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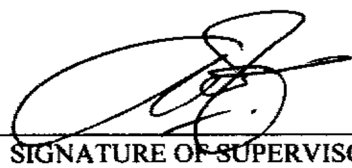

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AN INVESTIGATION ON EFFECT OF QUARRY DUST AS SAND REPLACEMENT ON COMPRESSIVE AND FLEXURAL STRENGTH OF FOAM CONCRETE

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AN INVESTIGATION ON EFFECT OF QUARRY DUST AS SAND REPLACEMENT ON COMPRESSIVE AND FLEXURAL STRENGTH OF FOAM CONCRETE

NORAZILA BINTI KAMARULZAMAN

A thesis submitted in fulfilment of the Requirements for the award of the degree of Bachelor of Civil Engineering and Earth Resources

Faculty of Civil Enginering and Earth Resources
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NOVEMBER 2010

I declare that this thesis entitled "*An Investigation on Effect of Quarry Dust as Sand Replacement on Compressive and Flexural Strength of Foam Concrete*" is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

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DEDICATION

TO

MY BELOVED FAMILY

MY BELOVED FRIENDS

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ABSTRACT

Foam concrete is a type of lightweight concrete which is lighter than conventional concrete. It is non-load bearing structural element which has lower strength than conventional concrete. Foam concrete is widely used in construction field and quite popular for some application because of its light weight such as reduction of dead load, non-structural partitions and thermal insulating materials. Because of its low strength, some material is used in order to increase the foam concrete strength. A study on the effect of quarry dust as sand replacement material on compressive and flexural strength of foam concrete was conducted. This study was conducted to determine the compressive strength and flexural strength of foam concrete by using quarry as partial sand replacement material. This report presents the feasibility of the usage of quarry dust as 10 %, 20 % and 30 % substitutes for sand in foam concrete. Mix design was developed for four different proportion of quarry dust in foam concrete. Tests were conducted on cubes and beams to study the strength of concrete made of quarry dust and results were compared with the control foam concrete. It is found that the compressive and flexural strength of foam concrete made of quarry dust are nearly 40 % more than the control foam concrete.

ABSTRAK

Konkrit berliang adalah sejenis konkrit ringan yang lebih ringan berbanding konkrit biasa. Ia adalah elemen stuktur bagi non-load bearing yang mempunyai kekuatan yang rendah berbanding konkrit biasa. Konkrit berliang telah digunakan secara meluas dalam bidang pembinaan dan popular penggunaannya disebabkan oleh sifat yang ringan seperti pengurangan beban mati, dan bahan penebat haba. Disebabkan oleh kekuatan yang kurang, sejenis bahan digunakan untuk meningkatkan kekuatan konkrit berliang. Satu kajian ke atas kesan habuk kuari sebagai bahan separa ganti kepada pasir telah dijalankan. Kajian ini adalah untuk menentukan kekuatan mampatan dan kekuatan flexure ke atas konkrit berliang dengan kehadiran habuk kuari. Laporan ini menunjukkan keberkesanan penggunaan habuk kuari sebagai bahan ganti kepada pasir sebanyak 10 %, 20 %, 30 % dalam konkrit berliang. Empat jenis campuran yang berbeza telah dikira meggunakan peratusan habuk kuari yang berbeza dalam konkrit berliang. Ujian kekuatan telah dilaksanakan ke atas rasuk dan kub kecil yang mengandungi habuk kuari dan keputusan telah dibandingkan dengan konkrit yang dibuat tanpa mengandungi habuk kuari. Hasil kajian dan ujian didapati konkrit yang mengandungi habuk kuari telah menyumbang hampir 40 % kekuatan berbanding konkrit yang tidak mengandungi habuk kuari.

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CHAPTER 1

INTRODUCTION

1.1 Background

Concrete is a manmade material used in the building construction consists of aggregates which is bonded together by cement and water. 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 refers to the size of aggregate used in making concrete slabs and smooth surfaces. Coarse aggregate is used for massive structures or sections of cement. Concrete can be categorized into two which are conventional concrete, and lightweight concrete. Both concrete shows different properties and usage. Generally, conventional concrete has a density of about 2300 kg/m^3, while lightweight concrete has a density between 300 and 1800 kg/m^3.

Anyway, historically concrete has been used in construction for over 2,000 years, perhaps first by the Romans in their aqueducts and roadways. There has been no looking back for concrete since its modern development. Known as the strongest building material, concrete has found major uses in dams, highways, buildings and many different kinds of building and construction. The Romans made many developments in concrete technology including the use of lightweight aggregates as in the roof of the Pantheon, and embedded reinforcement in the form of bronze bars. There are so many types of concrete with different applications in the constructions; for example pre-stressed concrete, reinforced concrete for carrying enormous load. Different types of concrete are produced depending upon the end application. The modern types of concrete include cellular or aerated concrete which is light weight and durable, making it easy to be handled.

Lightweight concrete is widely used for modern construction as it is mortar less and can be produced with different densities. Lightweight concrete also known as aerated, cellular lightweight concrete, or foam concrete. The first lightweight autoclaved aerated concrete factory was built in 1943 in Emmering, near Munich, Germany. The product is now made in a number of countries in Europe, Asia, South America and the Middle East. Production began at the Malaysian plant in August 1995. This study focuses on the foam concrete and quarry dust. Foam concrete is classified as lightweight concrete because it contains no large aggregates, only fine aggregate like fine sand, cement, water and foam.

Foam concrete is widely used in construction field and quite popular for some application because of its light weight such as reduction of dead load, faster building rates in construction and lower haulage and handling costs *(Kamsiah et al).* It also has several advantages because of its porous nature; it provides thermal insulation and considerable saving in materials *(Puttappa et al. 2008).* The important application of foam concrete includes structural elements, non-structural partitions and thermal insulating materials. Manufacturers developed foam concretes of different densities to suit the requirements. The density of foam concrete ranges from 300-1800 kg/m^3 and these products were used in trench reinstatement, bridge abutment, void filling, roof insulation, road sub base, wall construction, tunneling etc. *(Puttappa et al. 2008).*

Another material used in the formation of foam concrete is quarry dust as partial material replacement. Quarry dust is classified as fine material obtained from the crushing process during quarrying activity at the quarry site. In this study, quarry dust will be studied as replacement material to sand as fine aggregate. Quarry dust has been use for different activities in the construction industry such as for road construction and manufacture of building materials such as lightweight aggregates, bricks, tiles and autoclave blocks. *(M. Safiuddin et al.)*

1.2 Problem Statement

Generally, lightweight foam concrete can be used to construct a non load bearing precast structural element in construction industry. Furthermore, the strength of lightweight foam concrete is lower than the strength of conventional concrete. Thus, strength of the foam concrete need to be improved in order to wide its application. According to Hamidah et al. (2003), the finer aggregates used in the foam concrete, the more increment of strength of the foam concrete. For size specification, quarry dust has been selected since it is finer waste material and by utilizing the quarry dust as sand replacement perhaps could increase the strength of foam concrete to enhance the properties of foam concrete.

1.3 Objective

The main objectives of this study were :-

i) Determine the compressive strength of foam concrete under different percentage of quarry dust.

ii) Determine the flexural strength of foam concrete under different percentage of quarry dust.

1.4 Scope of Work

In this experimental study, the effect of quarry dust in lightweight foam concrete in terms of compressive strength and flexural strength had been focused. There were 36 numbers of cubes with dimension of 150 × 150 × 150 mm and 12 numbers of beams with dimension of 100 × 100 × 500 mm being considered.

Sample with 0% (no quarry dust), 10%, 20%, 30% of quarry dust in terms of sand mass were designated as B_1, B_2, B_3, B_4 for beam and C_1, C_2, C_3, C_4 for cube respectively. Foam concrete with density of 1200 kg/m^3 were prepared with the water cement ratio of 0.50 and sand cement ratio of 1.0

All samples were cured in water curing. The cubical samples were used as compression test specimens to determine the compressive strength at the age of 7, 14, and 28 days. The beam samples were undergoing the flexural test at the age of 28 days to determine the flexural strength. Table 1.1 represents the mix proportion of the foam concrete.

Table 1.1: Mix proportion of foam concrete

Sample Designated	No of Sample	% Quarry Dust	Cement (kg)	Sand (kg)	Quarry Dust (kg)	Water (kg)	Foam (liter)
Cube, $C_{0\%}$	9	0	33.08	33.08	-	16.54	29.27
Beam, $B_{0\%}$	3						
Cube, $C_{10\%}$	9	10	33.08	29.77	3.31	16.54	29.27
Beam, $B_{10\%}$	3						
Cube, $C_{20\%}$	9	20	33.08	26.46	6.62	16.54	29.27
Beam, $B_{20\%}$	3						
Cube, $C_{30\%}$	9	30	33.08	23.16	9.92	16.54	29.27
Beam, $B_{30\%}$	3						

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Lightweight foam concrete can be defined as a type of concrete which included an expanding agent in that it increased the volume of the mixture while giving additional qualities such as fallibility and lessened the dead weight (Mad Lazim Zakaria et al., 1978). It was lighter than the conventional concrete with the dry density of 300 kg/m^3 up to 1800 kg/m^3. Although the material was called foam concrete, it was not really concrete at all. Foam concrete is actually foamed mortar, where the mortar was made from cement and water or sand, cement and water. Foam concrete containing no coarse aggregates, only fine and extremely lightweight materials containing cement, water and foam. A few investigators had reported that foam concrete was one having an air content of more than 25 %, which disintegrated it from highly air entrained materials (C.G Puttappa et al. 2008).

