EXPERIMENTAL STUDY ON THE PRISM STRENGTH OF EXPANDED POLYSTYRENE LIGHTWEIGHT BRICK

NOR ATIQAH BINTI MAT REFIN
AA12018

Report submitted in partial fulfillment of the requirements for the award of the degree of Bachelor of Civil Engineering

FACULTY OF CIVIL ENGINEERING & EARTH RESOURCES
UNIVERSITI MALAYSIA PAHANG

14 JANUARY 2016
ABSTRACT

As urbanization is rapidly growing the construction of residential area is perpetrating intensely and at the same time the world is also facing the energy resource shortage. There be responsibility to modify the housing design and construction technologies which are used today to reduce the cost, CO₂ emission, and sustainable development and energy conservation concept. There is a need to focus on such materials which along with traditional construction materials as brick to satisfy the properties like thermal conductivity, embodied energy, durability, sound insulation, earthquake resistance and strength. The use of expanded polystyrene beads (EPS) is best suitable for this purpose. In this paper an attempt has be made to review the strength aspects of EPS embedded as a non-load bearing internal wall and its prospective design and implementation in the building to make it energy efficient. The main purpose of this study is to design the optimum mix percentage of the EPS brick for non-load bearing internal wall application and to compare the strength performance of EPS brick wall compared to conventional brick wall. With regard to the laboratory tests, several compression tests were performed on wall samples. Wall sample has been built with expanded brick connected with mortar. The mix proportions of EPS use are 0 %, 16.7 %, 33.3 % and 50 % of sand replacement. Depending on the four types of in situ tests carried out (compression test, deflection test, strain stress test, and thermal insulation test), same dimensions of prism were use. The test conducted based on ASTM C 129-85 (1990) testing standards. The experimental study shows that EPS prism application achieved the standard average strength 3.45 MPa, the highest compressive stress value for EPS brick prism by 16.7 % EPS brick, about 3.90 MPa with 18.48 kg weight. The modulus elasticity about 13.34 MPa for 16.7 % EPS is the highest among three sample. The lowest deflection value is about 1.75 mm for sample 16.7 % EPS. The thermal conductivity lowest value is 0.21 W/mK for 50 % EPS replacement. Conclude that, the EPS beads is suitable to replaced sand in brick making process and able to applied as non-load bearing wall in construction.
ABSTRAK

