WATER PERMEABILITY OF FOAMED CONCRETE

MOHD HAZIMAN BIN WAN IBRAHIM

KOLEJ UNIVERSITI TEKNOLOGI TUN HUSSEIN ONN

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Saya **MOHD HAZIMAN BIN WAN IBRAHIM (771126 – 03 – 5985)**

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Signature : ....

Supervisor : Assoc. Prof. Dr. Lee Yee Loon

Date : 15/4/04

Signature : ....

Co - Supervisor: Mr Koh Heng Boon

Date : 15/4/04

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MOHD HAZIMAN BIN WAN IBRAHIM

This dissertation is submitted
in fulfillment the requirement for the award of
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Faculty of Engineering
Tun Hussein Onn University College of Technology

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Dedicated to my beloved

Father

Mother

Wife, Nurfirdawati

My daughter Syafiqah Sofia

My son Amir Amzar

For the patience and support….

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ABSTRACT

This study focused on the compressive strength and water permeability of foamed concrete. Two types of foamed concrete mix with density 1500 kg/m^3 and 1700 kg/m^3 were experimented. Timber industrial ash (TIA) were used as the partial cement replacement material, replacing 10% of Ordinary Portland cement (OPC) in the mix design. The test cubes were 150 mm X 150 mm X 150 mm size subjected to wet-cured and air cured for up to 28 days. The density, compressive strength development and water permeability of the TIA foamed concrete were determined to compare with the control mix (without TIA). The test method adopted based on DIN 1048 was used to determine the water permeability of foamed concrete at 28 days. Compressive strength was determined at 3 days, 7 days and 28 days. It was found that the air-cured specimens achieved a higher compressive strength and lower water permeability compared with the wet-cured specimens. Foamed concrete with 10% TIA reduced the water permeability with a lower compressive strength at 28 days. The preliminary result indicated that TIA has potential to reduce the water permeability of foamed concrete.

ABSTRAK

Kajian ini menumpu kepada kekuatan mampatan dan kebolehtelapan air konkrit berbusa. Dua jenis bancuhan dengan ketumpatan 1500 kg/m^3 and 1700 kg/m^3 digunakan dalam kajian ini. Habuk kayu industri (TIA) telah digunakan sebagai bahan gantian simen bagi menggantikan 10% daripada kandungan Portland simen biasa (OPC) dalam rekabentuk bancuhan. Kiub 150 mm X 150 mm X 150 mm diawet dalam keadaan lembap dan juga udara sehingga 28 hari. Ketumpatan, kekuatan mampatan, dan kebolehtelapan air konkrit berbusa telah ditentukan untuk dibandingkan dengan bancuhan kawalan (tanpa TIA). Kaedah ujikaji berdasarkan DIN 1048 telah digunakan bagi menentukan kebolehtelapan air konkrit berbusa pada umur 28 hari. Kekuatan mampatan ditentukan pada umur 3 hari, 7 hari dan 28 hari. Didapati spesimen yang melalui pengawetan dengan udara mencapai kekuatan mampatan yang lebih tinggi dan kebolehtelapan air yang lebih rendah berbanding dengan spesimen dalam pengawetan lembap. Pada umur 28 hari kebolehtelapan air konkrit berbusa dengan kandugan 10% TIA adalah menurun dengan kekuatan mampatanya yang lebih rendah. Hasil dari saringan ini didapati bahawa TIA mempunyai potensi untuk mengurangkan kebolehtelapan air konkrit berbusa.

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LIST OF ABBREVIATIONS AND SYMBOLS

TIA	Timber Industrial Ash
PFA	Pulverized Fuel Ash
GGBS	Ground Granulated Blast Furnace Slag
RHA	Rice Husk Ash
ACI	American Concrete Institute
AAC	Autoclaved Aerated Concrete
SAA	Surface Active Agent
OPC	Ordinary Portland Cement
mm	millimeter
ASTM	American Society for Testing and Materials
BS	British Standard
C2S	Dicalsium Silicate
C3S	Tricalsium Silicate
CH	Calsium Hydroxide
C-S-H	Calsium Silicate Hydrate
MS	Malaysia Standard
MPa	Mega Pascal
g	Unit weight, gram
k	Coefficient of permeability
ρ	Density of foamed concrete;
m	Mass of cube after remove from the mould in unit kg;
v	Volume of the specimen calculated from its dimensions in (m^3);
ISO	International Standard Organization
°C	Degree Celcius

dq/dt	The rate of fluid flow
A	Cross sectional area
L	The thickness of the sample in m
Δh	The drop in hydraulic head through the sample, measured in m
BCA	British Cement Association

CHAPTER I

INTRODUCTION

1.1 General

Concrete is an important building material, playing a part in all building structure. It can be molded to take up any shape required for the various structural forms. According to the "Draft International Standard Model Code for Concrete Construction" classifies concrete as having densities around 2300 kg/m^3.

