DECLARATION OF THESIS AND COPYRIGHT

Author's full name : NOR ATIQAH BINTI MAT REFIN________

Date of birth : 12 JANUARY 1990______________________

Title : EXPERIMENTAL STUDY ON THE PRISM STRENGTH OF EXPANDED POLYSTYRENE_ LIGHTWEIGHT BRICK ________________

Academic session : 2015/2016___________________________________

I declare that this thesis is classified as:

☐ **CONFIDENTIAL** (Contain confidential information under the Official Secret Act 1972)

☐ **RESTRICTED** (Contains restricted information as specified the organization where research was done)

☑ **OPEN ACCESS** I agree that my thesis to be published as online open access (Full text)

I acknowledge that University Malaysia Pahang reserve the right as follows:

1. The thesis is the property of University Malaysia Pahang.
2. The library of University Malaysia Pahang has the right to make copies for the purpose of research only.
3. The library has the right to make copies of the thesis for academic exchange.

Certified by:

_________________________ _____________________

(Student's signature) (Supervisor's signature)

____900112-10-6058___ _ **Dr.Fadzil Bin Mat Yahaya**

New IC / Passport Number Name of Supervisor

Date: 14 JANUARY 2016 Date: 14 JANUARY 2016

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

SUPERVISOR'S DECLARATION

I hereby declare that I have checked this thesis and in my opinion, this thesis is adequate in terms of scope and quality for the award of the degree of Bachelor in Civil Engineering.

Signature	:	
Name	:	DR. FADZIL BIN MAT YAHAYA
Date	:	14 JANUARY 2016

STUDENT'S DECLARATION

I hereby declare that the work in this thesis is my own except for quotation and summaries which have been duly acknowledged. The thesis is not being accepted for any degree and is not concurrently submitted for award of other degree.

Signature	:	
Name	:	NOR ATIQAH BINTI MAT REFIN
ID No.	:	AA12018
Date	:	14 JANUARY 2016

Specially dedicated to

My late father, mother and family

ACKNOWLEDGEMENT

Allhamdullillah, finally I with support from supervisor have completed my study. I would like to thank everyone who had contributed to the successful completion of this study. Throughout this study, I have received so much help, cooperation and encouragement from others.

Firstly, I would like to express outmost gratitude to my study supervisors, Dr.Fadzil bin Mat Yahaya for his fruitful advice, guidance and patience throughout the study, which has led to the successful finish on this study. Puan Hazizah for her generous guidance for me to ultimately improved my study. Lab officers, who have been so friendly and cooperative, deserve a note of thanks from me as well. After that, I am thankful to have countless blessing from my family and friends which has always been the source of inspiration to finishing my study. Lastly, I would like to express my enormous thanks to Miss. Nur Atiqah Binti Sulaeman, a friend, second to none for always participating with me when during laboratory work as well as brainstorming so many ideas with my study.

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, CO_2 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 kawasan kediaman dilakukan dengan rancak dan pada masa yang sama,dunia juga menghadapi masalah kekurangan sumber asli. Ia menjadi tangungjawab untuk mengubah suai reka bentuk dan teknologi pembinaan perumahan yang digunakan hari ini untuk mengurangkan kos, pelepasan CO_2, 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. Pengunaan 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 dalaman bukan galas beban dan rekabentuk prospektif dan pengunaan didalam bangunan untuk menjadikan ia cekap tenaga. Tujuan utama kajian ini adalah untuk merekabentuk campuran optimum bagi dinding bata EPS bagi aplikasi dinding dalaman 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 mengunakan lepa simen. Nisbah bancuhan bata adalah mengunakan 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, pengunaan 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. Kekonduksian 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

LIST OF TABLES

Table No. **Title** **Page**

LIST OF FIGURES

LIST OF SYMBOLS

%	Percentage
^{o}C	Degree celcius
γ	Gamma

LIST OF ABBREVIATIONS

EPS	Expanded polystyrene
ASTM	American Society for Testing and Materials
CIDB	Construction Industry Development Board
USA	United State of America
MS	Malaysia Standard
SC-PC	Self compacting polystyrene concrete
WTP	Waste treatment plant
pH	Potential of hydrogen
EN	European Standard
SP	Superplasticizer
BS	British Standard

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 (expended 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 importance role to achieve the developed country status. The construction industry is also importance 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/m^3 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 porcelanite 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 monomerstyrene, aliquid 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 f 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/m^3, 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/m^3 , the density of a composite with large granules 214 kg/m^3, 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 ^oC 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 ^oC 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 ^{o}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 ^{o}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/m^3, 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/m$^{3.}$ 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 ^oC 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 ^oC. the higher compressive strength developed at 1100 ^oC 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/mm^2 is reached when fine granules are used at a density of 275 kg/m^3.