Pembangunan urbanisasi yang semakin pesat dengan pembinaan kediaman dilakukan dengan rancak dan pada masa yang sama, dunia juga menghadapi masalah kekurangan sumber asli. Ia menjadi tanggungjawab untuk mengubah suai reka bentuk dan teknologi pembinaan perumahan yang digunakan hari ini untuk mengurangkan kos, pelepasan CO₂, pembangunan mampan dan juga konsep pemuliharaan tenaga. Menjadi keperluan untuk memberi tumpuan kepada bahan-bahan tersebut dan bahan pembinaan yang konvensional seperti konkrit, untuk memenuhi ciri-ciri seperti keberaliran haba, tenaga semulajadi, ketahanan, penebat bunyi, tahan gempa dan kekuatan. Penggunaan butir polisterin (EPS) adalah paling sesuai untuk menjalankan ujikaji. Dalam ujikaji ini, percubaan telah dibuat untuk mengkaji aspek-aspek kekuatan EPS yang digunakan sebagai dinding dalam bukan galas beban dan rekabentuk prospektif dan penggunaan didalam bangunan untuk menjalankan ia cekap tenaga. Tujuan utama kajian ini adalah untuk merekabentuk campuran optimum bagi dinding bata EPS bagi aplikasi dinding dalam bukan galas beban dan untuk membandingkan kekuatan dinding bata EPS dengan dinding bata konvensional. Dengan menjalankan beberapa ujikaji di makmal, ujikaji tekanan dijalankan pada sampel dinding. Sampel dinding dibina daripada bata EPS yang di ikat menggunakan lepa simen. Nisbah bancuhan bata adalah menggunakan 0 %, 16.7 %, 33.3 % dan 50 % EPS sebagai pengatian pasir. Saiz dinding yang sama digunakan bagi menjalankan empat jenis ujikaji di makmal (ujian tekanan, ujian lenturan, ujian terikan, ujian penebat haba). Ujikaji dijalakan mengikut garispanduan ASTM C 129-85 (1990). Keputusan ujikaji menunjukkan, penggunaan dinding EPS mencapai piawai purata kekuatan 3.45 MPa, bacaan tekanan yang tinggi dari dinding EPS adalah 16.7 % bata EPS, iaitu 3.90 MPa dengan berat 18.48kg. Modulus keanjalan adalah 13.34 MPa untuk 16.7 % EPS adalah paling tinggi bagi ketiga nisbah campuran EPS. Nilai defleksi paling rendah adalah 1.75 mm untuk 16.7 % bata EPS. Keondusian haba terendah 0.21 W/mK bagi 50 % bata EPS. Kesimpulan dari ujikaji, menunjukkan EPS boleh mengantikan pasir didalam pembuatan bata simen dan ia sesuai diaplikasikan sebagai dinding dalam tanpa galas beban didalam pembinaan.
# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>SUPERVISOR’S DECLARATION</td>
<td>i</td>
</tr>
<tr>
<td>STUDENT’S DECLARATION</td>
<td>ii</td>
</tr>
<tr>
<td>ACKNOWLEDGEMENT</td>
<td>iv</td>
</tr>
<tr>
<td>ABSTRACT</td>
<td>v</td>
</tr>
<tr>
<td>TABLE OF CONTENTS</td>
<td>vi</td>
</tr>
<tr>
<td>LIST OF TABLES</td>
<td>viii</td>
</tr>
<tr>
<td>LIST OF FIGURES</td>
<td>ix</td>
</tr>
<tr>
<td>LIST OF SYMBOLS</td>
<td>x</td>
</tr>
<tr>
<td>LIST OF ABBREVIATIONS</td>
<td>xi</td>
</tr>
</tbody>
</table>

## CHAPTER 1    INTRODUCTION ................................................................. 1

1.1 Introduction......................................................................................... 1
1.2 Objective.............................................................................................. 2
1.3 Background of Study............................................................................. 2
1.4 Scope of Work........................................................................................ 4
1.5 Significant of Study........................................................................... 4

## CHAPTER 2    LITERATURE REVIEW ........................................................... 6

2.1 Introduction.......................................................................................... 6
2.2 Lightweight Concrete and Brick.......................................................... 6
2.3 Lightweight Aggregate.......................................................................... 8
2.4 Strength and Durability of EPS Aggregate Concrete............................ 10
2.5 Mixture Proportioning of Lightweight Concrete.................................... 12
2.6 Summary.................................................................................................. 14
### CHAPTER 3  METHODOLOGY

3.1 Introduction ........................................................................................................ 15  
3.2 Research Phase ................................................................................................ 16  
  3.2.1 Phase 1: Collecting Information and Material .............................................. 16  
  3.2.2 Phase 2: EPS Brick Prism ............................................................................. 17  
  3.2.3 Phase 3: Determination of Compressive Strength ....................................... 18  
3.3 Mixing Procedure .............................................................................................. 18  
3.4 Experimental Test ............................................................................................ 19  
  3.4.1 Prism Compression Test ................................................................................. 19  
  3.4.2 Strain Stress Test .......................................................................................... 20  
  3.4.3 Deflection Test ............................................................................................ 20  
  3.4.4 Thermal Conductivity Test .......................................................................... 21  

### CHAPTER 4  RESULT AND DISCUSSION

4.1 Introduction ....................................................................................................... 25  
4.2 Compression Test Result ................................................................................... 25  
4.3 Strain Test Result .............................................................................................. 27  
4.4 Deflection Test Result ...................................................................................... 29  
4.5 Thermal Test Result ......................................................................................... 31  

