DEVELOPMENT OF LIGHTWEIGHT POROUS CONCRETE AS WALL INSULATION

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This report as a to fully my bachelor in Mechanical Engineering Structure and Materials

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SUPERVISOR DECLARATION

"I hereby declare that I have read this thesis and in my opinion this report is sufficient in terms of scope and quality for the award of the degree of Bachelor of Mechanical Engineering (Structure and Materials)"

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DECLARATION

"I hereby declare that the work in this report is my own except for summaries and quotations which have been duly acknowledged."

Signature : ....
Author : NURULHILMI ZAIEDAH BINTI NASIR
Date : ....

DEDICATION

For my beloved father and mother,

Dearest family members,

Lecturers and friends

ACKNOWLEGEMENT

Assalammualaikum and Salam Satu Malaysia,

Thanks to Allah, for giving me permission to complete this project. I would like to witness my graceful thanks to all for the support, encouragement and inspirations that I have received during completing this project.

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ABSTRACT

Concrete is a material that widely used as building components. Concrete has a great strength as a construction material and it is easy to change into other materials accordance with needs. One of the uses of concrete is as partition wall where the design of concrete must be lightweight and have good strength. The most common concrete that have being use as a partition wall is porous concrete. Porous concrete is the term for mixture of coarse aggregate (usually sand, gravel or crushed stone), Portland cement and water. Although people commonly use the word “cement” as a synonym for concrete, the terms in fact denote different substances: cement, which encompasses a wide variety of fine-ground powders that harden when mixed with water, represents only one of several components in modern concrete. The raw material to develop this porous concrete are a fine aggregates, cement, lime (calcium carbonate), gypsum, water and polyurethane (additives/blowing agents). In preparing this final year project, the student obtained data from experimental, literature study and internet, while the selections of research methods are based on ASTM testing standards. This project was a laboratory –scale research to determine the optimum composition of the manufacture of lightweight concrete as a porous partition wall application. The preparations of specimens are by using various percentage compositions of mixed materials.

ABSTRAK

Konkrit adalah bahan yang digunakan secara meluas di dalam pembinaan bangunan. Konkrit mempunyai kekuatan untuk bahan binaan dan ia senang ditukar kepada bahan lain apabila diperlukan. Salah satu penggunaan konkrit adalah sebagai dinding atau pembahagian dinding dimana rekabentuk konkrit perlulah ringan dan mempunyai kekuatan yang bagus. Konkrit yang paling banyak digunakan adalah yang mempunyai liang. Konkrit berliang adalah terma bagi campuran diantara pasir kasar (biasanya pasir, batu atau batu hancur), simen Portland dan air. Kebiasaanya, orang ramai selalunya menggunakan perkataan 'simen' sebagai sama erti dengan konkrit walaupun pada hakikatnya ia mempunyai bahan perbezaan: simen, dimana digunakan secara meluas seperti pasir halus dan dikeraskan apabila dicampurkan air. Bahan mentah yang digunakan untuk membuat konkrit berliang adalah pasir halus, simen, kapur, gypsum, air and serbuk aluminium atau polyuretan sebagai bahan tambah untuk menghasilkan keliangan. Dalam perlaksaan projek tahun akhir ini, pelajar mengkaji data daripada ujikaji, kajian ilmiah dan internet. Pemilihan kaedah kajian bergantung kepada piawaian ujian (ASTM). Projek ini dilakukan didalam makmal untuk mengkaji optimum komposisi bahan untuk membuat konkrit yang ringan sebagai pembahagian dinding yang berliang. Persediaan untuk sampel dibuat dengan menggunakan peratus komposisi yang berbeza bahan campurannya.

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CHAPTER 1

INTRODUCTION

1.1 Background Research

Concrete is a material that widely used as building components. Concrete has a great strength as a construction material and it is easy to change into other materials accordance with needs. One of the uses of concrete is as partition wall where the design of concrete must be lightweight and have a good strength. The most common concrete that have being use as a partition wall is porous concrete.

Population growth led to high demand in housing and office buildings from years to years. One of the most crucial components in building structures is the partition wall because it needs to be good in its acoustic properties and have high strength. In order to obtain a good acoustic property, it is suggested to use the porous building materials which are good in absorbing sound waves.

In manufacturing of concrete block, blowing agents is required to produce pores in concrete. The most common blowing agent that being used is a aluminum powder or polyurethane. In addition, the necessary material that can be also making the concrete is expanding by adding gypsum. One of the advantages of the existence pores in the concrete causing the concrete to be mild.