Foam concrete can be placed easily, by pumping if necessary, and does not require compaction, vibrating or leveling. It has excellent resistance to water and frost, and provides a high level of both sound and thermal insulation. It is very versatile; since it can be tailored for optimum performance and minimum cost by choice of a suitable mix design especially the density of foam concrete.

This is because different density might give different use and performance of foam concrete.

The fact that foam concrete can be made using different mix designs meant that it was not a single product. Foam concrete was nearly made on-site and it was made using a mix design specifically selected for each application or job.

2.2 History of Foam Concrete

The history of foam or aerated concrete began much later than lightweight aggregate concrete. According to Dubral (1992), the development of the aerated concrete or foam concrete had begun approximately 100 years ago. In 1914, the Swedes first discovered a mixture of cement, lime, water and sand that expanded by adding aluminium powder. It entailed the use of aluminium powder to generate hydrogen gas in the cement slurry. Prior to that, inventive minds had tried beaten egg whites, yeast and other unusual methods of adding air to concrete. It was also reported that foamed concrete was developed in Europe over 60 years ago and has since then been on the international market for more than 20 years.

The foamed or aerated concrete was similar to wood in its characteristics but without the disadvantages of combustibility, decay, and termite damage, and this material was then further developed and later known as Autoclaved Aerated Concrete. AAC was developed by combining the processes of porosing concrete by means of metal powder and hardening the mixture through autoclave. This created a material that exhibited a wealth of desirable characteristics such as low weight, high material strength, very good heat insulation, excellent fire resistant and good impact and airborne sound insulation. In the same year, the first patent right on this particular method of producing foamed concrete was granted.

From then on, it took another 10 to 20 years for reinforced AAC elements to be developed. These elements were first used mainly in Scandinavia as roof and floor units and wall panels. The foaming process which is now most widely used was patented in 1931. It involved producing cellular concrete prepared by foaming methods followed by curing in high-pressure steam. Patents were issued in 1929 on foaming agent formulations, mixing procedures and mixing machines.

The Second World War halted temporarily the quick spread of AAC and foam concrete as the lightweight concrete, since it had quite same functions and characteristics. However, it regained its successful expansion in Europe and many parts of the world after the war ended, in 1950. The rapid development of the worldwide production of AAC products occurred in 1929 to 1975. In 1955, there were only thirteen (13) plants or licensed plants manufacturing AAC but later this number grew to more than 40 plants worldwide. By the year 1975, there were about two hundreds (200) AAC plants working on almost all continents in Western and Eastern Europeincluding the Asian part of the former Soviet Union fifty (50) plants in other Asia countries and six-teen (16) plants in other parts of the world. The global success of AAC was first achieved by two companies in Germany, YTONG Siporex and Durox, which are still well known today. Other companies such as Hebel in Germany and Hendriksen in Denmark followed with their own differing technologies (Dubral, 1991).

Preformed foam was developed in the early 1950's following the development of simple, reliable and easily controlled, foam-generating equipment and highly refined foam stabilizers. The method was cost effective and provided an accurate means of controlling density. This method had been widely used for the production of low-density cast-in-place roof decks, filling voids, tunnel gap filling and insulating underground heat distribution lines until today (Portland Cement Association, 1980).

2.3 Properties of Lightweight Foam Concrete

Foam concrete is not the same as conventional concrete and does not have the same characteristics. Foamed concrete is much lighter and does not have the same strength as conventional concrete. For this reason foamed concrete and conventional concrete are generally used for different applications, although there are applications where either may be specified. Properties of lightweight foam concrete can be classified into two properties which are mechanical properties and physical properties.

2.3.1 Air Void

The pore structure of cementitious material, predetermined by its porosity, permeability and pore size distribution, is a very important characteristic as it influences the properties such as strength and durability. The pore structure of foam concrete consists of gel pores, capillary pores as well as air-voids (Visagie et al., 2002). As foam concrete being a self-flowing and self-compacting concrete and without coarse aggregate, the possibilities of the entrapped air is negligible. The air-voids in the foam concrete can be characterized by a few parameters like volume, size, size distribution, shape and spacing between air-voids. The air-void distribution is one of the most important micro properties influencing strength of foam concrete. Foam concrete with narrower air-void distributions shows higher strength. The use of fly ash as filler helps in achieving more uniform distribution of air-voids by providing uniform coating on each bubble and thereby prevents merging of bubbles. At higher foam volume, merging of bubbles results in wide distribution of void sizes leading to lower strength. (Nambiar et al., 2007; Visagie et al., 2002). In addition to the air-void size and its distribution, the compressive strength of foam concrete is also be influenced by the void/paste ratio, spacing of air-voids, number (frequency) of air-voids. Because of the uniform shape (characterized by shape factor) of air-voids, its influence on strength is negligible. (Wee et al., 2006; Kearsley et al., 1996; Nambiar et al., 2007)

2.3.2 Density

Another property which is very important in determining the foam concrete is its density. Foam concrete can be formed with the desired density and requirement. The density of foam concrete is 300 kg/m^3 up to 1800 kg/m^3 to suit different application. Usually, the lower densities of 400-600 kg/m^3 are ideal for thermal insulation applications. The density range 800-1000 kg/m3 is utilized for making pre-cast blocks for non load bearing walling masonry in framed structures while the foam concrete range from 1200kg/m^3 to 1800 kg/m^3 is structural grade material utilized for in-situ casting of structural load bearing walls and roofs of low rise individual or group housing schemes or manufacture of reinforced structural cladding or partitioning panels or for making pre-cast blocks for load-bearing walling masonry for low-rise buildings. Density can be either in fresh or hardened state. Fresh density is required for mix design and casting control purposes. A theoretical equation for finding fresh density may not be applicable as there can be scatter in the results caused by a number of factors including continued expansion of the foam after its discharge, loss of foam during mixing (Regan et al., 1990). Many physical properties of foam concrete related to/depend upon its density in hardened state. While specifying the density, the moisture condition needs to be indicated as the comparison of properties of foam concrete from different sources can have little meaning without a close definition of the degree of dryness (Valore et al., 1954). McCormick (1967) studied the effect of types of fine aggregate, aggregate gradation, type of foam and sand–cement ratio on the wet density of foam concrete and reported that wet densities within about 5% of the design densities can be achieved by using solid volume calculations.

The cement–sand based non-autoclaved preformed foam concrete has relatively higher density and higher requirement of cement content. Greater the proportion of aggregate, higher will be the density. Compared to a product based on sand and cement, it is observed that replacement of sand with fly ash help in reducing the density with an increased strength (Durack et al., 1998). Alternately, to achieve a particular density of foam concrete, use of fly ash results in a reduction in foam volume requirement due to its lower specific gravity (Nambiar et al., 2006), thereby resulting in higher strength.

2.3.3 Stability

Furthermore, foam concrete cannot be subjected to compaction or vibration the foam concrete should have flowability and self-compactability. These two properties are evaluated in terms of consistency and stability of foam concrete, which are affected by the water content in the base mix, amount of foam added along with the other solid ingredients in the mix (Nambira et al., 2008). The stability of foam concrete is the consistency at which the density ratio is nearly one (the measured fresh density/design density), without any segregation and bleeding (Nambira et al., 2008). This ratio is higher than unity at both lower and higher consistencies due to either stiffer mix or segregation. The stability of test mixes can also be assessed by comparing the calculated and actual quantities of foam required to achieve a plastic density within 50 kg/m3 of the design value; and calculated and actual w/c ratios. The additional free water contents resulting from the foam collapse. Corresponded to an increase in actual w/c ratio (Jones et al., 2006). Thus the consistency of the base mix to which foam is added is an important factor, which affects the stability of mix. This consistency reduces considerably when foam is added and depends on the filler type also. Hence there is a need for determining the water–solids ratio, which would satisfy both stability and consistence of the mix. Regression equations based on the experimental results, for predicting the spread flow value of foam concrete, knowing the proportion of the other ingredients, will help in arriving at this water content for the production of a stable and workable foam concrete mix. For typical materials used, an appropriate workability value has been arrived at as 45% of spread at which a foam concrete mix of good stability and consistency can be produced (Nambiar et al., 2008).

2.3.4 Compressive Strength

Besides, the mechanical property of foam concrete is the compressive strength. Study done by Kearsley et al., (1996) has reported that the compressive strength of the foam concrete decreases exponentially with a reduction in density of the foam concrete. the specimen size and shape, the method of pore formation, direction of loading, age, water content, characteristics of ingredients used, and the method of curing are reported to influence the strength of foam concrete in total (Valore et al., 1954). Other parameters affecting the strength of foam concrete are cement sand and water cement ratio, curing regime, type and particle size distribution of sand and types of foaming agent used (Aldridge et al., 2005; Hamidah et al., 2005). For dry density of foam concrete between 500 kg/m^3 and 1000 kg/m^3, the compressive strength decreases with an increase in void diameter. For densities higher than 1000 kg/m3, as the air-voids are far apart to have an influence on the compressive strength, the composition of the paste determines the compressive strength. It has been reported that small changes in the water–cement ratio does not affect the strength of foam concrete as in the case of normal weight concrete.

