PERFORMANCE OF FOAMED CONCRETE USING LATERITE AS SAND REPLACEMENT

LEE KUN GUAN

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Faculty of Civil Engineering and Earth Resources
Universiti Malaysia Pahang

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ABSTRACT

Recent development in the field of concrete have led to a renewed interest in engineering properties of the concrete. Various aspects need to be considered in producing a high quality concrete. Lightweight Foam Concrete (LWC) is better characteristic than ordinary concrete and gives a lot of benefit to our life in long time period. LWC is getting popular in the construction field due to its lightness, versatility and its cost reduction potentials. The unique of LWC is does not use aggregate. But, recently the demand on used of natural sand in construction industry are increase. To overcome this problem, an alternative materials namely laterite was introduced as sand replacement to produce LWC - Laterite. In this study, LWC with density of 1600 kg/m^3 composed of cement to sand to water with ratio 2:1:1 were conducted. Each series of mix design were replaced with different percentage of laterite namely 5%,10% and 15% by the total weight of sand respectively. The aim of this study is to verify the effect of using percentage of laterite and curing ages subjected to the compressive strength test and modulus of elasticity (MOE) test. The results revealed that the strength improved when increases of percentage of laterite. It is also indicated that the curing ages influenced the compressive strength and modulus of elasticity. The 5% of laterite was performed as optimum mix design to produced LWC with laterite.

ABSTRAK

Pembangunan dalam industri konkrit kini telah membawa kita dalam mengkaji dengan lebih lanjut berkaitan sifat-sifat kejuruteraan sesuatu konkrit. Pelbagai aspek perlu diambil kira bagi menghasilkan konkrit yang berkualiti tinggi. Penggunaan konkrit buih berongga kini semakin penting berbanding konkrit biasa. Konkrit buih berongga memberikan banyak kebaikan dan kepentingan dalam kehidupan manusia pada zaman kini. Pengunaan konkrit buih berongga juga semakin popular kerana isipadunya yang ringan dan mampu mengurangkan kos pembinaan. Keunikan konkrit buih berangga adalah tidak menggunakan batu baur kasar. Tetapi, permintaan pasir dalam industri pembinaan semakin meningkat pada masa kini. Untuk mengatasi masalah ini, satu bahan alaternatif yang dinamakan tanah laterit diperkenalkan untuk mengurangkan penggunaan pasir secara keseluruhan. Dalam kajian ini, satu jenis ketumpatan campuran 1600kg/m^3 yang terdiri daripada nisbah simen kepada pasir kepada air iaitu 2:1:1 disediakan. Setiap campuran rekaan akan digantikan dengan peratusan tanah laterit yang berbeza berjumlah 5% ,10% dan 15% daripada jumlah berat pasir halus yang digunakan. Matlamat kajian ini ialah untuk mengkaji penggunaan peratusan tanah laterit berbeza dan pengawetan udara yang akan memberi kesan kepada kekuatan mampatan dan modulus elastik konkrit buih berongga. Keputusan menunjukkan bahawa kekuatan konkrit buih berongga meningkat dengan penambahan peratusan tanah laterit dalam konkrit buih berongga. Ini juga menunjukkan bahawa pengawetan udara akan mempengaruhi kekuatan mampatan dan modulus elastik. Didapati mrncampurankan 5% tanah laterit adalah campuran optimum untuk menghasilkan campuran konkrit buih berongga dengan tanah laterit.

TABLE OF CONTENTS

CHAPTER	TITLES	PAGE
	TITLE	**i**
	DECLARATION	**ii**
	DEDICATION	**iii**
	ACKNOWLEDGEMENT	**iv**
	ABSTRACT	**v**
	ABSTRAK	**vi**
	TABLE OF CONTENTS	**vii**
	LIST OF TABLES	**xi**
	LIST OF FUGURES	**xiii**
	LIST OF ABBREVIATION	**xv**
CHAPTER 1	**INTRODUCTION**	
	1.1 Background of Study	1
	1.2 Problem Statements	3
	1.3 Objectives of Study	4
	1.4 Scope of Work	4
CHAPTER 2	**LITERATURE REVIEW**	
	2.1 Introduction	6
	2.2 Constituent Materials	7