Lightweight nature of these provide several advantages, including providing convenience in the process and can reduce damage to buildings experienced the earthquake. Therefore, porous concrete is best choice in areas with highly risk of earthquake. To reduce the damage caused by earthquake, then the required earthquake resistant structures.

1.2 Objectives

The aim of this final year project is:-

- To development of alternative insulation material for wall insulation obtain the physical properties and mechanical properties.
- To manufacturing of lightweight porous concrete materials.
- To study the characteristic lightweight porous concrete products.

1.3 Problem statement

The use of concrete for insulating materials in building construction causes some problem such as having a high weight or relatively heavy. Concrete also has pocket and vein into which water can seep and cause damage to wall and floors. It is also cannot reflect the sound well. When the sound reaches to the concrete wall, it will be reflect the big wave signal to people surrounding.

Compared with the porous concrete, it has a porous that will be reduced the sound reflection. Porous concrete also available in many parts of the world and can be used in producing in wide range of units and suitable strength values for different fields of application such as internal and external wall, inner leaves of external cavity wall, fill panels and isolation of roof decks and floors.

1.4 Research scope

The scope for this final project is limited to the problem of fabrication and characterization of lightweight porous concrete as follows.

1. Research conducted at the Laboratory of Material Science UTeM.
2. Material that being are use gypsum, sand, aluminum powder/Polyurethane, water and Portland cement.
3. Analysis on the mechanical properties of porous concrete with various compositions that include compressive strength.
4. Analysis on the testing physical properties includes density and porosity testing.
5. In this study, researcher decides to add aluminum powder or polyurethane as a method in reducing the density of lightweight porous concrete.

1.5 Research methodology

Concrete is a material that widely used as building components. Concrete has a great strength as a construction material and it is easy to change into other materials accordance with needs. One of the uses of concrete is as partition wall where the design of concrete must be lightweight and have good strength. The most common concrete that have being use as a partition wall is porous concrete.

This study includes analysis of physical properties such as density and porosity while the analysis of mechanical properties such as compressive strength. The characteristic of materials were observed by using optical microscope.

CHAPTER 2

LITERATURE REVIEW

2.1 Concrete

Concrete is a material used in building construction, consisting of a hard, chemically inert particulate substance, known as an aggregate (usually made from different types of sand and gravel), that is bonded together by cement and water.

Figure 2.1: Concrete

The Assyrians and Babylonians used clay as the bonding substance or cement. The Egyptians used lime and gypsum cement. In 1756, British engineer, John Smeaton made the first modern concrete (hydraulic cement) by adding pebbles as a coarse aggregate and mixing powered brick into the cement. In 1824, English inventor, Joseph Aspdin invented Portland cement, which has remained the dominant cement used in concrete production. Joseph Aspdin created the first true artificial cement by burning ground limestone and clay together. The burning process changed the chemical properties of the materials and Joseph Aspdin created stronger cement than what using plain crushed limestone would produce.

The other major part of concrete besides the cement is the aggregate. Aggregates include sand, crushed stone, gravel, slag, ashes, burned shale, and burned clay. Fine aggregate (fine refers to the size of aggregate) is used in making concrete slabs and smooth surfaces. Coarse aggregate is used for massive structures or sections of cement.

Concrete that includes imbedded metal (usually steel) is called reinforced concrete or ferroconcrete. Reinforced concrete was invented (1849) by Joseph Monier, who received a patent in 1867. Joseph Monier was a Parisian gardener who made garden pots and tubs of concrete reinforced with an iron mesh. Reinforced concrete combines the tensile or bendable strength of metal and the compression strength of concrete to withstand heavy loads. Joseph Monier exhibited his invention at the Paris Exposition of 1867. Besides his pots and tubs, Joseph Monier promoted reinforced concrete for use in railway ties, pipes, floors, arches, and bridges.

2.2 Types of Concrete

2.2.1 Porous Concrete

Porous concrete (also referred to as enhanced porosity concrete, porous concrete, Portland cement pervious pavement and pervious pavement) is a subset of a broader family of pervious pavements including porous asphalt, and various kinds of grids and paver systems. Porous concrete is thought to have a greater ability than porous asphalt to maintain its porosity in hot weather and thus is provided as a limited application control.