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 ^{o}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/m^3 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/m^3 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 x b x 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 ^{o}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 devided into two section, there are project design and analysis. Research methodology is important to conduct the study using the method and procedure folowing standard.

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

This study are devided 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.

The test conducted according to ASTM and MS related. The test related to study the wall strentgh are compression test, strain stress test, thermal insulation tets and defelction test. The test conducted to study the strentgh of the EPS brick when be applied as non load bearing internal wall. It also study whether the EPS beads is suit to become a material in substituting the sand percentage in brick construction. The EPS beads will be used in replacing the percentage of sand use about 0 %, 16.7 %, 33.3 % and 50 % of sand replacement.

3.2 RESEARCH PHASE

3.2.1 Phase 1: Collecting Information and Material

The material needed in the mixture of the brick will also be collected. The material needed for the mixture would be cement, water and fine aggregate and EPS beads. For the replacement of the fine aggregate, which are EPS beads is used.

Before the test, moment of inertia in x and y axis direction for the prism are determined. The smallest moment inertia value axis is in y direction. According to lowest moment inertia axis, the strain gauge and transducer is replaced to the prism. The strain gauge and transducer are used for strain and deflection test.

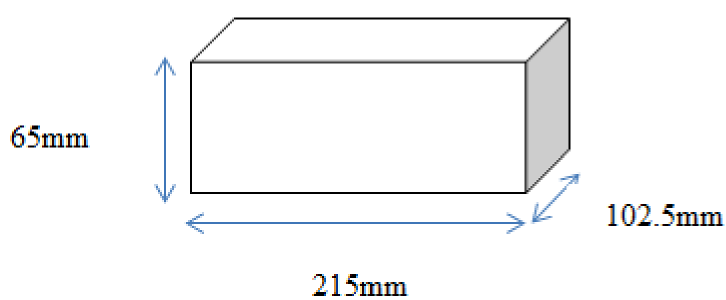

Figure 3.1 EPS single brick

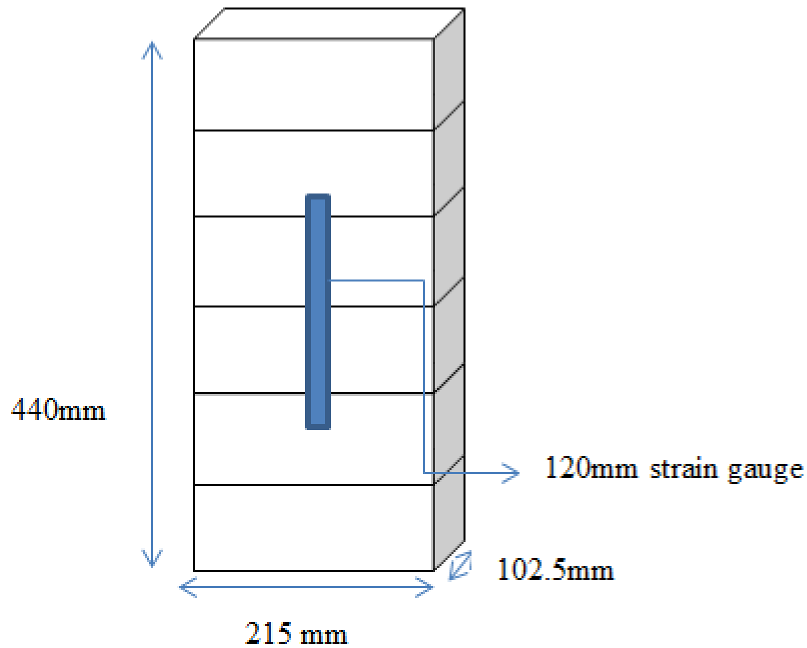

Figure 3.2 EPS brick prism

The EPS single brick samples are used for thermal conductivity test. While the prism EPS brick sample are used for compressive, strain and deflection test.

3.2.2 Phase 2: EPS Brick Prism Production

The second phase is producing brick from the combination of cement, fine aggregate, water, and EPS (control) without the presence of the coarse aggregate. The diameter for brick is 215mm, 102.5mm, and 65mm for length, width and height.

The brick is then built into prism form by connecting the brick with 10mm thick of mortar. The prism consists of 6 brick in row. The dimensions of the prisms are 215mm, 102.5mm and 440mm for length, width and height of the prism. The prism is air cured for 28 days period.