2.3.5 Water Absorption

The durability properties include the water absorption of foam concrete. The water absorption of foam concrete decreases with a reduction in density, which is attributed to lower paste volume phase and thus to the lower capillary pore volume. The water absorption of foam concrete is mainly influenced by the paste phase and not all artificial pores are taking part in water absorption, as they are not interconnected (Nambiar et al., 2006; Kearsley et al., 2001). Expressing water absorption as percentage by mass can lead to misleading results when foam concrete is concerned because of larger differences in density. The oxygen and water vapor permeability of foam concrete have been observed to increase with increasing porosity and fly ash content (Kearsley et al., 1998). Permeability coefficient of lightweight foamed concrete is proportional to unit weight and inversely proportional to pore ratio (Byun et al., 1998).

2.3.6 Resistance to Aggressive Environment

Foam concrete mixture designed at low density taking into consideration of depth of initial penetration, absorption and absorption rate, provided good freeze-thaw resistance (Jones et al., 2008; Tikalsky et al., 2004). Sulphate resistance of foam concrete, studied by Jones and McCarthy (Jones et al., 2005) for 12 months, reveals that foam concrete has good resistance to aggressive chemical attack. A study on accelerated carbonation of foam concrete by Jones and McCarthy (2005) indicate that lower density concrete appears to carbonate at a relatively higher rate. Comparing the performance of mixes with sand and fly ash, mixes with fly ash exhibited higher carbonation than that with sand. An accelerated chloride ingress tests suggested that foam concrete performance is equivalent to that of normal concrete, with enhanced corrosion resistance at lower density (Giannakou et al., 2002). The cell-like structure of foam concrete and possible porosity of cell wall do not necessarily make the foam concrete less resistant to penetration of moisture than dense concrete; the air-voids appears to act as a buffer preventing rapid penetration.

2.4 Advantages of Lightweight Foam Concrete

Foam concrete is classified as lightweight concrete because it contains no large aggregates, only fine aggregate like fine sand, cement, water and foam. There also air voids entrapped in it shows one of the properties of the foam concrete. Foam concrete is widely used in construction field and quite popular for application because of its light weight which ensures economic aspects such as the trench instatement. It also has several advantages because of its porous nature; it provides thermal insulation and considerable saving in materials (C.G Puttappa et al, 2008). The important application of foam concrete includes structural elements, non-structural partitions and thermal insulating materials. Manufacturers developed foam concretes of different densities to suit the requirements. The density of foam concrete ranges from 300-1800 kg/m3 and these products were used in trench reinstatement, bridge abutment, void filling, roof insulation, road sub base, wall construction, tunneling etc. (C.G Puttappa et al, 2008).

2.4.1 Thermal Insulation

Foam concrete has excellent thermal insulating properties due to its cellular microstructure. The thermal conductivity of foam concrete of density 1000 kg/m3 is reported to be one-sixth the value of typical cement–sand mortar (Aldrige et al.,2001). A study by Giannakau and Jones (2002) exploring the potential of foam concrete to enhance the thermal performance of low rise building has shown that the foam concrete ground supported slab foundation is possessing better thermal insulation and lower sorptivity properties while producing satisfactory strength. The thermal conductivity values are 5–30% of those measured on normal weight concrete and range from between 0.1 and 0.7 W/mK for dry densities values of 600–1600 kg/m3, reducing with decreasing densities. Thermal insulation of brick wall can be increased by 23% when inner leaf is replaced with foamed concrete of unit weight 800 kg/m3.

2.4.2 Sound Insulation or Acoustical Properties

Valore (1954) has stated that cellular concrete does not possess unique or significant sound insulation characteristics. Foamed concrete is stated to be less effective than dense concrete in resisting the transmission of air-borne sound (Taylor et al., 1969) because the Transmission Loss (TL) of air-borne sound is dependant on mass law, which is a product of frequency and surface density of the component. Tada (1986) attributed the TL to the rigidity and internal resistance of the wall, in addition to the mass law and gives an acoustical performance design of cellular concrete based on bulk density and thickness. Sound transmission of a cellular concrete wall, over most of the audible frequency range may be higher by 2–3% as compared to normal weight concrete. While dense concrete tends to deflect sound, foam concrete absorbs it, and hence the foam concrete has higher sound absorption capacity (Taylor et al., 1969).

2.4.3 Fire Resistance

At high temperature the heat transfer through porous materials is influenced by radiation, which is an inverse function of the number of air–solid interfaces traversed. Hence along with its lower thermal conductivity and diffusivity, the foam concrete may result in better fire resistance properties (Valore et al., 1954). Fire resistance tests on different densities of foam concrete indicated that the fire endurance enhanced with reductions in density. While reviewing earlier studies on fire resistance, Jones and McCarthy (2005) summarize that, for lower densities of foam concrete, the proportional strength loss was less when compared to normal concrete. As compared to vermiculite concrete, lower densities of foam concrete is reported to have exhibited better fire resistance, while with higher densities, this trend is stated to be reversed (Aldrige et al., 2005). Kearsley and Mostert (2005) studied the effect of cement composition on the behaviour of foam concrete at high temperature and concluded that foam concrete containing hydraulic cement with an Al2O3/CaO ratio higher than two can withstand temperatures as high as 1450 °C without showing sign of damage.

2.4.4 Construction Field (Tunnel Infill)

Foam concrete has been used for the tunnel infill in United Kingdom has showed many advantages. The infill of the tunnel was successfully completed in nine working days and required 1300 kg/m3 of foam concrete made. The superior flowing and self-compacting properties of foam concrete ensure that all voids are completely eliminated. As foam concrete is compressed during collapse or subsidence of material above, due to its cellular structure, the resistance of the foam concrete increases, absorbing the kinetic energy. Unlike some synthetic, lightweight foams (polystyrene for example), hardened foam concrete is not susceptible to breakdown due to the presence of hydrocarbons, bacteria or fungi. Foam concrete is insect, rodent and fireproof. The exclusive design and technology employed in on site batching plants allow recycled materials such as fuel ash and limestone dust to be used in many of the mixes. These industrial by-products are often disposed of in landfill sites but, by blending them with cement, they are encapsulated within the foam concrete, thereby mitigating any adverse effects on the environment.

2.4.5 Construction Field (Road Sub Base)

The foam concrete has been used as the road sub-bases. A recent development has been the use of foam concrete as a road sub-base. It is a highly effective way to improve unstable soil conditions or to replace unsuitable soils. A typical application would be to raise the elevation of the roadway by using foam concrete as a sub base, especially where the soil is unstable. Foam concrete does not require compacting, imposes no lateral forces on adjacent structures, may be applied directly to existing marginal ground such as peat concentrations or poor soils, and weighs 20-25% of the weight of the standard soils. Foam concrete can be applied on the uneven ground as it does not need a completely flat surface, eliminating the requirement for surcharging with soil. Less consolidation is required for subsoil and it also achieves equilibrium with surrounding pressures. Advantages of using foam concrete for road construction are ease and speed of placement, total void-fill, and good energy absorbing qualities. When judged against other more labor/time intensive methods, the ability to produce quantities of up to $400m^3$ a day means that construction times can be significantly reduced, with consequent cost savings. The flowing, self-compacting properties of foam concrete mean that you can be assured that all voids are completely eliminated. As the foam concrete is compressed during the collapse or subsidence of material above, due to its cellular structure, the resistance of the foam concrete increases, absorbing the kinetic energy. Unlike some synthetic lightweight foams (polystyrene for example), hardened foam concrete is not susceptible to breakdown due to the presence of hydrocarbons, bacteria or fungi. It is insect, rodent and fireproof. Using foam on-site batching plant means less traffic disruption both on-site and in the surrounding area. Around 109 m^3 of 400 kg/m^3 density lightweight foam concrete can be produced from one bulk powder tanker delivery, making it safer for site-workers and local residents as well as being friendlier to the environment.

2.4.6 Savings in Construction Material

Reduction in dead weights contributes substantially to savings in reinforcing steels in foundations. The dimensions and therefore, the overall quantity of steel reinforcement in foamed concrete can be reduced by as much as 50%. Savings are also substantial in transportation, crane- and man-handling related activities as well as in raw materials, as no gravel is required to produce foamed concrete but sand, cement, water and air, with the resulting mortar/paste subsequently embedded in the foam. Casting very slender walls can optimize the amount of concrete used, and wall as thin as 50 mm have been produced with foamed concrete. The high ability flow of foamed concrete makes vibration unnecessary, and thus requires no prescription of vibrating equipment/accessories (Liew, 2003).

2.4.7 Ease of Application

No special skill is required in using the system. It is fully adoptable or at least adaptable into existing concrete or prefabrication plants, adding only a foaming agent into the mixer at a precise dose, which is discharged from a foam generator. Foamed concrete may later be pumped using conventional concrete pumps. Due to the absence of gravel and the ball-bearing effect of the foam, foamed concrete possesses a high degree of flowability. No vibration is thus required and foamed concrete completely fill all gaps and voids in the concrete or mould, fully embedding any hoses, tubes, frames for windows and doors. John August (1997) indicated that lightweight concrete made with materials such as expanded shale, clay, perlite, vermiculite and diatomite can be sawn to some extent, and can hold fasteners.