Foamed concrete is a lightweight product produced by adding a foaming agent (usually some form of hydrolyzed protein or resin soap) to the mix. The agent introduces and stabilizes air bubble during mixing at high speed. In some processes, stable pre-formed foam is added to the mortar during mixing in an ordinary mixer.

Lightweight concrete may be defined as the concrete of substantially lower unit weight than that made from gravel or crushed stone. Concrete is considered lightweight if it's density falls between 1200 kg/m^3 to 2000 kg/m^3.

Ordinary concrete is quite heavy and it is not suitable for use in floor filling as filler in general because it will affect the dead weight of the structure. By using suitable aggregates, the density of concrete can be reduced. Beside that the foamed concrete also has a better insulation against heat and sound.

K. Schonlin et al (1988) stated that the durability of concrete structures has become a serious problem in many parts of the world. A number of deleterious processes in concrete are related to the pore structure and in particular to the diffusion characteristics and the permeability of the concrete.

Permeability is a measure of the capacity of a porous medium to transmit water. It is regarded as a material property affecting the durability of concrete and it is considered as one of the most important properties of the concrete.

J.F Young (1988) stated that the permeability is an important property with regard to the durability of concrete. It represents the ease with which water (or other fluids) can move through the concrete, thereby transporting aggressive agents. It is thus of critical importance for many types of distress experienced by concrete.

In this study there are many aspect which has been discussed by the researcher but what is relevant to this study is on the water permeability and compressive strength of the foamed concrete with densities 1500 kg/m^3 and 1700 kg/m^3 and with different composition, water cement ratio and ages.

1.2 Statement of Problem

Foamed concrete is new method of concrete that can be used in construction. "British Cement Association" (1991), were published the report about foamed concrete where all the properties of foamed concrete were reported but this report is lake of information about durability. We have identifying the durability is closed related to water permeability, therefore the water permeability of foamed concrete has to be investigate in detail and it is a intension to construct more water retaining structure of foamed concrete.

The durability and quality of concrete structures has become a major topic of interest in concrete industry. Mehta P. K (1997) stated that for the future, the durability of concrete would become a critical issue. These issues were come up when many structures had shown serious deterioration much before their intended service life (40 to 50 years). Mainly due to economic factors, the durability of concrete is being taken seriously.

Many factor affecting the concrete durability. Concrete durability depends largely on the ease with which fluids in the form of liquid or gas can migrate through the hardened concrete mass. Concrete is porous material. Therefore, moisture movement can occur by flow, diffusion or sorption. We are concerned with all three, but generally the overall potential for moisture in concrete by these three modes is referred to as its permeability. Permeability is a one of the significant factors that affecting the durability of concrete where the information or data about these is very important for the structure use. Generally, many methods have been done to determine the water permeability of concrete and one of the methods is DIN 1048 but the applicable of this method for the foamed concrete is unknown.

Timber industrial ash (TIA) is considered as a waste industries material and it were through the integrated micronising blending process to producing micronised silica. The micronised silica that is produced can be used as a cement replacement material in concrete. If TIA is used to replace cement in concrete it can utilize the waste material.

TIA has been found to increase the durability of normal concrete but for foamed concrete, it's still unknown especially in water permeability because a foamed concrete with TIA still a new material of concrete. This information is very important to determine the quality of foamed concrete and to increase the performance of foamed concrete.

1.3 Objective of Study

The objectives of this study are:

i. To determine the water permeability of foamed concrete

ii. To study the effect of micronized silica TIA on the foamed concrete

1.4 Scope of Study

A study was conducted to develop a new kind of building material base on foam. Laboratory test were carried out to determine the compressive strength and water permeability of foamed concrete at 1500 kg/m^3 and 1700kg/m^3 of densities. The 10% of TIA also were used as a replacement cement to produce a foam concrete which comparison were be done with a control sample (0% replacement material). The details of mix proportion are shown in Table 3.2. For each series of mix, 12 cube specimens were been cast. The detail of amount of cube is shown in Table 3.4. At age 3, 7 and 28 days, 2 cubes for each series were subjected to compressive strength. After age 28 days 4 cubes for each series were subjected to water permeability using DIN 1048 method where two cubes were cured with air curing and the other two cubes were carried out under water curing.