2.2.1. Constituents of Base Mix 7
2.2.2. Foam 8
2.3 Application of Foam Concrete 9
2.4 Advantages and Disadvantage of Foam Concrete 10
2.5 Properties of Foam Concrete 11
2.5.1 Stability 12
2.5.2 Air-Void Systems 12
2.5.3 Drying Shrinkage 14
2.5.4 Density 14
2.5.5 Compressive Strength 15
2.5.6 Modulus of Elasticity 17
2.5.7 Thermal Insulation, Fire Resistance and Acoustics of Foam Concrete 18
2.6 Laterite Soil Particles 19
2.6.1 Material and Method 21
2.6.2 Laterite Soil Particles Characteristic 22
2.6.3 Typical Shapes of Laterite 23
2.6.4 Specific Gravity and the Density of Laterite 24

CHAPTER 3 METHODOLOGY

3.1 Introduction 25
3.2 Experiment Work 26
3.3 Raw Material 27
3.3.1 Sand 27
3.3.2 Water 28
3.3.3 Foaming Agent 28
3.3.4 Laterite 29
3.3.5 Cement 30
3.4 Preparation of Material 30
3.4.1 Curing 31
3.4.2 Determinate of Density Lightweight Foam Concrete 32

3.4.3 Determination Weight Raw Material Used 33
3.4.4 Sieve Analysis 33
3.4.5 Batching and Mixing 34
3.4.6 Mould of Specimen 35
3.5 Properties of Laterite 37
3.5.1 Atterberg Limits Test 37
3.5.2 Plastic Limits Test 37
3.5.3 Liquid Limits Test 38
3.5.4 Relationship Plasticity Index Versus Liquid Limit 39
3.6 Mechanical Properties Testing Method 40
3.6.1 Compressive Strength Test 40
3.6.2 Modulus of Elasticity Test 42

CHAPTER 4 RESULTS AND DISCUSSIONS

4.1 Introduction 43
4.2 Particle Size Analysis 44
4.3 Plastic Limit 45
4.4 Liquid Limit 46
4.5 Effect of Compressive Strength of LWC-Laterite due to Different Curing Ages 48
4.5.1 Compressive Strength of Foamed Concrete due to Different Curing Ages of Laterite As Sand Replacement 48
4.5.2 Discussion on Effect of Different Curing Ages due to Compressive Strength with Various Percentage of Laterite 52
4.5.3 Compressive Strength of Foamed Concrete due to Different Percentage of Laterite for 7, 28 and 60 days 55

4.5.4 Discussion on Effect of Different Percentages due to Compressive Strength with Various Percentage of Laterite 59
4.6 Discussion on Modulus of Elastic of Foamed Concrete with Laterite due to Different Curing Ages 62
4.7 Discussion on Modulus of Elastic of Foamed Concrete due to Different Percentage of Laterite for 7, 28 and 60 days 63

CHAPTER 5 CONCLUSIONS AND RECOMMENDATIONS

5.1 Introduction 66
5.2 Conclusions 67
5.2 Recommendations 68

REFERENCE 69

LIST OF TABLES

TABLE NO.	TITLES	PAGE
1.1	Number of Sample of Foamed Concrete due to Air Curing Condition	5
2.1	The Typical Properties of Foamed Concrete	7
2.2	Application of Foam Concrete	10
2.3	Advantages and Disadvantage of Foam Concrete	11
2.4	The Relationships Proposed in Literature Between Dry and Fresh Density	15
2.5	Relations for Modulus of Elasticity (E) of Foam Concrete.	17
2.6	Fire Resistance Comparison Test Between Foamed Concrete & Vermiculite	19
2.7	Summary of Physical Properties of Constituent Materials	22
3.1	Quantity of Mould in Testing	31
3.2	Weight of Raw Materials for LWC in $1m^3$	33
4.1	Sieve Analysis Data % of Laterite Passing Limits for BS 882: 1992	44
4.2	Result of Plastic Limit Test for Sample Laterite	46
4.3	Result of Liquid Limit Test of Laterite	47
4.4	Compressive Strength for 0% of Laterite as Sand	