2.4.8 High Durability

It is shown that the durability of lightweight concrete is as good as normal concrete. Studies by Clarke (1993) showed that lightweight concrete incorporating lightweight aggregate has better chemical resistance compared to that of normal concrete. Other studies by Clarke (1993) showed that lightweight concrete containing air pores of diameter ranging of from 30 – 50 μm have shown better resistance to freeze-thaw than that of normal concrete. Lightweight concrete containing high-volume fly ash has significantly superior resistance to that of lightweight concrete without fly ash in freezing and thawing tests (Bilodeau, 1997). In addition, Amiri et al. (1994) indicated that lightweight aggregate concrete performs equally well under cryogenic conditions such as for the storage of liquid gases due to its low penetrability. Lightweight aggregate concrete also possess higher strain capacity which results in greater crack resistance. It is worth nothing that the stated properties are enhanced at low temperatures.

The rapid mixing and high fluidity of foamed concrete facilitates speedy casting of building elements. With the application of vertical moulds to cast complete houses in place and the omission of vibrating equipment result in the entire walls and ceiling/roof of a building being cast in one step. Openings (or the actual frames) for doors and windows, and ducting and conduits for sanitary and electrical services can be cast in place and firmly embedded in the foam concrete.

2.5 Properties of Quarry Dust

Quarry dust is classified as fine material obtained from the crushing process during quarrying activity at the quarry site. In this study, quarry dust will be studied as replacement material to sand as fine aggregate. Quarry dust quarry dust have been use for different activities in the construction industry such as for road construction and manufacture of building materials such as lightweight aggregates, bricks, tiles and autoclave blocks. (M. Safiuddin et al).

Quarry dust is made while blasting, crushing, and screening coarse aggregate. Quarry dust has rough, sharp and angular particles, and as such causes a gain in strength due to better interlocking and a concomitant loss in workability. The use of quarry dust sometimes causes an increase in the quantity of cement required to maintain workability. A survey of samples from six quarry dust suppliers in the Galle region of Sri Lanka revealed that they were all well-graded than the river sand provided by a supplier from the same region. The quarry dusts contained more fines smaller than the 200 μm sieve than the river sand (about 20% for quarry dust compared with 5% for river sand) (Silva et al., 2007). According to the guidelines for mix design according to the Department of the Environment of the United Kingdom (Teychenne et al., 1990), the finer the fine aggregate used in concrete, the higher the requirement of free water to maintain workability. However, the mix-design procedure limits the analysis of fines content of a fine aggregate to % passing 600 μm sieve. Therefore, the guidelines should clearly be used with trial mixes when inserting quarry dust.

Table 2.1 shows the physical properties of quarry dust and the natural sand while Table 2.2 shows the chemical properties of quarry dust and natural sand.

Table 2.1: The physical properties of quarry dust and natural sand

Property	Quarry Dust	Natural Sand	Test method
Specific gravity	2.54 – 2.60	2.60	IS 2386 (Part III) 1963
Bulk relative density (kg/m3)	1720 – 1810	1460	IS 2386 (Part III) 1963
Absorption (%)	1.20 – 1.50	Nil	IS 2386 (Part III) 1963
Moisture content (%)	Nil	1.50	IS 2386 (Part III) 1963
Fine particle less than 0.075 mm (%)	12 – 15	06	IS 2386 (Part III) 1963
Sieve analysis	Zone II	Zone II	IS 383 - 1970

Table 2.2: Typical chemical composition of quarry dust and natural sand.

Constituent	Quarry Dust (%)	Natural Sand (%)	Test Method
SiO_2	62.48	80.78	IS 4032 - 1968
Al_2O_3	18.72	10.52	
Fe_2O_3	06.54	01.75	
CaO	04.83	03.21	
MgO	02.56	00.77	
Na_2O	Nil	01.37	
K_2O	03.18	01.23	
TiO_2	01.21	Nil	
Loss of Ignition	00.48	00.37	

2.6 Effects of Quarry Dust to Concrete

Quarry dust is a waste material produced from the quarrying activities at quarry site. Quarry dust have been used for different activities in the construction industry such as for road construction and manufacture of building materials such as lightweight aggregates, bricks, tiles and autoclaved blocks (Safiuddin et al., 2001). Researches have also been conducted to study the effects of partial replacement of sand with quarry dust in the properties of freshly mixed (Zain et al., 2000; Tan et al., 2000) and hardened concrete applications studied by Tan et al. (2000) and Raman et al. (2004). It was deduced from those studies that partial replacement of sand with quarry dust without the inclusion of other admixtures resulted in enhanced workability in the concrete mixes, but in a reduced compressive strength and durability. Besides, Ho et al. (2002) have also researched quarry dust for self-compacting concrete applications.

A study done by Raman et al. on the suitability as quarry dust as partial replacement material for sand in concrete has concluded that the incorporation of quarry dust as partial replacement material to sand in concrete resulted in a reduction in the compressive strength, and this is more evident when the replacement proportion is increased. However, the reduction in the compressive strength of the quarry dust concrete was compensated by the inclusion of mineral admixtures into the concrete mix. In the presence of silica fume or fly ash, quarry dust can be a suitable partial replacement material to sand to produce concretes with fair ranges of compressive strength. They also reported that the aggregate crushing value, flakiness index, soundness and pH value of the quarry dust used in their study could contribute significant effects to the strength and durability of concrete.

Ilangovana et al. (2008) has studied on the strength and durability properties of concrete containing quarry rock dust as fine aggregate. From the study, they concluded that if the natural river sand is replace by hundred percent quarry rock dust may give equal or better than the reference concrete made with natural sand, in terms of compressive strength and flexural strength studies. Studies reported have shown that the strength of quarry rock dust concrete is comparatively 10-12 percent more than that of similar mix of conventional concrete. Also the result of the investigation shows that drying shrinkage strains of quarry rock dust concrete are quite large to the shrinkage strain of conventional concrete. However, at the later age, they have shown equal strain than conventional concrete. The durability of quarry rock dust concrete under sulphate and acid action is higher inferior to the conventional concrete permeability clearly demonstrates that the permeability of quarry rock dust concrete is less compared to that of conventional concrete. The water absorption of quarry rock dust concrete is slightly higher than conventional concrete. It also supported that the use of quarry dust as fine aggregates in concrete manufacturing. Thus, in this study in can be concluded that the replacement of natural sand with quarry dust as full replacement in concrete is possible. However, Ilangovana et al. (2008) has suggested that it is advisable to carry out trial casting with quarry dust proposed to be used, in order to arrive the water content and mix proportion to suit the required workability level and strength requirement.

Other than that, a study done by Khampul et al. on the compressive strength of concrete using quarry dust as fine aggregate and mixing with admixture type E has said that the compressive strength of concrete with quarry dust compared to the sand general concrete has increased without the adding the admixture at the age of 28 days. It is also reported that the compressive strength of the quarry dust without admixture type E has showed decreasing compared to the concrete with quarry dust add in the admixture type E.

All the experimental data obtained from the investigation of properties of green concrete containing quarry dust as fine aggregate studied by Shahul et al. (2009) has showed that the addition of the industrial wastes improves the physical and mechanical properties. These results are of great importance because this kind of innovative concrete requires large amounts of fine particles. Due to its high fineness of the marble sludge powder it provided to be very effective in assuring very good cohesiveness of concrete. From the above study, it is concluded that the quarry rock dust and marble sludge powder may be used as a replacement material for fine aggregate. The chemical compositions of quarry rock dust and marble sludge powder such as Fe_2O_3, MnO, Na_2O, MgO, K_2O, Al_2O_3, CaO, and SiO_2 are comparable with that of cement. The replacement of fine aggregate with 50% marble sludge powder and 50% quarry rock dust (Green concrete) gives an excellent result in strength aspect and quality aspect. (Shahul et al., 2009)

In normal concrete, the introduction of quarry dust to mixes is limited due to its high fineness. Its addition to fresh concrete would increase the water demand and consequently the cement content for given workability and strength requirements. Thus, the successful utilization of quarry dust in self compacting concrete (SCC) could turn this waste material into a valuable resource. Another potential benefit in the utilization of quarry dust is the cost saving. Obviously, the material costs vary depending on the source. In Singapore, the price of limestone powder as delivered can be as high as Portland cement (OPC). In this respect, the utilization of quarry dust could play a part in lowering the supply cost of SCC, which is currently some 80–150% higher than that of normal concrete. In Sweden, the application of SCC is well established and according to Petersson et al. (2000), the cost of SCC is only 10–15% higher, while in France (Ambroise et al., 1999) the cost is 50–100% higher than normal concrete. Although SCC offers many technical and overall economical benefits, the higher supplied cost of SCC over normal concrete has limited its applications (Ho et al., 2001).