1.5 Hypothesis of Study

The hypothesis of this study is a foamed concrete have low water permeability and TIA has a potential or tendency to reduce water permeability

1.6 Important and Contribution

From this study we can identify the process of manufacturing a foamed concrete. Beside that, this research also can be used for:

i. Manipulating the foamed concrete characteristic into practice by improving the compressive strength and water permeability of foamed concrete.

ii. Introducing new alternative materials of concrete in construction.

iii. Introducing the use of TIA in foamed concrete can be widely in the structural construction if found it is suitable

iv. Utilizing waste / secondary material in a production of aggregate that can meet the relevant requirement for structural use, therefore save the environment.

1.7 Layout of Report

This report is presented in five chapters. The objective and scope of work are covered in Chapter I. In this chapter also, the hypothesis of study, the problem statement and significant of study are specified. Literature review are summarize in Chapter II. The methodology, experimental and test methods are described in Chapter III. The water permeability test system is discussed in Chapter VI. The strength development and water permeability of foamed concrete are reported in Chapter V. The conclusion of the study is discussed in Chapter VI.

CHAPTER II

LITERATURE REVIEW

2.1 Introduction

Concrete is the product of reaction between hydraulic cement and water. But these days concrete can be made with several types of cement and also containing pozzolan, fly ash, admixtures, polymers, fibres and so on.

Many research have been done to produce a concrete, with technical environmental and economical advantages. Scientist, engineer and technologist are continuously on looking for the method or new material, which can be used to produce a concrete with enhanced performance especially in durability.

David et. al. (1988) has state that the concrete technologist throughout the world are becoming increasingly aware of the importance of permeability with regard to the durability and ultimate longevity of concrete structures. New materials for reducing permeability and techniques for its measurement are rapidly being developed.

Foamed concrete is a new alternative construction material that was introduced nowadays but the study about this concrete still not so many. Foamed concrete is manufactured by entraining relatively large volumes of air into the cement paste by the use of a chemical foaming agent. High air contents result in lower densities, higher porosities and lower strengths.

Kearsley et. al (2000) stated that the porosity of foamed concrete after replacing large volume of cement (up to 75% by weight) with both classified and unclassified fly ash was found to be dependent mainly on the dry density of the concrete and not on ash type or content. The volume of water absorbed by foamed concrete was approximately twice that of an equivalent cement paste but was independent of volume of air entrained, ash type and ash content. The compressive strength of foamed concrete when cured under sealed condition shows that up to 67% of the cement could be replaced without any significant reduction in strength

Permeability is an important property with regard to the durability concrete. It represents the ease with which water can move through the concrete, thereby transporting aggressive agents. It is thus of critical importance for many types of distress experienced by concrete.

Neville A. M (1981), found that the permeability of concrete is not a simple function of its porosity, but depends also on the size, distribution and continuity of the pores. Thus, although the cement gel has a porosity of 28 per cent, its permeability only about 7×10^{-16} m/s. The permeability of cement paste also is varies with the progress of hydration. In a fresh paste, the flow of water is controlled by the size, shape and concentration of the original cement grains and in the mature paste, the permeability depends on the size, shape and concentration of the gel particles and on whether or not the capillaries have become discontinuous.

The use of blended cement, which contains partial cement replacement materials (PCRM) such as pulverized fuel ash (PFA), ground granulated blast furnace slag

(GGBS), rice husk ash (RHA) and timber industrial ash (TIA) has been widely accepted in concrete construction. The use of such pozzolanic materials in concrete has been found to improve the durability performance of concrete, especially in terms of reduced hydration temperature.

Lee et al. (1997) revealed in TIA study, the appropriate use of TIA tends to enhance strength development and reduce water permeability of concrete if the cement replacement level is not more than 10%. Water permeability of around $1X10^{-13}$ m/s can be achieved for grade 80 concrete containing 5% TIA. Concrete of reduced water permeability are suitable for products and structures subjected to constant water pressure such as the pre-cast concrete piles and other concrete structures. He also stated that the TIA concrete was found to produce lower hydration temperature. The maximum hydration temperature is occurred at about 10 hours after the concrete specimens were cast if concrete containing less than 20% TIA but for concrete containing 20% TIA, the maximum hydration temperature occur at 7 days after casting.