### CHAPTER 5  CONCLUSION AND RECOMMENDATION

5.1 Conclusion ....................................................................................................... 33  
5.2 Recommendation ............................................................................................. 32  

REFERENCES ........................................................................................................... 35
<table>
<thead>
<tr>
<th>Table No.</th>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.1</td>
<td>Mix design for EPS brick</td>
<td>18</td>
</tr>
<tr>
<td>4.1</td>
<td>Test result for 28 days</td>
<td>25</td>
</tr>
<tr>
<td>4.2</td>
<td>Strain test result for 28 days</td>
<td>27</td>
</tr>
<tr>
<td>4.3</td>
<td>Deflection test result for 28 days</td>
<td>29</td>
</tr>
<tr>
<td>4.4</td>
<td>Thermal conductivity test result</td>
<td>31</td>
</tr>
</tbody>
</table>
## LIST OF FIGURES

<table>
<thead>
<tr>
<th>Figure No.</th>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.1</td>
<td>EPS single brick</td>
<td>16</td>
</tr>
<tr>
<td>3.2</td>
<td>EPS brick prism</td>
<td>17</td>
</tr>
<tr>
<td>3.3</td>
<td>Mixing of EPS brick</td>
<td>22</td>
</tr>
<tr>
<td>3.4</td>
<td>Samples EPS brick</td>
<td>23</td>
</tr>
<tr>
<td>3.5</td>
<td>Prism making process</td>
<td>23</td>
</tr>
<tr>
<td>3.6</td>
<td>Compressive test setup</td>
<td>24</td>
</tr>
<tr>
<td>3.7</td>
<td>Thermal test setup</td>
<td>24</td>
</tr>
<tr>
<td>4.1</td>
<td>Compressive strength for 28 days</td>
<td>26</td>
</tr>
<tr>
<td>4.2</td>
<td>Modulus elasticity value for prism sample</td>
<td>28</td>
</tr>
<tr>
<td>4.3</td>
<td>Deflection value for prism sample</td>
<td>30</td>
</tr>
<tr>
<td>4.4</td>
<td>Strength stress versus thermal conductivity</td>
<td>32</td>
</tr>
<tr>
<td>Symbol</td>
<td>Description</td>
<td></td>
</tr>
<tr>
<td>--------</td>
<td>--------------------</td>
<td></td>
</tr>
<tr>
<td>%</td>
<td>Percentage</td>
<td></td>
</tr>
<tr>
<td>°C</td>
<td>Degree celcius</td>
<td></td>
</tr>
<tr>
<td>γ</td>
<td>Gamma</td>
<td></td>
</tr>
</tbody>
</table>
**LIST OF ABBREVIATIONS**

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>EPS</td>
<td>Expanded polystyrene</td>
</tr>
<tr>
<td>ASTM</td>
<td>American Society for Testing and Materials</td>
</tr>
<tr>
<td>CIDB</td>
<td>Construction Industry Development Board</td>
</tr>
<tr>
<td>USA</td>
<td>United State of America</td>
</tr>
<tr>
<td>MS</td>
<td>Malaysia Standard</td>
</tr>
<tr>
<td>SC-PC</td>
<td>Self compacting polystyrene concrete</td>
</tr>
<tr>
<td>WTP</td>
<td>Waste treatment plant</td>
</tr>
<tr>
<td>pH</td>
<td>Potential of hydrogen</td>
</tr>
<tr>
<td>EN</td>
<td>European Standard</td>
</tr>
<tr>
<td>SP</td>
<td>Superplasticizer</td>
</tr>
<tr>
<td>BS</td>
<td>British Standard</td>
</tr>
</tbody>
</table>
CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