A study on the utilization of high volumes of limestone quarry wastes in concrete industry (self compacting concrete case). From the cement paste studies, substitution of 10% of cement with limestone quarry waste powder improved the compressive strength of cement pastes, which can be accepted as a positive factor in the utilization effort of limestone quarry waste powder in self-compacting paste applications. Higher substitution rates were investigated on concrete mixtures. The concept of workability box was used to designate the self-compactability of concrete mixtures. Quarry waste limestone powder can successfully be used in the production stage of proper SCC mixtures, although modest adjustments of mixture ingredients and in particular superplasticizer dosage were necessary. This study has been approved experimentally by Burak (2006).

Raman et al. has studied on the influence of quarry dust and fly ash on the concrete compressive strength development has found the partial replacement of river sand with quarry dust without the inclusion of fly ash resulted in a reduction in the compressive strength of concrete specimens. The reduction in the compressive strength of quarry dust concrete was compensated by the inclusion of fly ash into the concrete mix. Quarry dust can be utilized as partial replacement material to sand, in the presence of fly ash, to produce concretes with fair ranges of compressive strength. Study by Felix (2006) has concluded the workability of concrete decreases with the increasing of quarry dust usage. Results obtained from study done by Fauzi et al. showed that partial replacement of sand with quarry dust was able to increase the workability and flowability, and also the air content of fresh high performance concrete.

CHAPTER 3

RESEARCH METHODOLOGY

3.1 Introduction

There were three phases in order to prepare the foam concrete sample until the testing of samples. First phase was the raw materials which included the preparation of the materials and apparatus needed in the formation of foam concrete. The materials used were cement, sand, quarry dust, water and foaming agent. In this phase, the raw materials had been recorded and obtained with correct proportion as calculated in Table 3.1.

The materials then had undergone the batching and mixing phase. Batching and mixing phase was the second phase which included the materials mixing as designed to form foam concrete. The foaming agent was mixed together into the water, cement, sand and quarry dust mixture in concrete mixer. After obtaining the mixture, then mixture was casting into cubes and beams with the dimension of 150×150×150 mm and 100×100×500 mm respectively. All samples were cured in water curing.

After undergone second phase, all samples were tested into two types of test. The beam was considered to be tested to determine the flexural strength. The flexural test was executed at the age of 28 days of the beam. At the same times, the compression test also was executed to the cubical concrete. All cubical samples were tested at the age of 7, 14, and 28 days to determine its compression strength. Figure 3.1 represents the overall flow of work that will be conducted in this study.

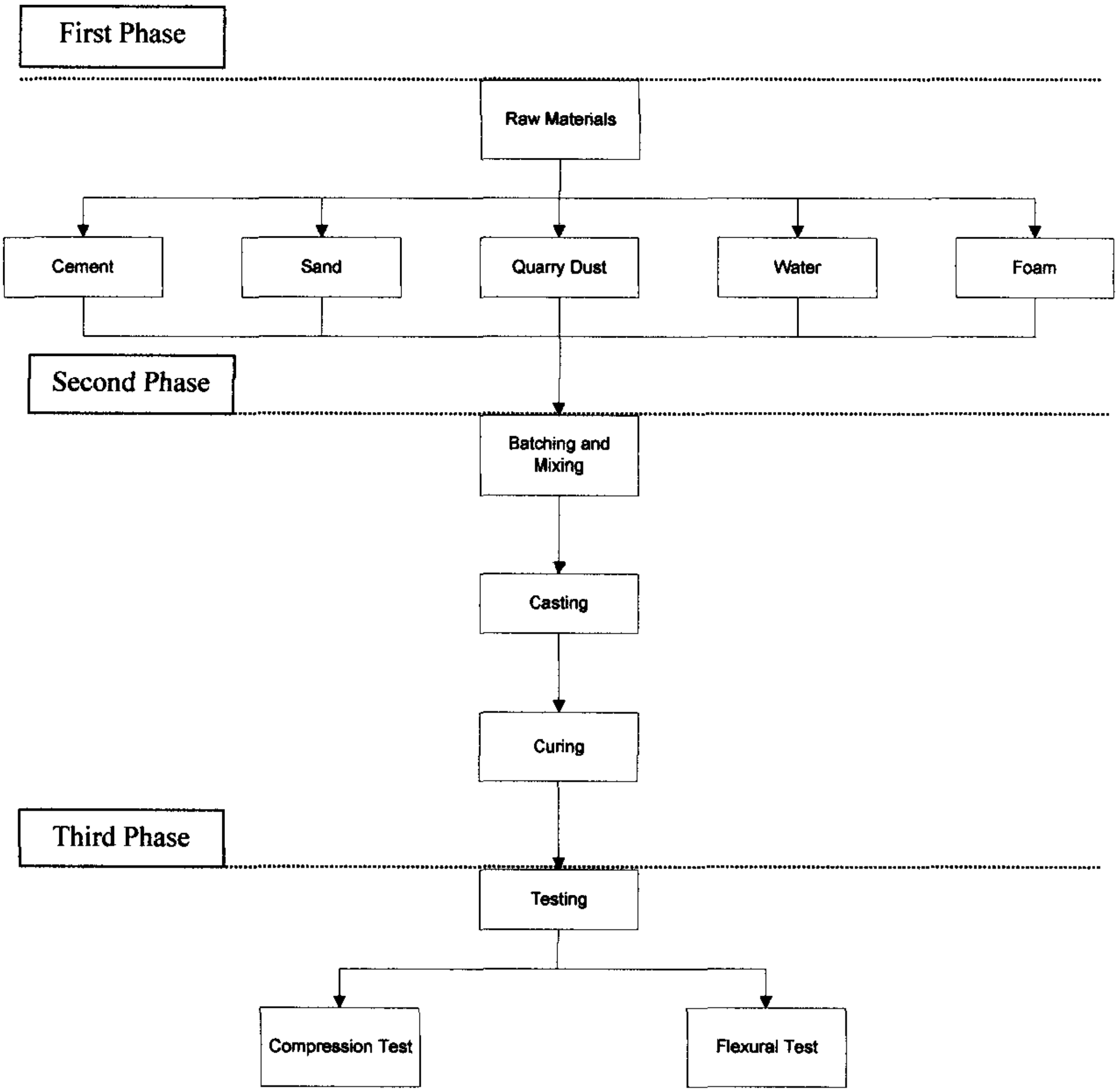

Figure 3.1: The overall flow of work.

3.2 Cement

Generally, there are so many types of Portland cement with the different use and properties. The properties of concrete depend on the quantities and qualities of its components. Because cement is the most active component of concrete and usually has the greatest unit cost, its selection and proper use are important in obtaining most economically the balance of properties desired for any particular concrete mixture. In this investigation, an ordinary Portland cement was used. There are some physical properties of ordinary Portland cement.

Ordinary Portland Cement (OPC) is the most common cement used in general concrete construction when there is no exposure to sulphates in the soil or groundwater. Ordinary Portland cements, which can provide adequate levels of strength and durability, are the most popular cements used by concrete producers. The specific gravity of the ordinary Portland cement is 3.15. Besides that, the compressive strength of ordinary Portland cement has been tested by 50 mm mortar cubes made by using standard sand and the strength of cement is noticed to be varied with time, therefore in general it is reported as 3 day, 7 day or 28 day strength.

The raw materials required for the manufacture of ordinary Portland cement (OPC) are calcareous material such as limestone or chalk and argillaceous materials such as shale or clay. A mixture of these materials is burnt at a high temperature of approximately 1400 0C in a rotary kiln to form clinker. The clinker is then cooled and grounded with a requisite amount of gypsum into fine powder known as Portland cement.

Ordinary Portland cement is a gray colored powder. It is capable of bonding mineral fragments into a compact whole when mixed with water. This hydration process results in a progressive stiffening, hardening and strength development. Table 3.1 shows the chemical properties contain in Portland cement, river sand and quarry dust. Figure 3.2 shows the cement at FKASA laboratory that had been used in production of foam concrete.

Table 3.1: Chemical Characteristic of Portland cement, river sand and quarry dust

Composition	River Sand, % Weight	Quarry Dust, % Weight	Portland Cement, % Weight	Test Method
Fe2O3	1.75	1.22	0.55	IS: 4032-1968
MnO	0.03	0.07	0.85	
Na2O	1.37	3.00	0.85	
MgO	0.77	0.33	2.15	
K2O	1.23	5.34	0.85	
Al2O3	10.52	13.63	5.50	
CaO	3.21	1.28	63.50	
SiO2	80.78	75.25	21.50	

Figure 3.2: Ordinary Portland cement

3.3 Sand

The fine sand had been chosen into the foam concrete mixture. The aggregate was generally ground down to finer powder, passing a 75 μm BS sieves, but sometimes medium aggregate (2mm and fines) was also incorporated. In this study, the fine sand was studied. According to ASTM Particle Size Distribution, medium sand is characterized in the range size of 0.42 to 2 mm. Table 3.2 shows the ASTM Particle Size Definition. Figure 3.3 and figure 3.4 show BS Sieve and the sieved medium sand and passing respectively.