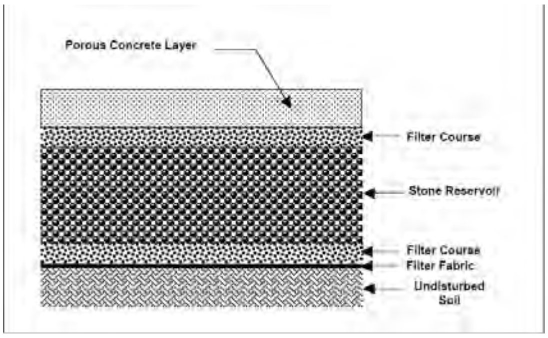

Figure 2.2: Porous Concrete

Although, porous concrete has seen growing use in Georgia, there is still very limited practical experience with this measure. According to the U.S. EPA, porous pavement sites have had a high failure rate – approximately 75 percent. Failure has been attributed to poor design, inadequate construction techniques, and soils with low permeability, heavy vehicular traffic and poor maintenance. This measure, if used, should be carefully monitored over the life of the development.

Porous concrete consists of a specially formulated mixture of Portland cement, uniform, open graded course aggregate, and water. The concrete layer has a high permeability often many times that of the underlying permeable soil layer, and allows rapid percolation of rainwater through the surface and into the layers beneath. The void space in porous concrete is in the 15% to 22% range compared to three to five percent for conventional pavements. The permeable surface is placed over a layer of open-graded gravel and crushed stone. The void spaces in the stone act as a storage reservoir for runoff.

Porous concrete is designed primarily for storm water quality, i.e. the removal of storm water pollutants. However, they can provide limited runoff quantity control, particularly for smaller storm events. For some smaller sites, trenches can be designed to capture and infiltrate the channel protection volume (Cpv) in addition to WQv. Porous concrete pavement has been used for over 30 years in England and the US. The interest and researching porous concrete has been generated worldwide especially in the US and Japan.

Although fundamental information including the influence of the void ratio/C, cement paste characteristic, volume ratio of coarse aggregate, size of coarse aggregate and strength of porous concrete have been studied, the optimum condition to produce good porous concrete has not been established. The mix design, method of mixing and compaction to produce porous concrete with potentially highest strength and durability at designed void ratio are still needed. This is mainly due to the fact that porous concrete is a special concrete with different mix design and compaction allowing continuous voids to be formed with relatively good compressive strength.

2.2.2 Polymer Concrete

Polymer concrete is a composite material. It consists of a mixture of graded aggregates and fine fillers bound together by an organic resin system. It is essentially a highly-filled thermoset material. Low-viscosity organic resins are used and the processing occurs at room temperature. Polymer concrete is not a "concrete". That is, there is hydraulic cement such as neither Portland cement nor water in it. The word concrete" is used only in an etymological sense (Gunasekaran, 1977).

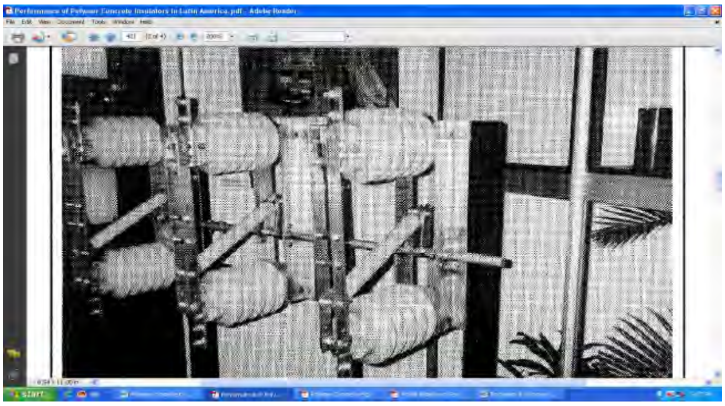

Figure 2.3: Polymer Concrete (Insulator)

Polymer concrete is a highly-filled material. Typically, polymer concrete formulations contain significantly less organic materials than one encounters in conventional "plastics". The organics content of polymer concrete usually does not exceed 15% by weight of the composite and there are applications with as little as 3%.

For many civil engineering applications, polymer concrete is mixed very much like ordinary concrete. In commercial practice, both simple batch mixing systems and specially-built, micro-processor controlled, continuous output machines are used. Field placement of polymer concrete is very much akin to that of conventional concrete with added precautions taken for the safe handling of the composite material.

In precast product applications, the polymer concrete in molds or forms is vibrated into place and compacted adequately on vibrating tables. The frequency and amplitude of the vibration have to be carefully selected depending on the nature of the mix, the complexity of the molds and their size, the mold material and the minimum thickness of the polymer concrete material in any particular section. For most non-dielectric applications, polymer concrete is rarely vacuum treated to eliminate entrapped air.