The construction industry has become a major consumer of non-renewable resources and a huge waste producer. Based on recent study in developed countries, 30 to 40% of natural resources were exploited by building industry, 50% of energy used for heating and cooling in buildings, a most 40% of world consumption of materials converts to build environment and 30% of energy use due to housing (Pulselli et al., 2007). Malaysia well known as developing country, so it is expected to achieve a similar percentage. This shown that, there will be huge amount of resources and energy consume in building life-cycle. It became responsible to industries to tackle these issues and develop sustainable and environmental friendly constructions. Using EPS (expanded polystyrene) as replacement material for fine aggregates in bricks was one of the innovation to develop sustainable and environmental friendly construction material. Therefore the strength of wall using EPS brick is top priority to be study on. To fulfill this requirement, proposed EPS brick wall must be able to resist the compressive and tensile force, and also thermal energy effect to be compared with conventional brick wall application.
1.2 OBJECTIVE

The main objectives for this research are:

- To compare the strength performance of EPS brick wall compared to conventional brick wall.
- To design the optimum mix percentage of EPS to obtain maximum strength for the wall.

1.3 BACKGROUND OF STUDY

In Malaysia, the construction industry plays an important role to achieve the developed country status. The construction industry is also important in contribution and influenced in development of social and economic infrastructures and buildings. ‘Malaysia construction output is estimated to be approximately RM 50 billion’, this represented 3-5 percent of Gross Domestic Product per annum (CIDB, 2007). This industry also provides the job opportunities for almost 1.03 million people that represent 8% of total workforce (CIDB, 2006). Manufacturing sector, financial and banking, agriculture, mining and professional services, are the multiplier effect by this industries. It also acts as catalyst of economic recovery and as a driver for the modernization of Malaysia.

Construction material that widely uses in Malaysia is bricks. Conventional clay bricks are widely being uses in construction, for example in form of wall for buildings. Ongoing mining of clay and sand will occur which it’s not sustainable for the industry. The oldest type clay brick consumed high energy in production process that will involve in fossil fuels burning.

After a year, there came the cement bricks as solution for the industry. Nowadays many researchers that came out with other type of brick that becomes a solution. They have combined the material to replace the aggregate or the cement for the brick. Introducing of
recycling solid wastes into useful supplementary raw materials for new building materials, is one of the methods. EPS waste is a by-product from packaging industry.

Expanded polystyrene beads (EPS) is one of the industrial solid waste that having serious problem for disposal. The world today has concern in environmental issue, the problem to accumulate of unmanaged solid waste. The EPS is not a biodegradable type; it will not provide an environmental friendly solution to landfills. In increase concern for environmental issues, the sustainable development and energy conservation concept has become paramount importance.

It is one of many lightweight, low strength materials with density between (16-27) kg/m³ and good energy absorbing characteristics. It is well known for its good thermal and acoustic insulation properties leading mainly to non-structural applications including precast roof and wall panels and lightweight infill blocks. It also in the way to reduce the density of the bricks, as well in improving thermal insulation properties, there forms the light weight brick innovation.

Brick technology is growing and many advances and innovations have appeared and a part of them are by use of artificial aggregates and lightweight aggregates such as slag, fly ash and porcelainite rocks. This project aims to experimental the suitability of lightweight brick applied as wall. The lightweight substituted material is expandable polystyrene (EPS). In this study, the bricks are arranged in prism form. Standard masonry panels and panel using EPS bricks were constructed and used as the test specimens as stated in standard.

Lightweight brick can be defined as a type of brick which includes an expanding agent in that it increases the volume of the mixture while giving additional qualities and
lessening the dead weight. The use of lightweight brick has been widely spread across countries such as USA, United Kingdom and Sweden.

Polystyrene is a synthetic polymer made from the monomer styrene, a liquid petrochemical. Polystyrene can be rigid or foamed. General polystyrene is clear, hard and brittle. It is a very inexpensive resin per unit weight. After almost 30 years in the ground, sample of EPS retrieved from location as little as 200mm above the ground water level, all have less than 1 % of water content by value.

This study aims to investigate the suitability of EPS as replacement for sand in the production of lightweight brick. The study are used three different percent of EPS replacement.