Table 3.2: ASTM Particle Size Distribution

	ASTM	
Definition	Metric Size (mm)	U.S. Size
Fine Gravel	4.67 to 10.0	4 to 3/4 "
Coarse Sand	2.0 to 4.76	10 to 4
Medium Sand	0.42 to 2.00	40 to 10
Fine Sand	0.074 to 0.42	200 to 40
Silt and Clay	< 0.074	< 200

Figure 3.3 : BS Sieve

Figure 3.4 : Sieved Medium Sand

3.4 Quarry Dust

The quarry dust had been used as an additional filler material (Puttappa et al., 2008). Quarry dust consists mainly of excess fines generated from crushing, washing and screening operations at quarries. The materials properties of this waste vary with the source, but are relatively constant at a particular site.

For this study, quarry dust was taken from a quarry site located at Penggorak, Sungai Pandan at Panching, Kuantan. The specific gravity of quarry dust is 2.60. The moisture content and bulk density of waste are less than the sand properties. The quarry dust used for this study passed through the sieve of 75 µm. Table 3.3 represents the physical properties of quarry dust and river sand. Figure 3.5 represents the quarry dust directly taken from Kuantan quarry site while Figure 3.6 shows the quarry dust that had been sieved and ready to be used in concrete mixing.

Table 3.3: Physical characteristic of quarry dust and river sand

Sample Code	Moisture Content (%)		Bulk Density (kg/m3)	Fineness Modulus	Effective Size (mm)	Coefficient of Uniformity	Coefficient of Gradation
	Wet	Dry					
Quarry Dust	24.25	1.59	1118	2.04	0.17	1.58	1.37
River Sand	25.00	2.50	1430	2.20	0.20	6.00	2.00

Figure 3.5 : Quarry dust directly taken from Kuantan quarry site

Figure 3.6 : Sieved quarry dust passing 75 μm BS Sieve

3.5 Foam

The foam is mainly added as a base material and the main requirement is that it must be capable of remaining stable and not collapsing during pumping, placement and curing. The density of foam is about 110 kg/m^3 and the investigators reported that foam materials below this density is to be manufactured with care.

Foaming agent is biodegradable, causes no chemical reaction with the surrounding matrix but serves solely as wrapping material for the air to be encapsulated in the foam concrete. Foaming agent can be divided into two types which are synthetic foaming agent and protein foaming agent. The foaming agent that had been selected to complete this study was protein Noraite PA-1. This protein foam agent was the usual agent used in FKASA laboratory. Figure 3.7, figure 3.8 and figure 3.9 show the foaming agent and the equipment used to form foam.

Figure 3.7: Protein foaming agent at FKASA laboratory

Figure 3.8 : Equipment for producing pressured foam

Figure 3.9: Pressured foam

3.6 Batching and Mixing

Initially the materials were weighed and dry mixing was carried out for cement, sand and quarry dust. This was thoroughly mixed in concrete mixer of capacity 200 kg. The mixing duration was about five minutes or until the ingredients were truly mixed. Then the water was added incrementally to obtain a reasonable working mix. The mixing was carried out for duration so that it became nicely mixed. The required quantity of foam was measured in volume and added to the wet mix and again the mixing then continued. Mixing for more duration after adding foam might disintegrate the foam. Then, the mix was poured into the cube moulds of size 150 × 150 × 150 mm and beam moulds of size 100 × 100 × 500 mm. Table 3.4 indicated the mix design of foam concrete. Figure 3.10 and 3.11 represent the tools and equipment used during concrete batching.

Table 3.4: Mix design of foam concrete

Sample Designated & No of Sample	% Quarry Dust	Cement (kg)	Sand (kg)	Quarry Dust (kg)	Water (kg)	Foam (liter)
Cube, $C_1 = 9$ Beam, $B_1 = 3$	0	33.08	33.08	-	16.54	29.27
Cube, $C_1 = 9$ Beam, $B_1 = 3$	10	33.08	29.77	3.31	16.54	29.27
Cube, $C_1 = 9$ Beam, $B_1 = 3$	20	33.08	26.46	6.62	16.54	29.27
Cube, $C_1 = 9$ Beam, $B_1 = 3$	30	33.08	23.16	9.92	16.54	29.27

Figure 3.10 : Tools and equipment used during concrete batching

Figure 3.11 : Concrete mixer capacity of 200 kg

3.7 Casting

The concrete mixtures were casted and divided into 36 cubes with dimension of 150 × 150 × 150 mm; and also 12 beams with the dimension of 100 × 100 × 500 mm. During conducting this project, there were insufficient steel moulds in FKASA laboratory, so the formworks had to be used for casting the foam concrete. Figure 3.12 shows the cube formworks while the Figure 3.13 shows the beam formworks.

Figure 3.12: Cube formworks

Figure 3.13: Beam formworks

3.8 Curing

All samples were immersed in water during the water curing in this investigation. Foam concrete is generally water cured. Curing might be accelerated by applying heat, steam or chemicals. A curing compound prevents excessive loss of water after casting and consequently increases strength. Continuous water curing is important to promote strength development through the chemical reaction in concrete mixture. Inadequate initial water curing would delay the hydration process causing failure to produce calcium hydroxide that is essential for chemical reaction to take place for strength development. Therefore, at least seven days initial water curing is needed for strength development of foam concrete. Figure 3.14 shows the concrete were cured in water for seven days at least.

Figure 3.14 : Foam concrete was immersed in water during curing phase

3.9 Testing

There were two tests that had been carried out to identify the strength of the foam concrete. The cubes were tested on compression test to determine the compressive strength while the beams were tested on the flexural test to determine the flexural strength.

3.9.1 Compression Test

Compression test was run on the cubical foam concrete at the age of 7, 14, 28 days. Three samples from the same proportion were tested at each age and the average of strength was recorded. Compression test was conducted in concrete laboratory in University Malaysia Pahang (UMP). All the samples were surface dried and were loaded in (Universal Testing Machine) UTM. The compressive strength on the 150 × 150 × 150 mm cubes was also recorded.

3.9.2 Flexural Test

In this study, three points bending flexural test was conducted to the beam with dimension of 100 × 100 × 500 mm. at the planning stage, the four points bending flexural test was supposed to be used. But because of the inconvenient to the machine, it cannot be used at the day of testing. Then, the three points bending flexural test had been used. Flexural strength represents the highest stress experienced within the material at its moment of rupture. The equipments used were Universal Testing Machine and Three Point Flexural Test Fixture.

The beams were tested at the age of 28 day after water curing. Three beams from the same proportion were tested and the average of the strength reading was recorded directly. All testing process was conducted in concrete laboratory.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Introduction

This chapter contains the analysis of results of the data collection from the laboratory experiments and the analysis of the data collected from the experiments carried out. The experiments regarding on the foam concrete with the different proportion of quarry dust as sand replacement. The results gained, then manipulated and analyzed and then presented in graphs for comprehensive observation. A thorough discussion about the results and the analysis of data are also included in this chapter. All the discussion and analysis are presented within the scope as mentioned in the objectives as stated in the earlier chapter. The analysis of the results is divided into several parts based on the experiment carried out which compression test and flexural test.

4.2 Data Analysis

After all the experiments had been done and all completed, all the data were recorded for further analysis. The experiments that had been carried out were compression test, and flexural test. All the data and results obtained from these experiments were tabulated and then manipulated to get the actual values for parameters. Besides, it is also easier to see the differences as the results are compared with each other and more understandable by using graph.

4.3 Compressive Strength

Table 4.1 shows the compressive strength of foam concrete. The compressive strength is important to identify the allowable strength that a concrete can withstand. Compressive strength of foam concrete mixtures made with different proportion of quarry dust as sand replacement was determined at 7, 14 and 28 days under water curing method. The averages of three samples from each proportion were taken for every testing age. Total of 36 cubes had been casted with various percentage of quarry dust. Cube samples for 0 %, 10 %, 20 % and 30 % were designated as $C_{0\%}$, $C_{10\%}$, $C_{20\%}$ and $C_{30\%}$ respectively.

Thus, the following graphs show the compressive strength of foam concrete for each proportion of foam concrete. Figure 4.1 represents the compressive strength of foam concrete containing 0 % quarry dust, Figure 4.2 represents the compressive strength of foam concrete containing 10 % quarry dust, Figure 4.3 represents the compressive strength of foam concrete containing 20 % quarry dust and Figure 4.4 represents the compressive strength of foam concrete containing 30 % quarry dust, while Figure 4.5 represents the compressive strength of foam concrete for all proportions designated.