	Replacement	49
4.5	Compressive Strength for 5% of Laterite as Sand Replacement	50
4.6	Compressive Strength for 10% of Laterite as Sand Replacement	51
4.7	Compressive Strength for 15% of Laterite as Sand Replacement	52
4.8	Compressive Strength using Different Curing Age of Laterite	54
4.9	Compressive Strength of Foamed Concrete for different percentages of Laterite for 7 days	56
4.10	Compressive Strength of Foamed Concrete for different percentages of laterite for 28 days	57
4.11	Compressive Strength of Foamed Concrete for different percentages of laterite for 60 days	58
4.12	Summary Result of Compressive Strength of Foamed Concrete Replaced With Various Percentage of Laterite	61
4.13	Discussion on Modulus of Elastic of Foamed Concrete with Laterite due to Different Curing Ages.	62
4.14	Discussion on Modulus of Elastic of Foamed Concrete with Laterite due to Different Percentage.	65

LIST OF FIGURES

FIGURE NO.	TITLES	PAGE
1.1	Dimension of Standard Specimen	5
2.1	Generalized World Map showing the Distribution of Laterite Soils	21
2.2	Typical Shape of Laterite	23
3.1	Flow Chart of Laboratory Work	26
3.2	Sand	27
3.3	A Bucket of Water	28
3.4	Foaming Agent	29
3.5	Laterite	29
3.6	Ordinary Portland Cement (OPC)	30
3.7	Air Curing	32
3.8	Weight of 1 Liter of LWC	32
3.9	Sieve Analysis	34
3.10	Foam Concrete Mixing	35
3.11	Cute Mould	36
3.12	Cylinder Mould	36
3.13	Semi Automated Cone Penetrometer	39

3.14	The Plastic Index Chart	40
3.15	Compressive Strength Machine	41
3.16	Universal Testing Machine	42
4.1	Gtaph on Grain Size Distribution Curve for Laterite Sample	45
4.2	Penetration Cone versus Moisture Content of Laterite	47
4.3	Compressive Strength of using 0% of Laterite as Sand Replacement	49
4.4	Compressive Strength of using 5% of Laterite as Sand Replacement	50
4.5	Compressive Strength of using 10% of Laterite as Sand Replacement	51
4.6	Compressive Strength of using 15% of Laterite as Sand Replacement	52
4.7	Disscussion on Compressive Strength using Different Percentage of Laterite as Sand Replacement	55
4.8	Compressive Strength Using Different Percentage of Laterite for 7 Days	56
4.9	Compressive Strength Using Different Percentage of Laterite for 28 Days	57
4.10	Compressive Strength Using Different Percentage of Laterite for 60 Days	58
4.11	Discussion on Compressive Strength using Different Percentage of Laterite	61
4.12	Discussion on Modulus of Elastic of Foamed Concrete with laterite due to Different Curing Ages.	63
4.13	Discussion on Modulus of Elastic of Foamed Concrete with laterite due to Different Percentage	65

LIST OF ABBREVIATION

BS	-	British Standard
MOE	-	Modulus of Elasticity
FKASA		Falkuti Kejuruteraan Awam dan Sumber Asli
LWC		Lightweight Foam Concrete
f_c	-	Compressive strength
OPC	-	Ordinary Portland Cement
cm	-	Centimeter
in	-	Inch
kg	-	Kilogram
kg/m^3	-	Kilogram per meter cube
m	-	Meter
m^3	-	Meter cube
mm	-	Millimeter
N/mm^2	-	Newton per millimeter square
N/mm^3	-	Newton per millimeter cube
kN/mm^2	-	Kilo Newton per millimeter square

MPa	-	Mega Pascal
W/mk	-	Watt per meter per Kelvin
%	-	Percent
E		Modulus of elastic
w_L		Plastic Limit
PL		Plastic Limit
LL		Liquid Limit
PI		Plastic Index

CHAPTER 1

INTRODUCTION

1.1 Background of Study

Concrete most widely used man made construction material in the world, and is second only to water as the most utilized substance on the planet. It is obtained by mixing cementitious materials, water and aggregate and sometimes admixtures in required proportions. The mixture when placed in forms and allowed to cure, hardens into a rock like mass known as concrete. The hardening is caused by chemical reaction between water and cement and it continues for a long time and consequently the concrete grows stronger with age. The strength, durability and other characteristics of concrete depend upon the properties of its ingredients, on the proportions of mix, the method of compaction and other controls during placing, compaction and curing (Gambhir, 2004).