3.2.3 Phase 3: Determination of Compressive Strength

This phase focused on the main objective which is to determine the compressive strength of the lightweight EPS brick prism. Before the compressive strength of the prism was determined, the samples needed to undergo 28 days air curing.

After the curing, the testing for the compression strength was carried out. The 28-day compressive strength was achieved by 16.7 % EPS mix proportion, which is 3.90 MPa. Table 3.1 shows the mix design for EPS brick during this research.

Table 3.1 Mix Design for EPS brick

Cement volume	Sand volume	EPS volume	Cement Kg	Sand Kg	EPS Kg	Weight	Wet Density	M^3
1	3	0	1506	4800	0	6908	2250	3.07
			490	1563	0	2250		1.00
1	2.5	0.5	1506	4000	15	6123	1900	3.22
			467	1241	5	1900		1.00
1	2	1	1506	3200	30	5388	1626	3.24
			464	987	9	1646		1.00
1	1.5	1.5	1505	2400	45	4553	1550	2.94
			513	817	15	1550		1.00

3.3 MIXING PROCEDURE

The material that needs assembled which are EPS, sand, cement, and water. For the control samples, the ratio is 1:3:0 which are cement, sand, and EPS by volume respectively. First, mix sand, EPS and cement together and blend it until both of the material is truly mixed and uniform. After that, water is added to the mixture and blends it until it is uniform.

The mixture is poured into the brick mold .The brick is demolded after 5 minutes. The wet brick is left in room temperature to dry for one day. Then, the brick be arranged and attached to become a panel by cement mortar. The panel be air curing about 28 days period before be tested.

3.4 EXPERIMENTAL TEST

3.4.1 Prism Compression Test

The compression test was conducted using machine UTC-5600 compressive strength machine. The test was performed as BS 1881: part 16:1983 requirement. An axial compressive load with a specified pace rate was applied to 440 mm prism until failure occurred. The compressive data is recorded into computer.

The prism was placed on the center of the compression machine. Test specimen was loaded gradually with constant rate set until the specimen fail. The maximum load carried by the specimen was recorded in computer and the compressive strength value was calculated according to equation 3.1.

$$Sc = \frac{P}{(Width\ x\ Thickness)} \tag{3.1}$$

Sc	= Compressive strength, MPa
P	= Maximum load, N
Width	= width of specimen, mm
Thickness	= thickness of specimen, mm

3.4.2 Strain Stress Test

The strain test was conducted using machine UTC-5600 compressive strength machine. The test was performed as ASTM C 67-12 requirement. The 120mm strain gauge is placed vertically on one side of prism before compressed. The strain gauge wire connected to data logger.

The prism was placed on the center of the compression machine. Test specimen was loaded gradually with constant rate set until the specimen fail. The strain data obtained by the specimen was recorded in computer and the modulus elasticity for the specimen is obtained from ratio of stress and strain of specimens.

3.4.3 Deflection Test

The deflection test was conducted using machine UTC-5600 compressive strength machine. The test was performed as ASTM C 67-12 requirement. The transducer is attached at back and front of prism in the same level to measures the deflection occur. The transducers are connected to data logger.

The prism was placed on the center of the compression machine. Test specimen was loaded gradually with constant rate set until the specimen fail. The deflection data for both transducers are obtained and recorded in computer and the graph of stress versus deflection is plotted.

3.4.4 Thermal Conductivity Test

Thermal conductivity test was performed according to BS EN 12664 (2001). The brick was air cured for 28 days. The brick is oven dried at 48 ^{O}C for 24 hour to remove the moisture content of brick where the presence of moisture in brick will affect the result as moisture increase the heat transfer rate.

The brick was taken out from the oven and cooled down to room temperature about 28 ^{O}C. the thermocouple was connected between the hot plate surface and brick surface. The thermocouple connected to data logger for record the temperature reading for 3 hours testing. The thermal conductivity, k was calculated according to Eq. (3.2)

$$K=\frac{Qh}{A(T1-T2)} \tag{3.2}$$

K = Thermal Conductivity, W/mK

Q = Heat Conduction, J/s

H = Thickness of specimen, m

A = Cross sectional area, m^2

T1 = Temperature of hot plate, k

T2 = Temperature of cold plate, k

The heat conductivity, Q was calculated based on equation 3.3 where the value of specific heat capacity, c is 840 J/KgK for brick referred to appendix A. The time taken t is 3 hours equivalent to 10800 second.

$$Q = [\ mc\ (T1-T2)]/t \tag{3.3}$$

Q = Heat Conduction, J/s

M = Brick Mass, Kg

c = Specific Heat Capacity, J/KgK

T1 = Temperature of hot plate, K

T2 = Temperature of cold plate, K

T = Time, s

Figure 3.3 Mixing of EPS brick

Figure 3.4 Samples of EPS brick

Figure 3.5 Prism making process

Figure 3.6 Compressive test setup

Figure 3.7 Thermal test setup

CHAPTER 4

RESULTS AND DISCUSSION

4.1 INTRODUCTION

This chapter discusses mix results for EPS lightweight brick panel incorporated with different percentage of EPS replacement to get the strongest compressive strength, strain stress data, deflection and thermal insulation reading after curing of 28 days.