1.4 SCOPE OF WORK

In this study, MS 76:1972 for specification on bricks and blocks of fired brick earth are used, to highlight the importance of proposed dimension and specification of brick wall. With the use of EPS brick as a wall, does it affected the wall strength or not is going to be observed and analyzed. Furthermore, the advantages of using EPS brick wall in replacing the usage of conventional brick wall are discussed.

1.5 SIGNIFICANT OF STUDY

This study is hoped to act as a basic requirements and control specimens for the next related researches. Furthermore, it is expected to successfully achieve the objectives in while manage to conduct the laboratory apparatus and equipment as the research goes further. It is important for me to be able to determine the effect of using EPS brick whether
it makes it stronger or worst. The data obtained will help engineers to determine the suitability of proposed EPS brick design wall to be applied.
CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

The literature reviews are discussed in detail on properties and strength of EPS concrete. Details will focus on how the nature properties of EPS brick wall able to resist the loading without or having fail in the structure. Thus this literature review will help to improve understanding on the study field that will be conducted despite of getting an initial overview on the data and results pattern that will be obtained from experiments in the laboratory.

2.2 LIGHTWEIGHT CONCRETE AND BRICK

A group of research has been carried out to study on the various properties of the light weight concrete.

Xu and Jiang (2011) has study on lightweight concrete in application of expanded polystyrene (EPS) as substituted to fine aggregate on mechanical properties. The cement content about 500 kg/m³, the volume of EPS is about 25 % and 35 % of sand ratio have result to minimum density of concrete. A saving the sand content could be achieved.
A study done by Chiang and Chou (2009) was on the lightweight brick manufactured from water treatment sludge and rice husk. The idea came from environmental problem arise in Taiwan. They stated that the production of sludge in water treatment plant will increase day by day. Taiwan government has aim to reduce landfill disposal by encouraging beneficial reuse. The same case goes to rice husk production, it resulting in approximately 0.24 million of waste. Most of this material is either burnt or stockpiled that will result on environmental issues. The WTP sludge was collected from drying beds at Fong-Yuan. They be shredded and sieved to give particle size between 74 and 300 micrometer. The rice husk was sieved into particles with size between 74 and 300 micrometer for use in subsequent experiments. Samples that contain up to 20wt.% ice husk have been fired using a heating schedule that allowed effective organic burn-out.

Aim of this study is to produce one type of self-compacted lightweight concrete and also known as self-compacted polystyrene concrete. The study is conducted by Manolia (2012) from Al-mustansiriya University. Polystyrene concrete is a lightweight concrete made with expanded polystyrene beads, it is known for its good thermal and caustic insulation properties, it has also been considered for use as core material in sandwich panels, beams and slab. The mixing of it was done by adding the dry cement and sand together in to mixer and mixed for approximate one minute. It is possible to produce various type of self-compacting polystyrene concrete (SC-PC) by the addition of polystyrene beads as a partial replacement of fine aggregate and using (SBR) polymer with ratio of (10 %) by weight of cement and superplastisizer.

The study on the effect of foam polystyrene granules on cement composite properties is done by A.Laukaitis et al. (2005). Research shown that, the density of specimens decreased, when the concentration of polystyrene granular increased. When the ratio is 1:2 (foam cement and polystyrene granules), the density a composite, in which fine granules are used, is 181 kg/m³, the density of a composite with large granules 214 kg/m³,
crushed granule composite density 248 kg/m$^3$. The lowest material density is obtained when they are mixed at the ratio of 1:3. Highest decrease of density takes place when using large granules. They conclude that the recycled polystyrene waste as well as blown polystyrene granules can be used as the filler for light weight thermo-insulating foam cement composite. The density of such composite is 150-170 kg/m$^3$, the thermal conductivity coefficient 0.06-0.064 W/m.K, compressive strength 0.25-0.28 N/mm$^2$.