Lee et al (1999) stated that the water permeability of concrete cover is related to durability and usually associated with good concrete practice, which involves a suitable choice of constituent material together with good concrete mix design and workmanship. Good concrete practice should include adequate compaction and suitable curing. Early and long (first 7 to 14 days) moist curing has been identified as an important requirement for durable concrete. He also stated that, the permeability of cement paste is related to concrete durability. A great deal of work has been done measuring and predicting permeability of cement paste. One aspect of the work related pore structure to its permeability.

Nyame B. K (1985), investigated the permeability of normal and lightweight mortars. It was found that the permeability of mortar increased as the porosity was reduced by the addition of aggregates that have a lower porosity than the mortar. Nyame suggested that the inclusion of the aggregate creates microcracks at the interface with the mortar resulting in increased permeability. By increasing the aggregate volume there are more interfaces resulting in higher permeability. Aggregates therefore have two opposing influences upon permeability: size and volume obstructions can reduce permeability but interfacial effects and aggregate properties can increase permeability. In the case of foamed concrete the small air voids that are entrained can effectively be considered as an aggregate, their inclusion might not reduce the permeability by obstructing flow but they are also unlikely to lead to an increase because of the absence of microcracking

According to Neville A.M (1995), entrained air in concrete produces, in the cement paste, discrete, nearly spherical bubbles approximately 50 micrometer in diameter resulting in the formation of very few channels for the flow of water and very little increase in the permeability. The volume of air normally associated with air entrainment is no more than about 6% and what needs to be established is whether or not this statement holds true for foamed concretes which contain much larger volumes of air.

In the study on capillary pore structure and permeability of hardened cement paste Nyame et. al (1981) concluded that porosity is not a unique function of permeability. They concluded that total porosity of hardened cement paste is not uniquely related to permeability but depends on whether the change in porosity derives from differences in the water/cement ratio or hydration times. They identified well-defined trends for the effect of the time of hydration at constant water/cement ratio on permeability

Day R.L et al (1988) conducted research on the pore structure characteristics affecting the permeability of cement paste containing fly ash. They concluded that the pozzolanic reaction of fly ash in blended cement pastes could cause substantial reductions in permeability.

Aldea. et. al (2000) found that for the cracked material the water permeability significantly increased with increasing crack width and flow was quite repeatable for the same cracking level.

Kwangusen. J. et. al (2002) in studies about the effect of pressure on water permeability of concrete stated that the water permeability of concrete is effected by the pressure, the compressive strength of concrete and the curing period. If the higher pressure is applied, the higher water permeability moreover. When low compressive strength of concrete and less curing period, it can cause the better water permeability.

Perraton. D. et. al (1988) in studies of the permeability of silica fume concrete were found that concretes with water cement ratio of 0.5 or less are practically impervious to any water flow whether silica fume is admixed or not.

Whiting (1988) stated that the importance of mix design variables and curing with respect to concrete permeability have been confirmed. If concrete is not moist cured for at least seven days, permeability may increases fourfold or more.

2.2. Foamed Concrete

The American Concrete Institute International (ACI-116R-90) defined "Foamed Concrete" is a lightweight product consisting of Portland cement, cement-silica, cement-pozzolan, lime-pozzolan, lime-silica pastes, or pastes containing blends of these ingredients and having a homogeneous void or cell structure, attained with gas-forming chemicals or foaming agents.

Generally foamed concrete is defined as a lightweight concrete with Portland cement base containing many small air cells uniformly distributed throughout the concrete. These cells may account for up to 80% of the total volume. Cellular concrete can be thought of as a concrete, which utilizes a stable air cell structure rather than fine aggregate.

Neville. A. M. at. al (1987) state that foamed concrete is produced by adding to the mix of foaming agent (usually some form of hydrolyzed protein or resin soap), which introduces and stabilizes air bubbles during mixing at high speed. In some processes stable pre-formed foam is added to the mortar during mixing in an ordinary mixer. He also were classified a lightweight concrete in three categories which is:

a) Lightweight aggregate concrete is a mixture of concrete using porous lightweight aggregate of low apparent specific gravity such as 2.6.

b) A sizeable void present within the concrete or mortar mass; these voids should be clearly distinguished from the extremely fine voids produced by air entrainment. This type of concrete is variously known as aerated, cellular, foamed or gas concrete.

c) A large number of interstitial voids are present by omitting the fine aggregate from the mix and replacing it with normal weight coarse aggregate. This concrete is known as no-fines concrete.