4.2 Compression Test Results

Compressive strength test results for EPS lightweight brick panel were shown in table 4.1.

Table 4.1 Test results for 28 days

Prism sample	Average weight (Kg)	Average Stress (MPa)
Control (0% EPS)	24.92	7.32
16.7 % EPS	18.48	3.90
33.3% EPS	16.57	3.48
50% EPS	14.65	2.54

Table 4.1 show the compressive strength is decrease in increasing of EPS content in mix. For lightweight EPS brick wall, the highest 28-days compressive strength was achieved by 16.7 % of EPS mix proportion, which is 3.90 MPa, while the control brick with 0 % EPS is 7.32 MPa. The prism test inly done for 28 day curing because, that shown 99 % hardened of the brick. At 28 day, lightweight brick show less compressive value compared to control mix brick 0 % EPS use.

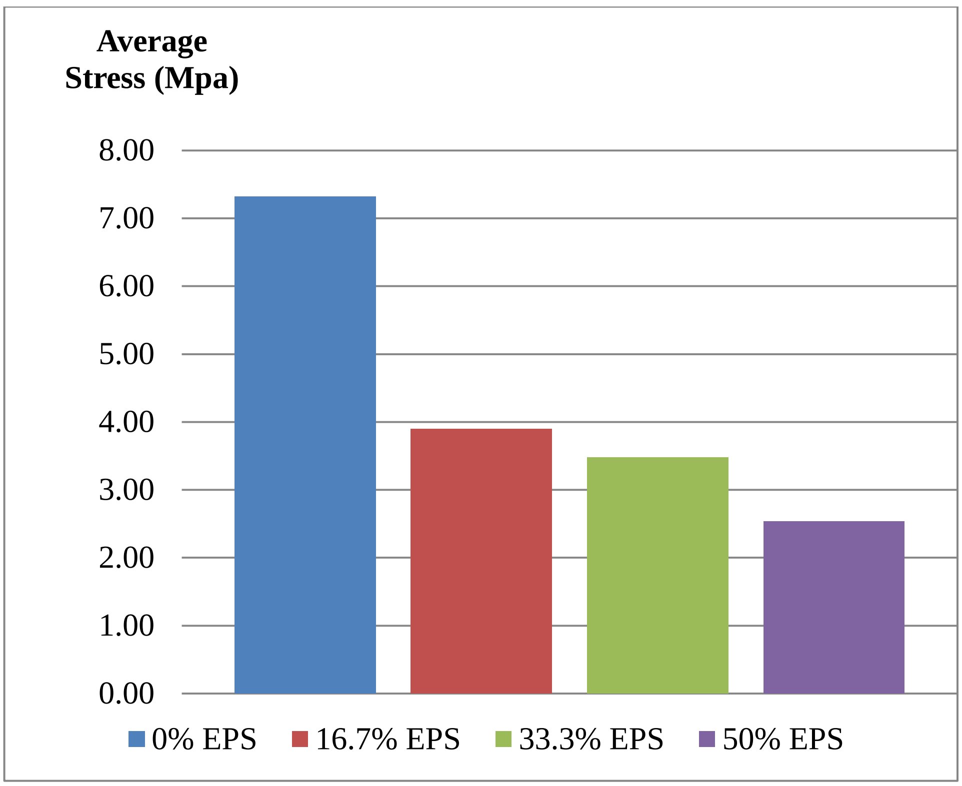

Figure 4.1 Compression Strength for 28 days

Figure 4.1 shows the compressive strength of each mix proportion for 28 days curing. The compressive value decreased with increasing of EPS content in the mixture. Prism with 50 % of EPS gives a lowest value of compressive strength which is 2.54 MPa. The average weight for the prism also decreased with increasing of EPS percent used in mixture. This shows more EPS beads used, helps to reduce in wall weight but decreased the wall strength. For achieved the objective to design lightweight wall panel to be apply as non-load internal wall, 16.7 % EPS replacement mix with 3.90 MPa strength, achieved the standard of non-load bearing wall about 3.45 MPa.