2.3 LIGHTWEIGHT AGGREGATE

It is possible to substituted EPS as fine aggregate for concrete has studied by Xu and Jiang (2011). They study the aggregate properties like workability and density of EPS aggregate when be applied in concrete mixture. It shown the good workability but there was tendency of segregation and collapse due to their higher EPS aggregate. They also conclude that when EPS ratio increase, the workability was reduced because of the hydrophobic property and increased surface area of EPS beads.

Moisture content of WTP sludge and rice husks was determine by heating samples to 105 °C for 48 hour, was the study by Chiang and Chou (2009). Then it continued determine the combustible fraction in triplicate using American Public Health Association (APHA) standard methods. X-ray fluorescence (XRF, SPECTRO, X-LAB 2000) was used to determine the chemical composition of WTP sludge. The X-ray diffraction, detected that that light weight aggregate contain crystalline minerals. The pH was determined in triplication using aqueous extracts from dried samples at a 1:10 ratio of solid: distilled water (w/v). The bulk density, water absorption, open porosity and dimensional change in the sintered products were determined from their weights and dimensions in term of ASTM C373 and C20-00 standard test methods. The bulk densities decreased with increasing rice husk addition from 2.4 to 1.6 g/cm$^3$ from samples sintered at 1100 °C as the rice husk addition increased from 0 % to 20 %. While for the water absorption, decrease from 40 %
to 2 % when the sintering temperature is increased from 900 to 1100 °C for samples containing no rice husks. In the case of 10 % rice husk addition the water absorption of sintered specimens decreased from 55 % to 9 % when the sintering temperature was increased from 900 to 1100 °C water absorption decreased significantly with increasing sintering temperature.

Study carried out by Manolia (2012), was stated the polystyrene beads been chosen due to its lightweight properties with density between (16-27) kg/m³, good thermal energy absorbing characteristics and good thermal insulator leading mainly to non-structural application. She also stressed on the main aim of the study to use polystyrene beads to produce (SC-PC) which is a special type of concrete mixture characterized by high resistance to segregation that can be cast without compaction or vibration, because it becomes leveled and compacted under its self-weight. Polystyrene beads with diameter of 4mm used as partial replacement of fine aggregate with apparent density of 16.5 kg/m³. The study shown that, density of (SC-PC) mixes decreased with increase the polystyrene content as a partial replacement of fine aggregate. The percentage of reduction in density was (7.1 and 12.4 %) when the percentage of sand replacement with polystyrene beads was (33.3 and 50 %), respectively compared with their density at 16.7 % replacement.

K.Miled et al. (2003) have done the study on compressive behavior of an idealized EPS lightweight concrete on the size effects and the failure mode. Two type of idealized 2D- EPS concrete specimen were obtain by perforating prismatic mortar sheers according to two periodic holes patterns with two diameter sizes. Then the specimens were subjected to standard uniaxial compressive test. Results shown, similar compressive strength obtained for two specimens. The specimen tensile failure mode with no cracks localization been observed. They conclude that, the different size of EPS using 5mm and 3mm for concrete mixture as substituted to aggregate give no effect engendered by the quasi brittle behavior.
2.4 Strength and Durability of EPS Aggregate Concrete

EPS dosage played most important role in determining density and compressive strength of light weight aggregate concrete, and then be followed by water and cement ration. That statement concludes by Xu and Jiang (2011). Increasing in EPS percent use (25 %), there will be lower degree of compaction and the strength will reduced. The density value of EPS concrete showed an almost linear decrease as the volume of EPS and water content parameter increased, but results in a decrease in compressive strength. The relationship between density and compressive strength was proposed as $f_c = 2.43 \times \gamma^{2.997} \times 10^{-9}$. Compression test and shear test be conduct to determine the strength of the concrete, the average value of the three test series was equal to 6900 MPa.