Foamed concrete commonly produced by two different methods. The first method, consists of mixing a pre-formed foam (surfactant) or mix-foaming agents mixture into the cement and water slurry. As the concrete hardens, the bubbles disintegrate leaving air voids of similar sizes. The second method, known as Autoclaved Aerated Concrete (AAC) consists of a mix of lime, sand, cement, water and an expansion agent.

The bubble is made by adding expansion agents (aluminum or hydrogen peroxide) to the mix during the mixing process. This creates a chemical reaction that generates gas, either as hydrogen or as oxygen to form a gas-bubble structure within the concrete. The material is then formed into molds. Each mould is filled to one-half of its depth with the slurry. The gasification process begins and the mixture expands to fill the mold above the top. After the initial setting, it is then cured under high-pressured-steam [180° to 210 °C / 356 to 410 F] "autoclaved" for a specific amount of time to produce the final micro/macro-structure.

Foamed concrete is free flowing but exhibits thixotropic behaviour. It is easily placed, requires no compaction and flows into the most restricted and irregular cavities. The bubbles also inhibit segregation and bleeding and the material can be pumped successfully over vertical and horizontal distances similar to those for pump able dense concrete.

Foamed concrete can be produced with dry densities of 400 to 1600 kg/m^3 with 7-days strength 1 to 10 N/mm^2 respectively. It is also fire resistant, and its thermal and acoustical insulation properties make it ideal for a wide range of purposes, from insulating sub- bases and roof screeds, to void filling. Beside that, foamed concrete also particularly useful for trench reinstatement.

2.3 Foam

Preformed foam is commonly used to make lightweight foamed concrete to improve the properties of conventional concrete. It can be divided into two main groups that are natural foaming agents and Synthetical foaming agents. Foamers which are surface active agents (SAA) can be divided into anion-active foaming agents (sodium salts of carbon and naphthene acids), cation-active foaming agents (amines and their derivatives), non-ionic foaming agents (derivatives of polyethyleneglycol esters of grades OP-7 and OP-10). The most commonly used foam concentrates to manufacture foamed concrete are based on protein hydrolyzates or synthetic surfactants. Approximately 75% to 85% of the bubbles are of 0.3 mm to 0.15 mm in diameter (Figure 2.1). According to Khitrov's classification (Table 2.1), the Foaming agents presented with ionic solutions of SAA are divided into five groups.

Table 2.1: Group of surface-active agents by chemical nature

Group of SAA	Technical name	pH	Surface tension H/m	Relative lathering power	Relative foam stability	Number of carbonic atom in hydrophilic part of molecule
Ion active SAA						
Alkylsulphonates	Sodium sulfate dodecyl	2 to 12	26 to 35	1,9	0,4	12
	Foaming agent no.1			2,5	0,6	10 to 12
	Progress			2,9	0,3	6 to 16
Alkylbenzolsulfonates	Sulphanol-40	6 to 10	32 to 35	2,1	0,4	10 to 14
	Three ethanolamine (Sulphanol NP-1)				0,3	10 to 14
Derivatives of carbon acids	Sodium miristinate	8 to 9	40 to 45	1,0	0,8	13
	Sodium palmitate			0,8		14
	Sodium stearate			0,6		15
	Sodium oleate			0,7		15
Resinate Derivatives	Saponified lignenous resin	8 to 9	36 to 40	1,2	1,0	16
	Glue-colophony foaming agents			1,4		16
Amphoteric SAA						
Oligopeptides and protein hydrolisates	NEOPOR	6 to 8	40 to 48	1,0	1,0	5 to 10
	Hydrolyzed blood					
	UNIPOR					

Figure 2.1: Foam

2.4 Properties of Foamed Concrete

The compressive strength of foamed concrete will depend on the density, initial water/cement ratio and cement content. The density of the foam can have an influence on the ultimate strength, particularly for the lower density foamed concretes. Uniformly sized small bubbles appear to produce higher ultimate strength at all densities.

This avoids segregation, improves the strength for a given density and reduces the higher drying shrinkage associated with the lower density mixes. Ordinary Portland Cement (OPC) is used as the binder in most foamed concretes. Cement contents for the most commonly used mixes are between 300 and 375 kg/m^3.