4.3 Strain Test Result

Strain test results for EPS lightweight brick panel for all specimens were shown in table 4.3.

Table 4.2 Strain test results for 28 days

% EPS replacement	Modulus elasticity (MPa)	Item
0	14.85	1
16.7	13.34	2
33.3	12.98	3
50	9.72	4

Table 4.2 show the modulus of elasticity of the prism that obtained from compressive strength test result versus strain ration, that calculated from the data logger data generated. Modulus elasticity is analyzed to shown the elasticity of the prism to the applied load. Figure 4.2 show the modulus elasticity value of the sample prism.

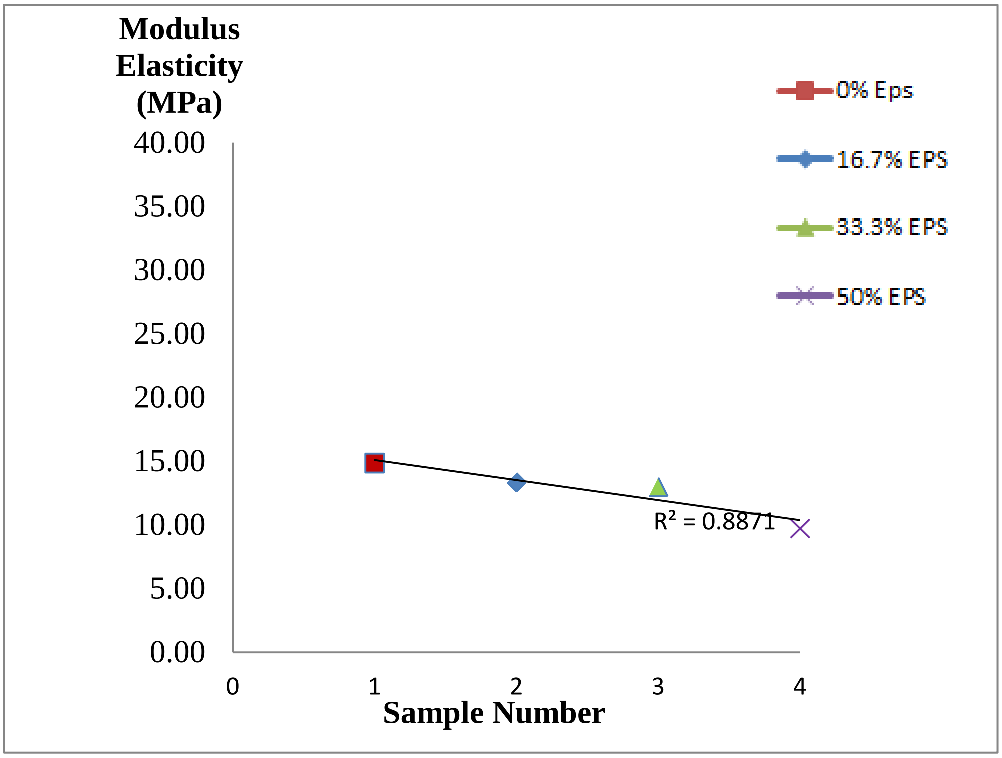

Figure 4.2 Modulus elasticity value for prism sample

The specimens with higher content of EPS give a lower value of modulus elasticity. That show the modulus elasticity is increase with strength. Modulus elasticity for lightweight prism is lower than normal prism, because of the polystyrene will reduce the strength of the prism. When the modulus elasticity is higher, the stiffer the materials that will result in small deflection occur on structure. Modulus elasticity is important for structure that required strict control of deformability. Result from the test, show sample with 50 % EPS have a lowest of modulus elasticity value about 9.72 MPa than others, and the control mixture with 0 % of EPS have a highest modulus elasticity about 14.85 MPa.

4.4 Deflection Test Result

Deflection test results for EPS lightweight brick panel all specimens were shown in table 4.3.