The study by Chiang and Chou (2009), have shown that result for the sludge and risk husk brick. The compressive strength increased with increased sintering temperature and decreased with increased added rice husks. Compressive strength increased from 23 to 540 kgf/cm$^2$ when the sintering temperature was increased from 900 to 1100 °C for samples containing no rice husks. In the 10 % rice husk addition case, the sintered specimen compressive strength increased from 7 to 217 kgf/cm$^2$, when the sintering temperature was increased from 900 to 1100 °C. the higher compressive strength developed at 1100 °C sintering temperature with the rice husk ratio at 15 % and below, ranging from 162 to 540 kgf/cm$^2$, thereby fulfilling the code requirement (150 kgf/cm$^2$) with respect to lightweight bricks for construction work.

Manolia (2012), have study on the possibility of produce self-compacted polystyrene concrete. The result for the concrete compressive, tensile and flexural strength was decreased to 30.17, 37.93 and 43.3 % respectively when the polystyrene content increased from 16.7 % to 50 % by volume of sand. The test to determined compressive strength was carries out according to BS. 1881: part 116:1989 by using 100mm cube. The
compressive strength of each mix represent the average of three specimens, they were tested after 28 days of water curing. While the splitting tensile strength test conducted according to ASTM C496-68 on 100 x 200 mm concrete cylinder tested at 28 days after curing. Three specimens were used for each mix. To determine the modulus of rupture or flexural strength, the test carried out according to ASTM (78-84) by using 100 x 100 x 500 mm prism specimens. The prisms subjected to two point load, tested after 28 days water curing.

Refer to the study done on compressive behavior of an idealized EPS lightweight concrete on the size effects and the failure mode by K.Miled et al. (2003) have shown that the compressive strength test on specimen conducted on a MTS servo-hydraulic testing machine of 100 KN capacity. The result obtains between 3 mm and 5 mm size holes specimens is not significant (at maximum 6.5 %) and it is wholly discounted as a statistical variation. They conclude that size of EPS have given no effect on the ultimate compressive strength for the idealized EPS lightweight concrete structure.

The study conducted by A.Laukaitis et al. (2005), on the effect of foam polystyrene granules on cement composite properties. The stated that the compression strength gained by the composite complies with the standard foamed concrete complies with the standard foamed concrete compression strength. Since polystyrene granules were used, the comparison method was adjusted for 10 % deformation, similar to the case of lightweight thermal insulating materials. When the deformation reaches 10 %, the failure of the specimens is observed. Here to conclude that the compressive strength of the investigated material depends on its density and the type of granules used. The highest composite compressive strength of 0.75 N/mm² is reached when fine granules are used at a density of 275 kg/m³.
2.5  MIXTURE PROPORTIONING OF LIGHTWEIGHT CONCRETE

Combination of different concrete ingredients based on their properties to obtain the fresh and hardened concrete is known as mix proportion.

The study carried out by Xu and Jiang (2011). The mix proportion parameters of expended polystyrene (EPS) lightweight aggregate concrete are analyzed using Taguchi’s approach. The optimal mixture of EPS concrete was selected among experiments under consideration to manufacture the lightweight concrete. They study on three sample of different mix proportion. Cement used 400 kg/m$^3$, 450 kg/m$^3$, and 500 kg/m$^3$, water content 0.45, 0.50, 0.55, where the volume of EPS used was 15 %, 20 %, and 25 %, and the sand ratio used are 35 %, 38 %, and 41 % respectively for the 3 mixes. The best possible levels of mix proportions are investigated for the maximization of compressive strength and for the minimization of the concrete density. According to Taguchi method, to find the proper combination of structural parameters and to analyze it, the number of experiment need was nine experiments. The concrete specimens were cast in steel molds, and followed immediately by curing at room temperature for 24 hours before being demolded. After demolding the specimens were stored in control room to maintained temperature about 20 °C, until the day of test.