Table 2.2 show the details of typical mixes used for foamed concretes of various densities. An indication only of batch weights is given because the type and grading of the sand and the characteristic of the foam will all influence the weight required. For optimum results the water cement ratio of the base mix should be kept fairly high to provide a base mix with a high workability. A base mix that is too dry and stiff is liable to extract water from the foam and cause it to collapse. In general, the optimum water cement ratio for the base mix lies between 0.5 to 0.6. The water used in the mixes, as with dense concretes, should be potable. This is particularly important when using protein-based foaming agents. As any organic contamination could have an adverse effect on the quality of the foam produced.

Table 2.2: Typical mix details for foamed concrete

Wet Density (kg/m3)	500	900	1300	1700
Dry Density (kg/m3)	360	760	1180	1550
Cement (kg/m3)	300	320	360	400
Base Mix W/C Ratio	Between 0.5 and 0.6			
Sand (kg/m3)	-	420	780	1130
Air Content (%)	78	62	45	28

*Source: Foamed Cocrete – Composition and Properties, British Cement Association

Based on Table 2.3, gives an indication of properties at various densities. The dry shrinkage for foamed concrete is higher than that of dense concrete; the highest shrinkage being associated with the lowest densities, where the material is essentially a foamed cement paste.

Table 2.3: Typical properties of foamed concrete

Dry Density (kg/m3)	Compressive Strength (N/mm2)	Thermal Conductivity (W/mK)	Modulus of Elasticity (kN/mm2)	Drying Shrinkage (%)
400	0.5-1.0	0.10	0.8-1.0	0.30-0.35
600	1.0-1.5	0.11	1.0-1.5	0.22-0.25
800	1.5-2.0	0.17-0.23	2.0-2.5	0.20-0.22
1000	2.5-3.0	0.23-0.30	2.5-3.0	0.18-0.15
1200	4.5-5.0	0.38-0.42	3.5-4.0	0.11-0.09
1400	6.0-8.0	0.50-0.55	5.0-6.0	0.09-0.07
1600	7.5-10.0	0.62-0.66	10.0-12.0	0.07-0.06

*Source: "Foamed Cocrete – Composition and Properties". British Cement Association

An advantage of lower density foamed concrete it its lower thermal conductivity, which gives better insulation properties. As shown in Table 2.3, the thermal conductivity is between 5 to 30% of that for dense concrete. The modulus of elasticity is also of a similar order when compared with dense concrete

2.5 Composition of Foamed Concrete

Foamed concrete is produced by incorporating a metered volume of preformed foam (air bubbles) into a cement paste or mortar mix known as volume and density. The foam is produced by a foam generator in which a foam concentrate usually diluted in the ratio of one part of concentrate to between 5 and 40 parts of water is combined with air (frequently compressed) in pre-determined quantities. The mix is then forced through a restriction to produce the foam. The generator can be hand-held, or fixed to discharge directly into a mixer. The density of the foam is typically between 25 and 80 g/litre.

The most commonly used foam concentrates are based on protein hydrolyzates or synthetic surfactants. They are formulated to produce air bubbles that are stable and able to resist the physical and chemical forces imposed during mixing, placing and hardening of the concrete. Between 75 and 85% of the bubbles are of 0.3 to 1.5 mm in diameter.

Foamed concrete with dry densities below 600 kg/m^3 usually consists of cement, foam and water, or cement, fly ash, foam and water. Adding sand produces higher densities. Building sand or concreting sand of 5 mm maximum size may be used, but research has indicated that, for given cement content, a higher strength is obtained using finer sand 2 mm maximum size with 60 to 95% passing the 600 micron sieve. Waste sands, such as single-sized falling and granite dust, have been used successfully, but the same restrictions on grading and maximum size apply.

Coarse natural aggregates cannot be used because they would segregate in the lightweight foamed concrete, but it is possible to use lightweight aggregates with a similar density to the foamed concrete.

2.6 Advantages of Foamed Concrete

Foamed concrete has a several advantage as below:

a) Foamed Concrete is an environmental friendly sustainable material produced with least energy demand.

b) Foamed concrete containing industrial waste such as TIA is one of its constituent fine materials to reduce environmental pollution.

c) Self-compacting property of foamed concrete expected to achieve enhanced productivity and quality of construction.

d) Thin wall in lightweight concrete signify substantial dead weight reduction of superstructure thereby saving on the cost of superstructure, foundation and the input materials.

e) Its ability to flow around pipes and cables in situation where "crowded" excavations would make it difficult to adequately compact other materials.