Table 4.3 Deflection test results for 28 days

0% EPS		16.7% EPS		33.3% EPS		50% EPS	
Axial Load (KN)	**Deflection (mm)**	**Axial Load (KN)**	**Deflection (mm)**	**Axial Load (KN)**	**Deflection (mm)**	**Axial Load (KN)**	**Deflection (mm)**
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
25.34	0.21	24.26	0.41	24.31	0.67	19.78	0.82
36.39	0.35	2953	0.65	26.25	1.07	20.32	0.98
43.41	0.5	32.44	0.71	28.53	1.34	25.43	1.32
67.73	0.67	34.13	0.82	31.05	1.57	27.19	1.45
75.18	0.78	36.17	1.09	33.26	1.70	31.17	1.57
82.85	0.94	36.58	1.16	48.87	1.87	33.04	1.78
91.46	1.01	48.79	1.33	57.53	1.95	35.56	2.13
93.67	1.05	55.37	1.43	65.78	2.15	37.77	2.44
113.44	1.26	58.22	1.52	75.34	2.34	47.97	2.87
163.68	1.55	85.95	1.75	77.13	2.43	56.42	3.01

Table 4.3 show the deflection of the prism that obtained from transducers that be setup at the back and front of the prism to read the deflection occur during the compression stage of the prism, the transducers connected to data logger to generate deflection data. The

deflection graph is draw to make it clear. Figure 4.3 show the load deflection graph relationship.

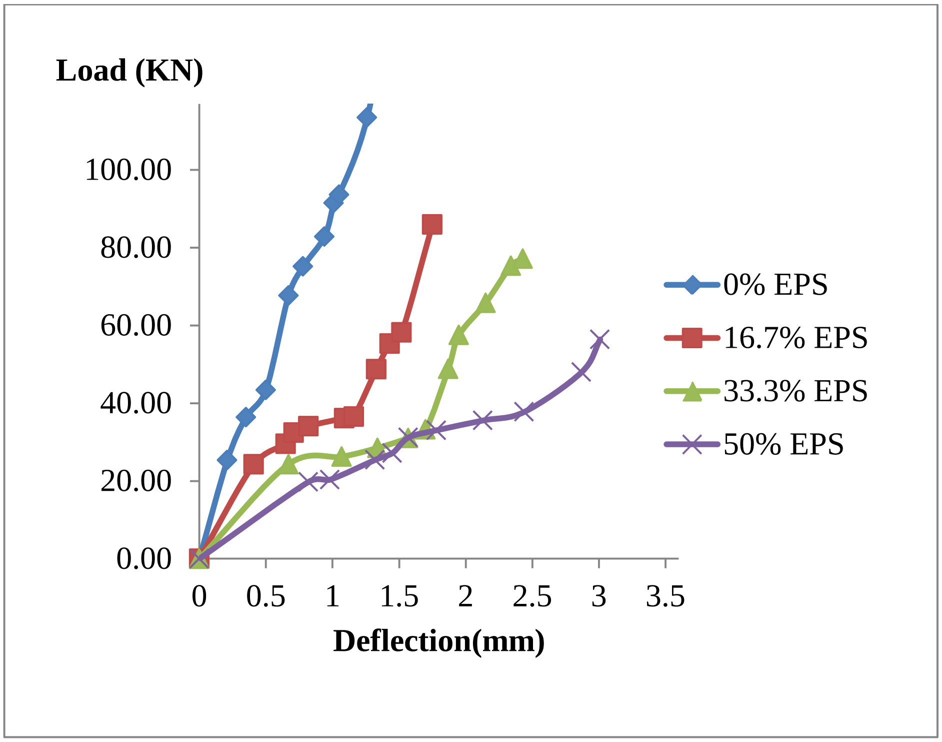

Figure 4.3 Deflection value for prism sample

Deflection test is conducted to define the value of wall bends before failed in compression. Determine the deflection is important in designing product which can only be allowed to deflect by certain amount. The deflections of the prism result are in crack or break of the prism. The deflection increase with the percent increase in EPS used. From the graph show that the lowest deflection value is represent by control mix (0 % EPS), about 1.55 mm. The 16.7 %, 33.3 % and 50 % EPS specimen brick give deflection value about 1.75 mm, 2.43 mm and 3.01 mm. With increasing EPS percent in mixture, the deflection value of prism increase. That shown the prism with more EPS will deflect more before it failed, because EPS nature is elastic.

4.5 Thermal Test Result

The result of thermal test is compared with compressive strength to identify the best mix proportion towards compressive strength and thermal conductivity. Result of thermal test for EPS lightweight brick unit are shown in table 4.4.

Table 4.4 Thermal conductivity test results

% EPS replacement	Strength stress (MPa)	Thermal Conductivity (W/mK)
0	7.32	0.46
16.7	3.90	0.32
33.3	3.48	0.30
50	2.54	0.21

Table 4.4 shows the thermal conductivity test result. The thermal conductivity value is gained by formula, which uses the information of different in two temperature, from bottom and top temperature reading. Figure 4.4 show the stress and thermal conductivity relation graph.