Table 4.1 : Average compressive strength (MPa) of foam concrete

Sample Designated	Average Compressive Strength in MPa		
	7 days	14 days	28 days
$C_{0\%}$	4.74	4.76	4.82
$C_{10\%}$	5.55	5.69	5.84
$C_{20\%}$	6.03	6.30	6.48
$C_{30\%}$	6.27	6.52	6.67

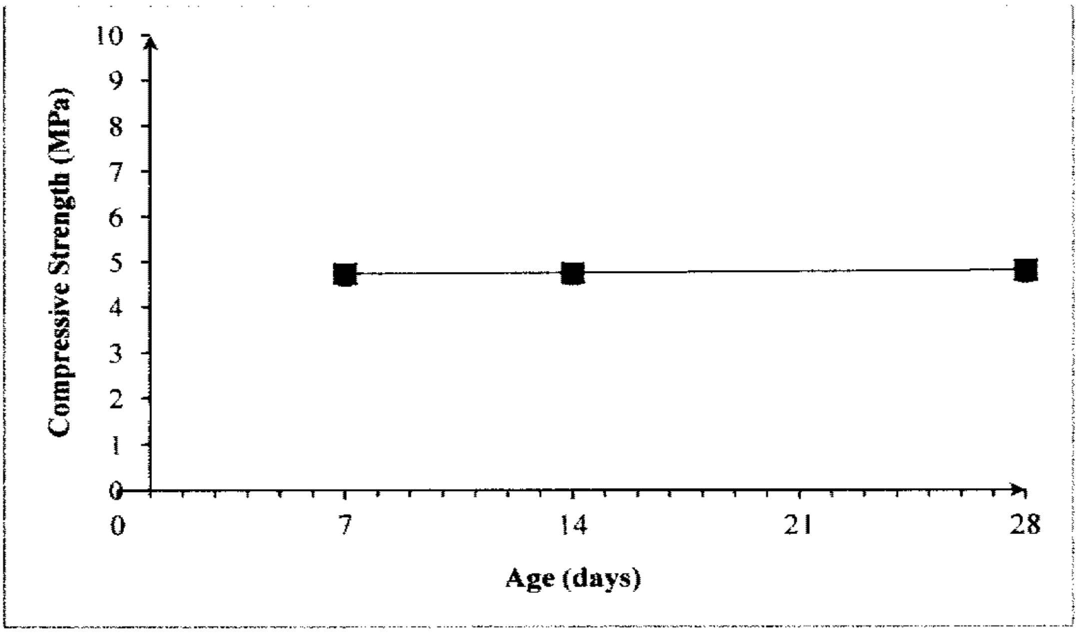

Figure 4.1 : Compressive strength of foam concrete with 0 % quarry dust (concrete control)

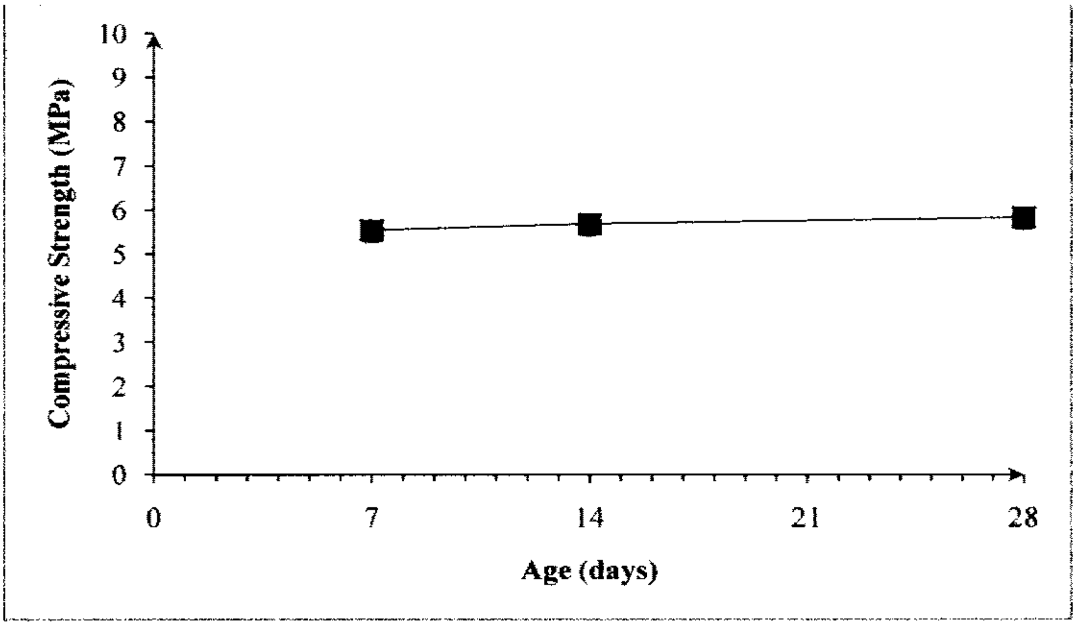

Figure 4.2 : Compressive strength of foam concrete with 10 % quarry dust

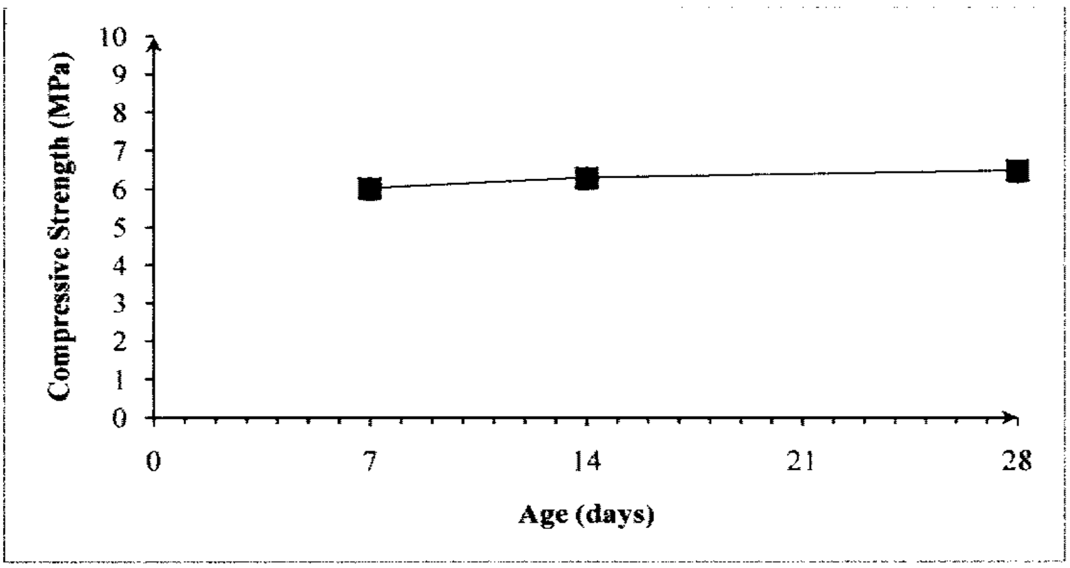

Figure 4.3 : Compressive strength of foam concrete with 20 % quarry dust

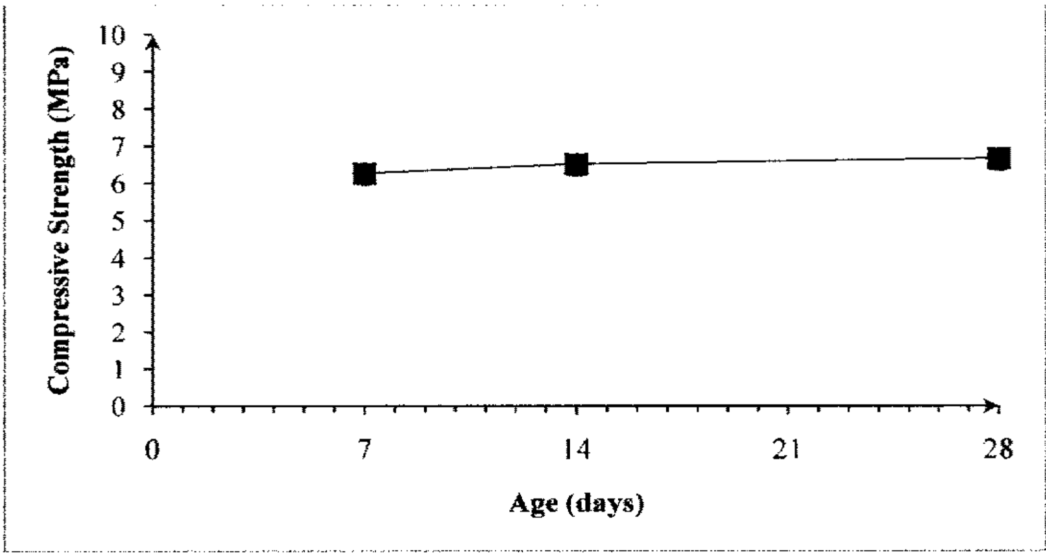

Figure 4.4 : Compressive strength of foam concrete with 30 % quarry dust

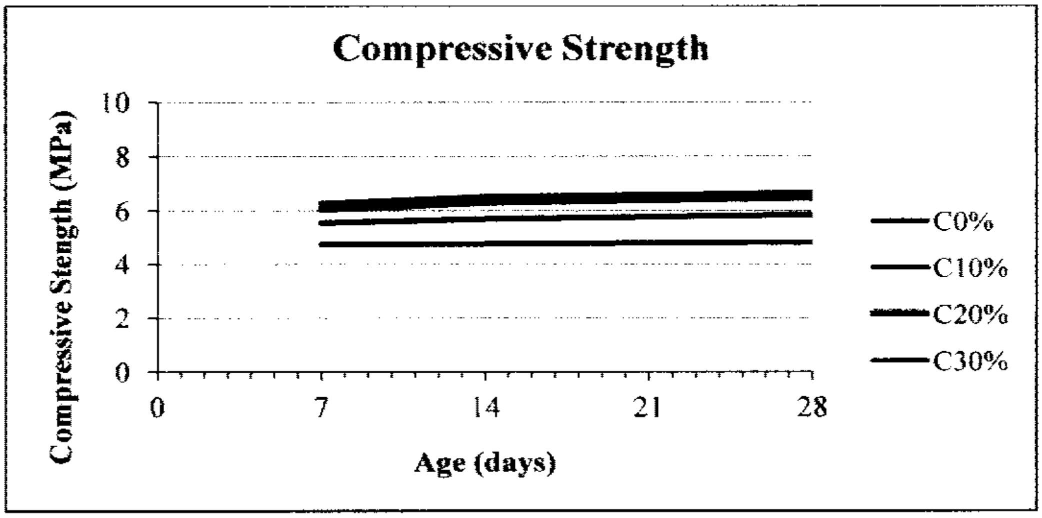

Figure 4.5 : Compressive strength of foam concrete

Foam concrete containing 0 % of quarry dust acts as concrete control in this study. By referring to Figure 4.1, it shows that the strength increase from day seven to day 28. There is slightly difference which is about 1.7 % increment from day seven to day 28. Even though it is increasing, the result has been compared with the previous study done by researchers. It is shown that there is quite big difference which means this study has lower value of compressive strength about 60 % compared with the previous study. This reduction in strength might because of several reasons such as difference size of sand, type of foaming agent used, and technique of batching and placing of foam concrete.