Since concrete is most wide use in construction but it also have failure in certain case. The disadvantage of concrete is liable to disintegrate by alkali and sulphate attack.

Beside that concrete is not entirely impervious to moisture and contains soluble salts which may cause efflorescence. Fresh concrete shrinks on drying and hardened concrete expands on wetting. Provision for contraction joints has to be made to avoid the development of crack due to drying shrinkage and moisture movement. Concrete also expand and contracts with the changes in temperature. Hence expansion joint have to be provided to avoid the formation of crack due to thermal movement (Gambhir, 2004).

Foam concrete offer many benefits such as reducing the dead weight of a structure which economises the design of supporting structures including the foundation and walls of lower floor. With appropriate design, a range of foam concrete with densities ranging from from 300 kg/m^3 to 1600 kg/m^3 can be produced as stated by.(Beningfield et al., 2005). Strength of foam concrete is mainly dependent on the amount of sand while density is dependent on the amount of foam introduced. Other parameter affecting the strength of foam concrete are sand-cement ratios, water –cement ratios curing regimes, types of sand and particle size distributions of sand. On the contrary, a cheaper mix foamed concrete would only be possible through maximizing the sand content. For a lower density foamed concrete, the amount of sand that could be incorporated is also limited due to the problem related to mix segregation and stability. Therefore, sand content in foamed concrete required comprehensive optimization to ensure production of a sufficiently strong mix for the intended purposes without sacrificing both the economics of the production and the practicality in the mixing and placing of such concrete (Ravindra et al., 2005).

Sand is a well-known building material and has occupied a very important place in construction work but Sand is more expensive than laterite because it is more difficult to collect sand from rivers than to dig laterite from pits. The locations of the collecting sites of sand are usually far from many construction sites whereas laterite may be easily dug from the foundation of a building or near the site thereby reducing the cost of transportation and the price of laterite. The periodic fluctuation of price of sand is caused by floods whereas the price of laterite is stable and therefore more reliable for cost estimation (Adepegba, 1975).

The laterite and sand samples are well graded comformed to the British Standard Specification (BS 812, 1985). Laterite is more suitable material to replace sand to design foam concrete In this present study, four different various percentage of laterite with one mix proportion were tested. The basic approach of this study is to determine the compressive strength and modulus of elastic of foam concrete by the replacement of sand with laterite. On the other hand, the test also to estimate the mechanical properties of foamed concrete.

1.2 Problem Statements

Nowadays world has been a lot of revolution in the using of LWC for the construction industry. Many research done to find any materials that can be used to replace the raw material in foam concrete. Basically, the main ingredients of foam concrete are cement, foam agent, fine aggregate (sand) and water.

Sand was key ingredient in foam concrete provision because it demand in rising construction field, in the course of time it will decline and might be due one time later it will completely been used. Beside that, activity sand mining could also cause ecological system in disturbed river. As such to overcome this a study reduce sand use in foam concrete should be conducted. Through this problem, one solution suggested is the use of soil namely laterite as replacement with a portion by total weight of sand. Study the optimum percentage composition of laterite can replace sand would be made for overcome this problem.

1.3 Objectives of Study

This research main purpose conducted would be to set optimum percentage composition of laterite as sand does not affect the foam concrete strength.

i To determine the compressive strength and modulus of elasticity of foam concrete replace with different percentage and age of laterite as sand replacement.

ii To determine the effectiveness of laterite and it's potential as partial replacement mixes in foam concrete.

