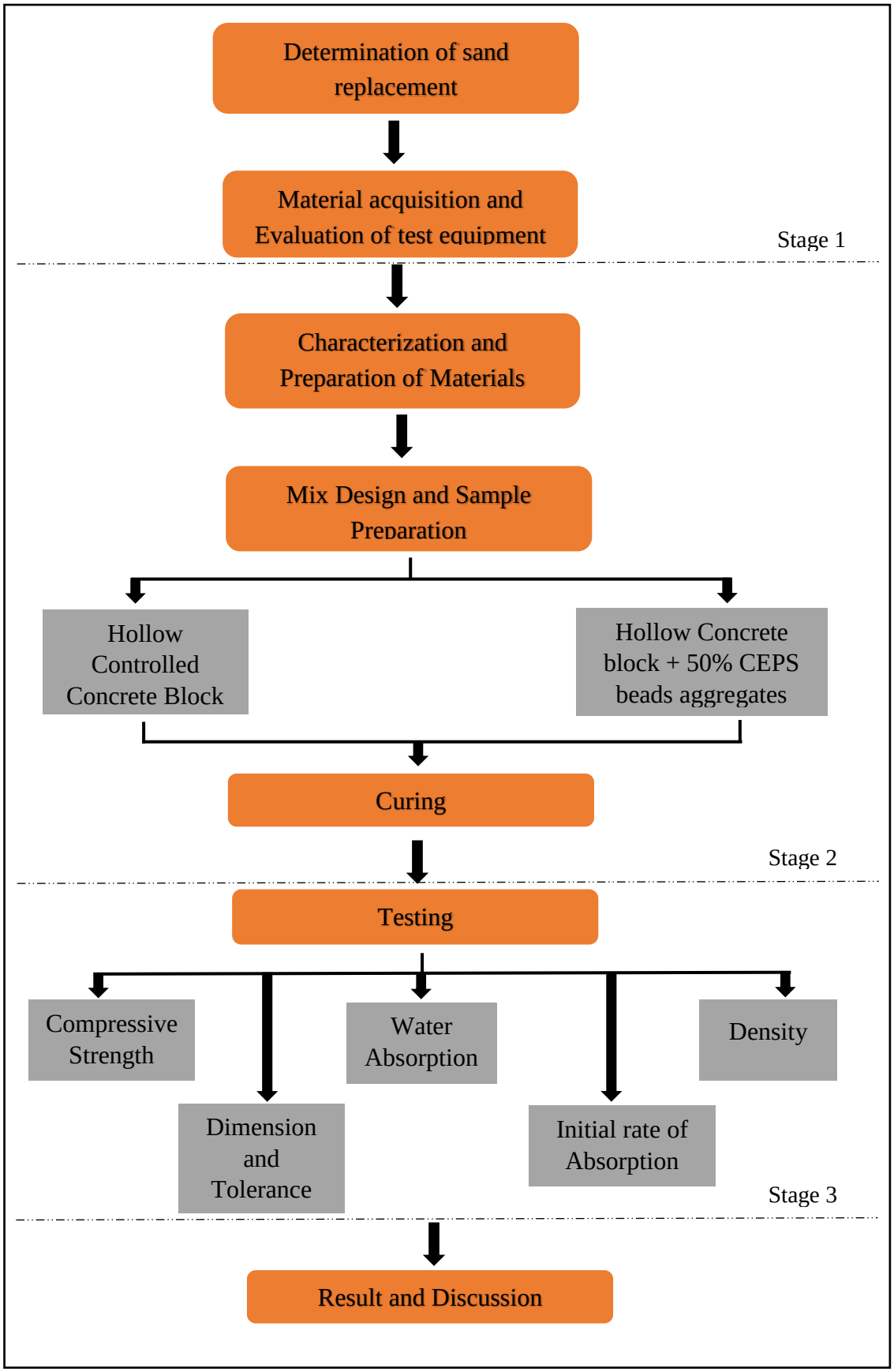



**Figure 3.1** Flow chart of the research methodology.

## 3.3 Materials

The materials that used in this research to produce CEPS concrete block are;

1. Natural fine aggregate
2. Water
3. Coated EPS (CEPS) beads aggregates
4. Ordinary Portland Cement (OPC)

### 3.3.1 Natural Fine Aggregates

In this study, fine aggregates will be used as part of the component needed in producing the concrete block. Fine aggregates usually consist of natural sand or crushed stone with most particles passing through a 3/8-inch sieve. Natural sand is usually dug or dredged from a pit, river, lake or seabed.