The required amount of styrene-butadiene rubber copolymer (SBR) was then added and mixing continued for a further two minutes. After the water and superplasticizer (SP) were added slowly until the desired consistency is reached. Then the polystyrene beads were added and thoroughly mixed into the mortar. In this study, Manolia (2012) have use the concrete mix with proportion of (1:3:0) by volume of (cement: sand: polystyrene) with cement content of 300 kg/m$^3$ and water cement ration of 0.45 as control mix. Three different (PC) mixes from the control mix by a partial replacement of sand with polystyrene beads. It prepared by volume because the beads are very light in weight and density
compared with other material. Results of three samples by undergo slump flow, L-box and V-funnel was gathered. First mixture sample has the most suitable mix to be used for the production of masonry units which are used for load bearing internal wall with density an compressive strength of 1859 kg/m³ and 14.65 MPa. While third mixture sample is suitable to be used for non-structural purpose and mainly for thermal insulation purpose with density about 1660 kg/m³ and compressive strength 10.23 MPa.

Two types of idealized EPS concrete specimens were fabricated with 7mm and 5mm EPS diameter. The study was conducted by K.Miled et al. (2003). The dimension $a \times b \times e$ according to the two holes patterns. Fines aggregate use as an additional material to cement. Its content in the mix was kept at 25 % of cement weight. The water to cement ratio was kept at 6.0. A metallic mold was fabricated in which prismatic mortar sheets of dimensions stated were cast. It be demolded after 24 hour and protected from desiccation with an aluminium paper, then be placed in an oven adjusted at the temperature of 60 °C for three days.

Here the study by A.Laukaitis et al. (2005), they prepared three different ratios between foam cement and foam polystyrene granules, 1:1; 1:2; 1:3. After casting into the forms 100 x 100 x 100 mm and 400x400x400 mm the polystyrene granules and foam cement composure were allowed to harden for 28 days at ambient conditions. After 28 days the test conducted.

Four different mix proportions for EPS concrete have been done by Idawati et al. (2003). They are tagged as PC and P1 to P4. The mixes were prepared by volume, because the beads are very light in weight and density. The control mix, specimen PC has proportion 1:3:0, 1 part cement, 3 parts sand and 0 part polystyrene. The polystyrene was added in proportions as part of sand replacement. The P4 specimen is content the most
polystyrene, which is 1 part of cement, 1 part of sand and 2 parts of polystyrene. The water content use is water-cement ratio 0.4 for all specimens. They find that mix of P2 with compressive strength of 14.0 N/mm$^2$ and density of 1646 kg/m$^3$ is most suitable mix to be used as a load bearing internal wall. While mix P3 and P4, can be used as non-load bearing internal wall.

2.6 SUMMARY

Nowadays, many innovation of light weight concrete have been done. They design it by applied artificial aggregate such as a fly ash, slag and porcelinite rocks. Use of EPS (expanded polystyrene) as replacement for the aggregate in concrete are also be applied in large scale nowadays. There were a lot of advantages of light weight concrete and aggregate substituted will give a lot of option to select the suitable alternate material for develop the sustainable construction material.

It is prove from the review of literature that comprehensive studies has been carries on the characteristics of EPS application in concrete related to strength and durability. However, not much attention has been focused on the strength of EPS brick, in form of wall application.

Hence, the present work the EPS brick have been completely replaced the conventional brick and an attempt has been made to study the strength and durability aspect of EPS brick.
CHAPTER 3

METHODOLOGY

3.1 INTRODUCTION

Methodology is to explain the material design and analysis method that is conducted during the experimental study. Discussion in this section is divided into two section, there are project design and analysis. Research methodology is important to conduct the study using the method and procedure following standard.

To conduct the study, understanding in theoretical related with study field and general knowledge on experimental method is needed. It can be gain from literature review study. The theoretical understanding and research will make the experimental study systematic to comply with objective of study.

This study are divided into several stage. Other method including observation, data analysis and others. In observation method, device like camera is used to record the sample picture, test conducted, the result and others.

Test for this study is conducted in the concrete laboratory University Malaysia Pahang, Gambang.