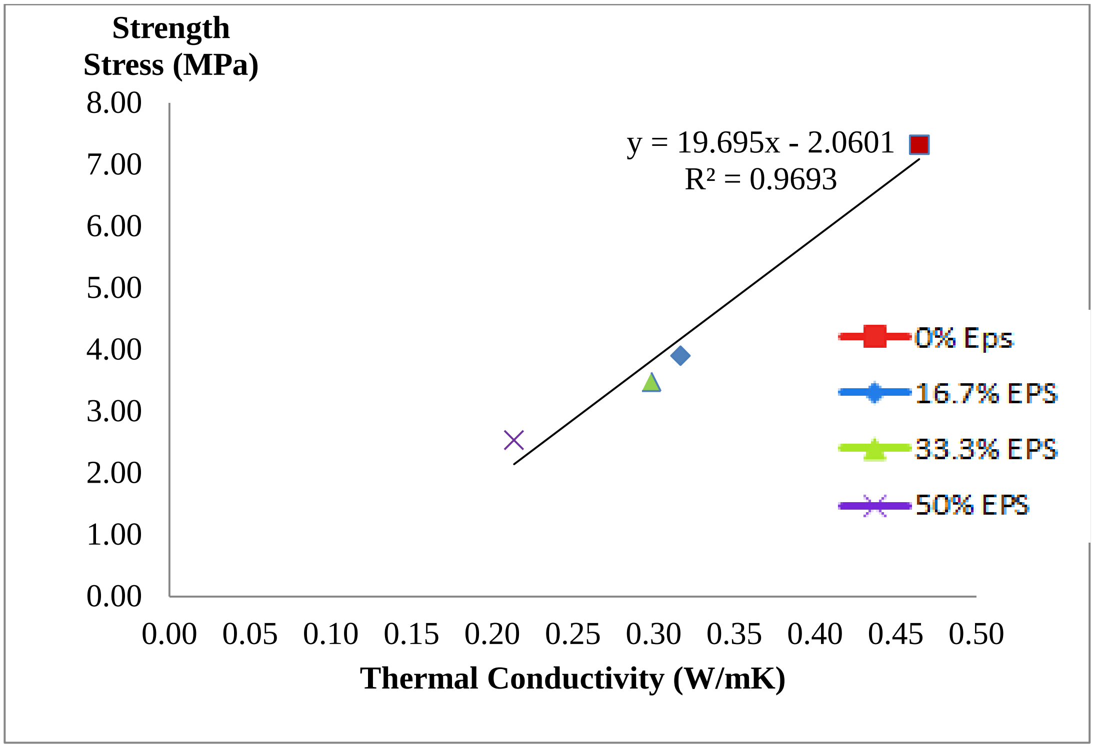

Figure 4.4 Strength stress versus thermal conductivity

Thermal conductivity test is the method to investigated thermal insulation where the lowest thermal conductivity gives the highest thermal insulation of the material. From the graph show that the highest thermal conductivity value is represent by control mix (0 % EPS), about 0.46 W/mK. The 16.7 %, 33.3 % and 50 % EPS specimen brick give thermal value about 0.32 W/mK, 0.30 W/mK and 0.21 W/mK.

According to standard the common brick should have thermal conductivity value about 0.65 W/mK to 0.8 W/mK. The EPS specimen brick give a lower thermal conductivity value that show EPS beads help in thermal insulation for the building. With increase in the percent use of EPS, the thermal insulation increase and thermal conductivity decrease.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 CONCLUSION

This research has focused on the study of the suitability of the expanded polystyrene (EPS) in a lightweight brick mixture as a fine aggregate replacement. Based on the laboratory results, the following conclusions can be drawn corresponding to the respective objective that are listed out at the beginning of this study.

This research has focused on the study to design the optimum mix percentage of EPS brick for non-load bearing internal wall application. It also studies on comparison on EPS brick prism with conventional brick prism. The performance of lightweight brick that use EPS beads in order to replace the natural resources, which is fine aggregate in construction material production and also to decrease the load on structure. Based on the laboratory results, the following conclusions can be drawn corresponding to the respective objective that are listed out at the beginning of this study.

Main objective for this research is to compare the strength performance of the prism. This comparison achieved the minimum standard for non-load bearing brick is 3.45 MPa, when determine the optimum compressive strength of lightweight EPS brick prism. This was achieved, because the maximum compressive strength is 3.90 MPa for sample with 16.5 % EPS replacement.

The second objective is to study comparison on EPS brick prism with conventional brick prism. This was achieved when the thermal conductivity value and weight for EPS brick prism is lower than conventional. The modulus elasticity and strength of EPS brick is decreased with increasing in EPS per cent. Deflection value was increase when increasing in EPS percentage displacement.