2.7 Uses of Foamed Concrete in Construction

Foamed concrete has potential structural applications in constructions. Typical of these is insulation for piping and conduit, above or below ground, as infilling for ducts, trench reinstatement (the filling of trenches dug in roads when pipes are laid or repairs are carried out) and is used for geotechnical applications such as tunnel backfill, void filling, load reducing fill for bridge approaches, replacement of unstable soils, fill for abandoned underground structures and for shock energy absorption. Boilers and tanks also are insulated with cellular concrete, as well as cold storage and conventional buildings. In floor both insulation and weight saving can be exploited; use as a topping over precast elements is common. Poured insulated roof and floor deck are similarly a frequent application. Obviously the design mix and operating process of foamed concrete offer substantial economic savings.

2.8 Density of foamed concrete

Foam concrete exhibits a much lighter density than the typical normal concrete. Normal concrete has a density of 2400 kg/m^3. Foam concrete densities range from 300 kg/m^3 to 1800 kg/m^3. One of the most useful features of a foamed concrete system is to produce wide range of density. The amount of foaming agents introduced into mortar will govern the density. Foamed concrete can be classified according to the purpose for which it is being used. Below are listed some of the classifications foamed concrete by density:

a) According to ASTM C 330-82a, for structural lightweight concrete, the 28-day compressive strength should not be less than 17 MPa. The density of such concrete should not exceed 1840 kg/m^3 and usually are between 1400 kg/m^3 and 1800 kg/m^3.

b) Masonry concrete generally has density between 500 kg/m^3 and 1800 kg/m^3 and strength between 7 MPa and 14 MPa.

c) For insulating concrete, the coefficient of thermal conductivity usually below 0.3 $J/m^2s\ {}^{\circ}C/m$ and the strength is between 0.7 MPa and 7 MPa.

2.8.1 Wet Density

Wet density of concrete was measured during the foamed concrete still fresh. The density of the mortar should finding first before adding foaming agents. Normally the mortar has a wet density between 2.1 to 2.2 kg per liter. This is can be done by take 1 liter of the mix and weight it. It is guidelines to us to estimate the amount of foam required to the mortar. To know exactly the mix density after adding the foam, take 1 liter of the foamed concrete and weight it again, if the mix weights 1.7 kg per liter, it means the wet density of foamed concrete is 1700 kg/m^3.

2.8.2 Air dry density

Air-dry density is the mass of a unit volume of foamed concrete expressed in kilograms per cubic meter. It were calculated by using following formula:

$$\boxed{\rho = m / v} \quad \text{------------- } \textit{Equation 2.1}$$

Where

ρ is the density of foamed concrete;

m is the mass of cube after remove from the mould in unit kg;

v is the volume of the specimen calculated from its dimensions in (m^3);

2.9 Micronized Silica – Timber Industrial Ash (TIA)

Some waste can add in concrete mixtures as a cement replacement. These wastes have a high silica content, which are micronize form and easily dissolve in OPC hydration process and forming calcium silicate hydrate (CHS) according to Gambir (1986). In many cases, this type of admixtures will react slowly compare to OPC, and it will contribute in strength development and improvement in permeability concrete (Pratt, 1994).

Lee at. Al (1999) stated that the material technology requires the use of a quality assured pozzolan to react with Ca $(OH)_2$ liberated during cement hydration to produce microstructure with more stable C-S-H resulting in pore refinement and reduced water permeability.

The use of TIA as a partial replacement cement has an environmental, technical and economical advantages as cement production is highly energy intensive and the extraction of the raw materials required is not always environmentally friendly. The appropriate use of TIA has the potential to:

- Reduce bleeding
- Reduce segregation
- Reduce heat of hydration
- Reduce water permeability
- Improve workability, flow properties and pumpability

- Increase long term strength
- Improve surface finish
- Increase resistance to chemical and physical attack, including sulphates, chloride ingress and alkali-silica reaction or concrete cancer.

Lee at al. (1999) stated that, TIA is derived from controlled incineration of rubber wood bark. It has 60% silica content which are in micronized form and can easily dissolve in OPC hydration process and forming calcium silicate hydrate (CSH). There are two types of micronized silica that is A90 and A60 and has been used as a cement replacement. There is traverse from crushing process and A90 has a 90% $Si0_2$ content and A60 has a 60% $Si0_2$. When micronized silica is react with cement and water it can forming the more stable compound and it is show in Figure 2.2 but if cement and water not react with micronized silica it can forming the unstable compound (Figure 2.3).