1.4 Scope of Work

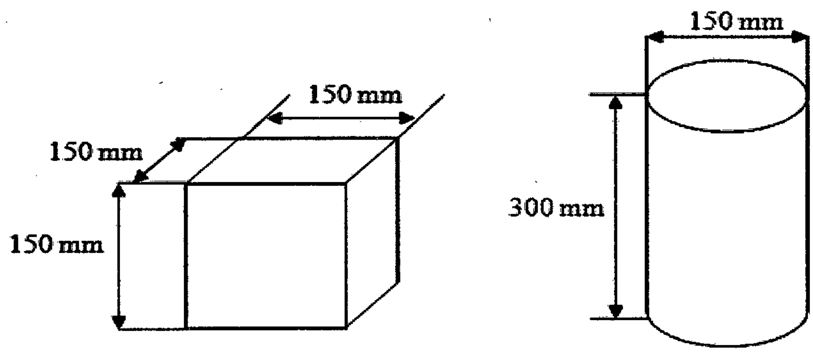
In this study is determining the effect of laterite compression strength and modulus of elasticity was needed to determine whether there are improvements of the result. Four types of samples were compared, which first sample is 0% is control sample, second is 5% laterite, third is 10% laterite and last is 15% laterite. The samples dimension for compression strength test are 150 mm x 150 mm x 150 mm (length x width x height) while samples dimension for modulus of elasticity are 150 mm x 300 mm (diameter x height). Figure 1 shows the standard dimensions of the samples. The design of density for lightweight concrete must be obtained is 1600 kg/m^3.

The water-cement ratio for the specimens were cast using mix ratio of 2:1:1 (cement: sand: water) with water-cement ratio of 0.5. Total of 48 cubes and 48 cylinders were casted which 12 cubes and 12 cylinders for each type of the sample were tested for its compression strength and modulus of elasticity on 7, 28 and 60 days after the foamed concrete has been cast. The 12 cubes and 12 cylinders were consisting of air curing. The number of sample prepared as shown in Table 1.1.

All the cubes and cylinders were tested at Faculty of Civil Engineering and Earth Resources of Universiti Malaysia Pahang laboratory using Compression Testing Machine and Universal Testing Machine. The example of standard code of practice for compression strength test and the dimension of the cube are referred to BS 1881: Part 115:1986 and BS 1881: Part 116:1983 while modulus of elasticity test and the dimension of the cylinder are referred to BS 1881: Part 121:1983.

Table 1.1: Number of Sample for Foamed Concrete due to Air Curing Condition

Label of Samples	Mix Proportion	Number of sample (cubes)/(cylinders)/days		
	Percentage of Laterite	7	28	60
A1600	Control Sample	4	4	4
B1600	5%	4	4	4
C1600	10%	4	4	4
D1600	15%	4	4	4



i. Cube Specimen

ii. Cylinder Specimen

Figure 1.1: Dimension of Standard Specimen

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Foam concrete is defined as cement paste which air-voids are trapped in mortar by foaming agent. The first construction application of foam concrete to structural was first presented by Valore in 1954, and treated by Rudnai, Short and Kinniburgh in 1963 (Valore, 1954). The components in foam concrete mix should be as follows, foaming agent, binding agent, water, aggregate and admixtures. Lightweight foamed concrete is very light but its strength is reducing due to the density which is reduced.stated that foamed concrete is classified as having an air content of more than 25% (Ban et al., 2003). Foam concrete need minimum of aggregate quantity, hence it is lightweight and high flow ability. To mix a stable foam concrete, it depends on many factors such as, method of foam preparation, selection of foaming agent, addition for uniform air-voids distribution, material grade and mixture design ratio (Ramamurthy et al., 2009).

2.2 Constituent Materials

Lightweight concrete is a cement based slurry in which a stable, homogeneous foam is mechanically blended, either by mixing or injecting. Its physical characteristics are determined by various mix design of cement, fly ash, aggregate, fillers, and volume of entrained foam (Aldridge, 2005). Typical foamed concrete properties are summarized at Table 2.1.