2.3 Insulation Material

Thermal insulations are materials or combinations of materials that are used primarily to provide resistance to heat flow. One feature shared by all insulating materials used in building applications is their low thermal conductivity l, usually lower than 0.1 W/m K (Y.A. Cengal, 1998). Since insulating materials act as barriers on the path of the flow it is obvious that insulation plays an important role in energy saving. Thus, substantial cost savings can be achieved by correctly insulating buildings.

Figure 2.4: Insulation Materials

The first time a building was insulated was in USA in 1880 when builders installed mineral wool in houses. From the 70s new and more effective insulation materials have been discovered (Y.A. Cengal, 1998). Today, in the European market inorganic fibrous materials, glass wool and stone wool account for 60% of the insulation materials, and, organic foamy materials, expanded and extruded polystyrene and to a lesser extent polyurethane accounts for some 27% (EURIMA, 2006). In Spain the three most common insulation materials used in buildings are polyurethane, mineral wool and polystyrene.

At present many types of hollow concrete blocks are manufactured, but with little attention to the thermal resistance of the units. Two types of standard blocks are manufactured in the Sultanate of Oman for the construction of single skin masonry walls and partitions (Pierzchlewicz, 1995). External walls constructed from these blocks are characterized by high thermal conductivity in which the temperature within buildings without cooling is very high especially in the summer.

However, in order to reduce the energy consumption during summer, cavity and double skin walls should be used. Construction of cavity walls requires the erection of two thin walls separated by an air-gap and braced with metal ties. For durability considerations, ties are made of stainless steel, which increases the cost. Double skin walls are similar to cavity walls but polystyrene or a thermal insulation board is inserted between the two walls, which fills the air-gap.

The introduction of the air-gap or the thermal board reduces the heat transfer through the wall which improves the thermal resistance of the wall (Pamela, 1969). Despite the fact that these walls possess lower thermal insulation characteristics than single skin walls, they are costly and more labor and time consuming. However, due to the method of construction of cavity walls, many thermal bridges are introduced (Ahmad et al). The thermal bridges in external cavity walls will render the thermal resistance of the whole enclosure much lower than that assigned for the cavity wall itself, because much more heat flows through thermal bridges than through the cavity wall.

Thermal performance of fibrous insulations that are widely used in construction all over the world has been studied numerically by a large number of researchers. Several researchers studied different heat transfer mechanisms (J.D Vershoor et al). Other studies have focused on heat transfer modeling (B.K Larkin et al). There are also specific studies focused on obtaining approximate expressions for thermal conductivity (B.G. Rennex et al), and thermal diffusivity (J.V. Beck, 1966). Ucar and Figen (A. Ucar, 2009) determined numerically the optimum insulation thickness of the external wall for four cities from different climate zones in Turkey. Typical insulations used in buildings in Turkey were studied (Foamboard 3500, Foamboard 1500, extruded polystyrene and fiberglass)

2.4 Cement

Cement is a binder, a substance that sets and hardens independently, and can bind other materials together. Cement used in construction is characterized as hydraulic or non-hydraulic. Hydraulic cement (Portland cement) hardens because of hydration chemical reactions that occur independently of the admixture's water content; they can harden even underwater or when constantly exposed to wet weather. The chemical reaction that results when the anhydrous cement powder is mixed with water produces hydrates that are not water-soluble.

Figure 2.5: Cement

2.5 Aggregates

Aggregates generally constitute about 70–80% by volume of Portland cement concrete. Due to the large volume fraction it occupies in concrete, aggregates exert a major influence on the elastic modulus of concrete and can be expected to have an important influence on other properties as well.

Figure 2.6: Aggregates

Apart from the density of the aggregates, the density of the concrete also depends upon the grading of the aggregates, their moisture content, mix proportions, cement content, water-to-binder ratio, chemical and mineral admixtures, etc. Besides the material, it also depends upon the method of compaction, curing conditions, etc.

2.5.1 Lightweight Aggregates

The production of lightweight aggregate concrete has been expanding, and now includes all types—from no-fines concrete of low density, mainly for block production, with densities from 300 to 1200 kg/m^3, to structural concrete with densities from 1000 to 2000 kg/m^3 and compressive strengths from 1 to 100 MPa. The production of all types of concrete is closely connected to the availability of lightweight aggregate, and economics dictate the use of lightweight aggregate concrete in place of normal-weight concrete (NWC).