Figure 2.2: Hydration of cement with presence of TIA A90 and A60

$$\text{OPC} + H_2O + SiO_2 \xrightarrow[\text{Hydration}]{} \text{CSH} + [Ca(OH)_2 + SiO_2]$$

OPC: Ordinary Portland Cement, which Content C_3S and

H_2O: Water

SiO_2: Silicon Dioxide (from A90 and A60)

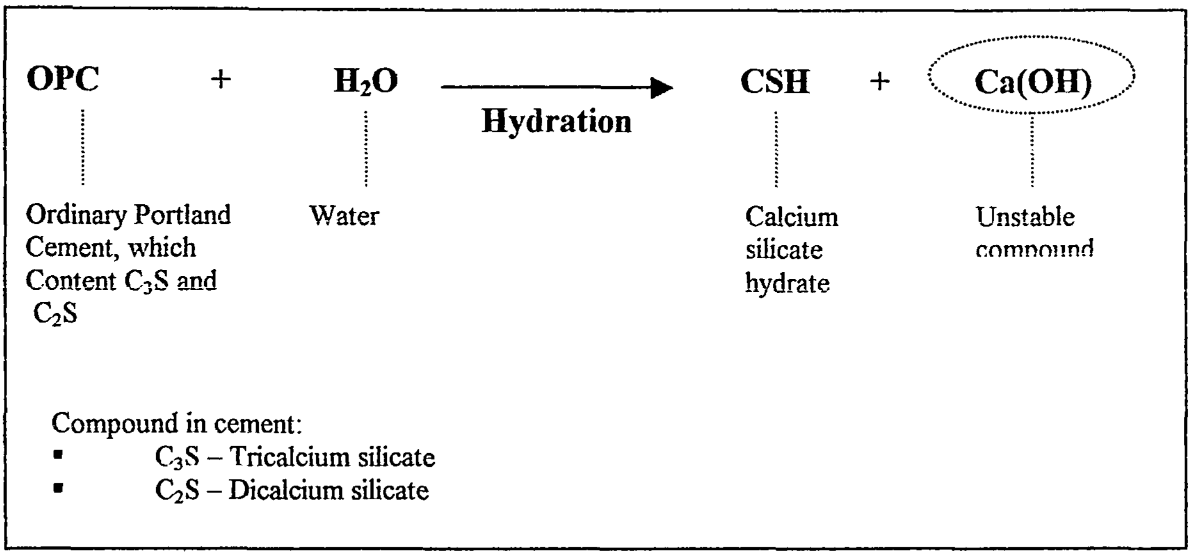
CSH: Calcium silicate hydrate

$[Ca(OH)_2 + SiO_2]$: Forming more stable compound

Compound in cement:

- C_3S – Tricalcium silicate
- C_2S – Dicalcium silicate

Figure 2.3 : Hydration of cement without presence of TIA A90 and A60



In additional to determine and ecological benefits, the use of pozzolana micronize silica in concrete improves its workability, reduces segregation, bleeding, heat evolution and permeability, inhibits alkali-aggregation reaction, and enhances sulphate resistances (Orchard, 1979).

Lee at al (1997) stated that the TIA complied with the requirement of Class F fly ash according to ASTM C 618-819. The relevant oxides and physical properties are shown in Table 2.4

Table 2.4: Chemical composition and physical properties of OPC and TIA

Chemical Composition, (%)	Material	
	OPC	TIA
Aluminium Oxide	7.16	2.80
Calcium Oxide	60.00	0.10
Iron Oxide	3.98	1.53
Magnesium Oxide	2.01	2.00
Potassium Oxide	0.55	0.53
Silica Dioxide	18.58	67.70
Sodium Oxide	0.33	0.60
Sulphur Trioxide	1.90	1.59
Titanium Dioxide	<0.001	<0.001
b) Physical Properties		
Loss of Ignition	3.55	0.45
Specific gravity	3.15	2.39
Finenesse (m^3/kg)	3.15	2.39

Source : Lee at. al, (1997). " Timber Industrial Ash Blended Cement Bricks and Lightweight Concrete, Institute Technology Tun Hussein Onn ,

2.10 Durability and Permeability

According to ACI Committee 201 on durability of concrete, the durability of Portland cement concrete is defined as its ability to resist weathering action, chemical attack, abrasion or any other form of deterioration. A durable concrete should maintain its original form, quality and its serviceability when exposed to surrounding environment for a long service life. The designed life of a concrete structure may vary

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