5.2 RECOMMENDATION

The research work on lightweight EPS brick mixed is quite handy and it promises a great scope for future studies. The following aspects related to the EPS brick and can be further explored;

1. Thermal test period extend for 24 hours for more accurate test result.
2. Recommended way in preparing EPS brick mixture is to mix EPS beads with aggregate for two minutes, after that, both cement and water added, and mix about 5 minutes in order to get homogeneous mix.
3. Explore on the effect when the prism pattern be replaced by standard brick wall pattern.

REFERENCES

I.H Ling, Teo D.C.L. 2012. Compressive Strength and Durability Properties of Lightweight Concrete Bricks under Full Water Curing and Air-Dry Curing. *Journal of Sustainable Energy Development.* **1**(4): 14-18 (online). http://infonomics-society.org/IJSED/CompressiveStrengthandDurabilityPropertiesofLightweightConcreteBricksunderFullWaterCuringandAirDryCuring.pdf (2 July 2015).

Yang Li, Yi Xu, Linhua Jiang. 2011. Mechanical Properties of Expanded Polystyrene Lightweight Aggregate Concrete and Brick. *Journal of Construction and Building Materials.* **27**(2012): 32-38 (online). http://www.elsevier.com/locate/conbuidmat.html (4 July 2015).

Kung-Yuh Chiang, Ping-Huai Chou. 2009. Lightweight Brick Manufactured from Water Treatment Sludge and Rice Husks. *Journal of Hazardous Materials.* **171**(2009): 76-82 (online). http://www.elsevier.com/locate/jhazmat.html (4 July 2015).

Lect. Manolia Abed Al-Wahab Ali. 2012. The Possibility of Produce Self Compacted Polystyrene Concrete. *Journal of Engineering and Development.* **16(**2012): 1813-7822 (online). http://www.iasj.net/iasj?func=fulltext&ald=68207

A. Laukaitis, R. Zurauskas. 2005. The Effect of Foam Polystyrene Granules on Cement Composite Properties. *Journal of Cement & Concrete Composites.* **27**(2005): 41-47 (online). (online). http://www.sciendirect.com/locate/cemconcomp.html (6 July 2015).

K. Miled, R. Le Roy, K. Sab. 2004. Compressive Behavior of Idealized EPS Ligthweight Concrete: Size Effects and Failure Mode. *Journal of Mechanics of Materials.* **36**(2004): 1031-1046 (online). http://www.sciendirect.com/locate/mechmat.html (6 July 2015).

R.M. Pulselli, E.Simoncini, F.M Pulselli, S. Bastianoni. 2007. From Waste to Commodity: Transforming Shells Into High Purity Calcium Carbonate. *Journal of Energy and Buildings.* **39**(2007): 620-628 (online). http://www.sciencedirect.com/science/article/pii/S09592608001881.html (9 July 2015).

Malaysia Standard (MS) Standard 76:1972. *Specification For Bricks And Blocks Off Fired Brickearth,Clay Or Shale*. Malaysia. 1972

American Standard Testing and Materials (ASTM) Standard C496-86, *Standard Test Method For Sampling and Testing Brick and Structural Clay Tile*. West Conshohocken, PA. 1986

American Standard Testing and Materials (ASTM) Standard C67-08. *Standard Test Method For Splitting Tensile Strength Of Cylindrical Concrete Specimens*. West Conshohocken, PA. 2008

American Standard Testing and Materials (ASTM) Standard C129-14a. *Standard Non-Loadbearing Concrete Masonry Units.* West Conshohocken, PA. 2014

American Standard Testing and Materials (ASTM) Standard C78-84. *Standard Test Method for Flexural Strength Of Concrete (Using Simple Beams With Third Point Loading).* West Conshohocken, PA. 1984.

American Standard Testing and Materials (ASTM) Standard C373-72. *StandardTest Methods for Water Absorption, Bulk Density, Apparent Porosity and ApparentSpecific Gravity of Fired Whiteware Products.* Philadelphia, PA, USA.1972.

American Standard Testing and Materials (ASTM) Standard C 20-00. *Standard Test Methods for Apparent Porosity, Water Absorption, Apparent Specific Gravity, and Bulk Density of Burned Refractory Brick and Shapes by Boiling Water.* West Conshohocken, PA, USA. 2005.

British Standard European Norm (BS EN) Standard 12664:2001, *Thermal Performance of Building Materials and Products. Determination of Thermal Resistance by Means of Guarded Hot Plate and Heat Flow Meter Methods. Dry and Moist Products of Medium and Low Thermal Resistance*. London. 2001.