Fine aggregates (sands) make up the main bulk of masonry mortar; therefore, having a significant effect upon the properties of the product in both fresh and hardened state. The selection of suitable aggregates, which are capable of producing a product with the optimum properties is very important.

Mortar is one of the constituents of the concrete block. Mortar is responsible for creating a uniform stress distribution correcting the irregularities of blocks and accommodating deformations associated to thermal expansion and shrinkage. Mortar is the material responsible for the distribution of stresses in masonry structure including concrete block. The knowledge about the fresh and hardened properties of mortar is fundamental to ensure a good performance of the concrete block (Vladimir et al., 2011).

### 3.3.2 Coated EPS Beads Aggregates

EPS beads aggregates have a hydrophobic characteristic that will repel water. Thus due to this characteristic, uses of this material in the mortar mixture of the hollow concrete block will lead to segregation issues with the cement paste. Therefore, to address the segregation issues, a bonding agent need to be used to coat the EPS aggregate in order to enhance the bond between EPS aggregates and cement paste in the mortar mixture (Tang and Nadeem, 2008).

Therefore, for this study, coated EPS (CEPS) beads was being used which named Poly-A. Poly-A is a special polystyrene aggregates that is specially designed to be able to adhere firmly with cement even without fine aggregates (sands). First, the resin of polystyrene was being steamed to form expanded polystyrene beads. Then, the EPS beads will be coated by coating materials to enhance their performance with cement paste. Poly-A will be used as sand replacement in the hollow concrete block for this study. Poly-A CEPS beads aggregates were supplied by Cebau Industries in Kapar, Klang.

### 3.3.3 Water

In the production of the hollow concrete block, water is one of the materials needed for the mixture of mortar. Water is added to the cement and sand for making a strong and workable cement mortar and they are important for the chemical reaction known as hydration by which the mortar will harden.

Without water, hydration reaction of cement will not take place and adding water is necessary to make a paste which can be applied to vertical surfaces as well as overhead surfaces. Too much water will not only cause loss of strength but the excessive workability will cause the mortar to drip off. As for this study, dry mortar mixture are being incorporated. Therefore, the right amount water to cement ratio are crucial in order

to have the desired mortar mixture. In addition, water to cement ratio in cement water is best decided according to the state of moisture in the sand, as well as the atmospheric temperature.

### 3.3.4 Portland cement

In addition to the materials needed to produce hollow concrete block for this study, Portland cement is the most important material. Hollow concrete block will be produced by mixing powdered Portland cement, fine aggregate and water together.

Whether present as an integral part of masonry or mortar cement or as a separate ingredient added at the mixer with hydrated lime, Portland cement acts as the glue that holds the mortar and ultimately the masonry (concrete block) together.

Portland cement is defined as a hydraulic cement produced by grinding clinker consisting of hydraulic calcium silicates, usually containing one or more of the calcium sulphates as an inter-ground addition. The term hydraulic indicates that the material sets and hardens in a reaction with water and will do so under water.

Compressive strength and bond strength are related to the Portland cement content of mortar. ASTM C150, the Standard Specification for Portland cement, defines eight different types of Portland cements. However, only types I, IA, II, IIA, III, and IIIA are used in conventional masonry construction.

### 3.4 Mix Design

Mortar is a mixture of a binding material, sand and water and is different from concrete which contains large-sized coarse aggregate. Thus, for the mortar to be workable and strong the ratio of cement to sand should normally be 1:3 to1:6 by weight. As for this study, we use ratio 1:6.

There are two different mortar mixture produced in this study. Dry mortar mixture was used for this study that have zero slump because the sample preparation is using hydraulic compression machine. The mechanism of this machine does not allow the uses of normal mortar mixture which is wet mortar mixture.

The mix design for CEPS hollow concrete block sample was based on partial replacement of the natural fine proportion by using volume replacement while the mix design for the controlled concrete block was using conventional mixture of mortar. Twice of the batched quantity were used in order to produce the concrete block using the hydraulic compression machine. Constant water to the cement ratio was applied for both controlled and CEPS samples with average dimensions of 400mm x 200mm x 95mm for both controlled samples and CEPS samples. Table 3.1 show the proportion of the mortar mixture for a batch.