Besides that, foam concrete containing 10 % quarry dust also shows slightly increment in strength from day seven to day 28 which is about 5 %. There are also increment in all proportion of foam concrete such as 6 % and 7 % increasing in foam concrete containing 20 % and 30 % quarry dust respectively.

Figure 4.5 shows a graph of compressive strength of foam concrete with different proportion of quarry dust as sand replacement by different age of testing. By referring to the graph, the strength of foam concrete is developed uniformly with the increasing of quarry dust percentage. It also shows that strength of foam concrete is increasing with the increment age of foam concrete. The foam concrete which contained 30 % of quarry dust by sand weight gives highest compressive strength compared to 20 % and 10 % of quarry dust and concrete control as well. The increment of concrete contained 30 % quarry dust is about 2.85 % of the concrete 20 % quarry dust. Besides that, the increment of concrete contain 20 % quarry dust is about 9.87 % of concrete 10 % quarry dust. The difference between the concrete contained 30 % of quarry dust with the control concrete is about 27.7%.

Those descriptions above directly show that the quarry dust which has been used as sand replacement is experimentally proven to increase the foam concrete strength. In previous study, quarry dust shows better performance in terms of conventional concrete strength (Ilangovana et al. 2008). This might be influenced by the different percentage of quarry dust used in the mixtures. The more the quarry dust used, the more strength increases. This is because; the quarry dust used is a finer material compared to the sand used. Thus, quarry dust acts as filler to the concrete and also partial sand replacement material. According to Hamidah et al. (2003), the finer aggregates used in the foam concrete, the more increment of strength of the foam concrete. So this statement is experimentally proven. But replacement of sand by quarry dust beyond 30 % cannot be identified its results since it is allowable to use till 30 % of other material being replaced (Hamidah et al. 2003).

After thorough discussion, it can be concluded that the quarry dust can be used as partial sand replacement in foam concrete in order to enhance the concrete properties especially compressive strength.

4.4 Flexural Strength

Flexural test was carried out to the 12 beams at the age of 28 days. There were three beams casted for each proportion of foam concrete and the averages of flexural strength had been recorded. Table 4.2 shows the average flexural strength of foam concrete after testing was carried out at the age of 28 days. Beam samples were designated for each 0 %, 10 %, 20 % and 30 % quarry dust as $B_{0\%}$, $B_{10\%}$, $B_{20\%}$ and $B_{30\%}$ respectively.

Table 4.2 : Average flexural strength (MPa) of foam concrete at age of 28 days

Sample Designated	Flexural Strength (MPa)
$B_{0\%}$	4.70
$B_{10\%}$	5.18
$B_{20\%}$	6.55
$B_{30\%}$	6.66

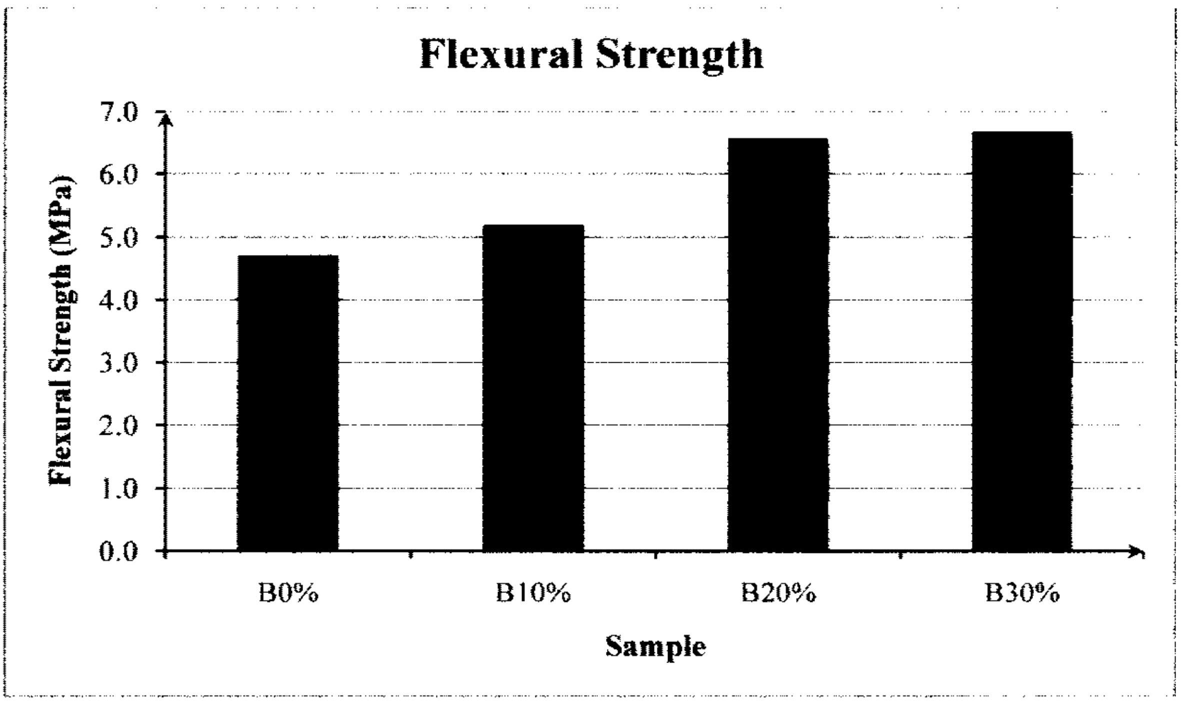

Figure 4.6 : Average flexural strength (MPa) of foam concrete

Figure 4.6 gives the comprehensive observation of flexural strength for all proportion of foam concrete. From the graph, it can be seen that the flexural strength of foam concrete is increasing with the increment proportion of foam concrete. There is difference between foam concrete containing 30 % quarry dust and control concrete which is about 29.4 % where foam concrete containing higher quarry dust has higher value of strength. There is slightly difference between foam concrete contain 20 % and 30 % of quarry dust which about 1.65 %. There is also quite drastic increment between concrete contain 10 % and 20 % of quarry dust where the concrete 20 % quarry dust shows higher value of strength. As the increasing quarry dust in the foam concrete mixture gives the increasing strength value.

This can be concluded that the quarry dust as sand replacement is experimentally proven its function and efficiency. The finer material used in the foam concrete mixture, the higher strength development can be obtained till 30 % of replacement material is used. Beyond 30 % of quarry dust used cannot be proven its strength because it is unallowable by the reported studies (2003).

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Introduction

The entire tests that have been carried out important to find out the feasibility of quarry dust as a replacement material for sand in foam concrete application. All the tests were conducted in FKASA laboratory, UMP according to exact standard in order to obtain successful results. There are still needs a lot of further studies, many of improvements for future works that can be made for this study in order to obtain and achieve a better and good result. The conclusion made is entirely based on the objectives of the study.

5.2 Conclusion

By referring to the data analysis taken from the compressive and flexural test, several conclusion have been highlighted below :-

i. It is agreed that the quarry dust used has influenced in strength of foam concrete. There are incremental in value of both compressive and flexural strength with increasing of quarry dust by weight.

ii. Different percentage of quarry dust by weight gives different results in both strengths. Foam concrete contain 30 % of quarry dust by weight has increment of compressive strength up to 38 %, and 42 % of flexural strength compared to control foam concrete.

iii. The incorporation of quarry dust as partial cement replacement for sand in foam concrete resulted in increasing in compressive and flexural strength, and this was more evident when the replacement proportion was increased.

5.3 Recommendation

From the survey results, a few improvements are essential in the future study. The recommendations are as follows :-

i. A series of investigation on increasing the replacement proportion of quarry dust as sand replacement beyond 30 % should be conducted.

ii. A series of investigation on foam concrete properties such as shrinkage, water absorbent, and fire resistance of foam concrete should be considered.

iii. A series of investigation on trial casting with quarry dust proposed to be used, in order to achieve the strength requirement need to be carried out.

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