Table 2.1: The Typical Properties of Foamed Concrete.
(Source: Aldridge, 2005)

Dry Density, (kg/m^3)	Compressive Strength, N/mm^2	Thermal Conductivity, W/mk	Modulus of Elasticity, kN/mm^2	Drying Shrinkage, %
400	0.5 – 1.0	0.1	0.8 – 1.0	0.3 – 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 – 5.5	0.38 – 0.40	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

2.2.1 Constituents of Base Mix

In addition to Ordinary Portland cement, rapid hardening Portland cement (Kearsley et al., 2001), high alumina and Calcium Sulfoaluminate (Turner, 2001) have been used for reducing the setting time and to improve the early strength of foam concrete. Fly ash (Jones et al., 2005) and ground granulated blast furnace slag have been used in the range of 30–70% and 10–50%, respectively (Wee et al., 2006) as cement replacement to reduce the cost, enhance consistence of mix and to reduce heat of hydration while contributing towards long term strength. Silica fume up to 10% by mass of cement has been added to intensify the strength of cement (Kearsley, 1996, Byun, 1998). Alternate fine aggregates, viz, fly ash, lime, chalk and crushed concrete (Aldridge, 2001) incinerator bottom ash, recycled glass, foundry sand and quarry finer (Jones, 2005) expanded polystyrene and Lytag fines (Lee et al., 2005) were used either to reduce the density of foam concrete and or to use waste recycled materials. Concrete with densities between 800 and 1200 kg/m^3 have been produced using lightweight coarse aggregate in foamed cement matrix (Regan et al., 1990). The water requirement for a mix depends upon the composition and use of admixtures and is governed by the consistency and stability of the mix (Karl, 1993). At lower water content, the mix is too stiff causing bubbles to break while a high water content make the mix too thin to hold the bubbles leading to separation of bubbles from the mix and thus segregation (Nambiar et al., 2006). Water–cement ratio used ranges from 0.4 to 1.25 (Kearsley et al., 1996). Though super plasticisers are also sometimes used (Jones, 2001) its use in foamed concrete can be a possible reason for instability in the foam (Jones, 2006) and hence compatibility of admixtures with foam concrete is of importance. Chopped polypropylene fibers of 12 mm length in the dosage range of 1–3 kg/m^3 has been reported to enhance the shear behavior of foam concrete equivalent to that of normal concrete. Optimum combinations of strength, ductility, density, workability and also cost can be obtained by selecting a suitable fiber type, air content and w/c ratio of base mortar (Yamamoto et al., 1999).

2.2.2 Foam

Foam concrete is produced either by pre-foaming method or mixed foaming method. Pre-foaming method comprises of producing base mix and stable preformed aqueous foam separately and then thoroughly blending foam into the base mix. In mixed foaming, the surface active agent is mixed along with base mix ingredients and during the process of mixing, foam is produced resulting in cellular structure in concrete (Byun et al., 1998). The foam must be firm and stable so that it resists the pressure of the mortar until the cement takes its initial set and a strong skeleton of concrete is built up around the void filled with air (Koudriashoff, 1949). The preformed foam can be either wet or dry foam. The wet foam is produced by spraying a solution of foaming agent over a fine mesh, has 2–5 mm bubble size and is relatively less stable. Dry foam is produced by forcing the foaming agent solution through a series of high density restrictions and forcing compressed air simultaneously into mixing chamber. Dry foam is extremely stable and has size smaller than 1 mm, which makes it easier for blending with the base material for producing a pump able foam concrete (Aldridge, 2005).

2.3 Application of Foam Concrete

Lightweight foam concrete (LWC) has several and always increasing applications in all types of construction work. Generally the application, of LWC are depend on the its density. The application of LWC commonly for constructions, houses, highway constructions, blinding, void filling, footing, tunnel lining, trench reinstatement, roof insulation and others.

The first major application of Lightweight Construction Method (LCM) foamed concrete in Malaysia is at the SMART tunnel project in Kuala Lumpur. The foamed concrete specified was of density 1800 kg/m^3 which achieved compressive strength of 3 N/mm^3 at the age of 28 days. Foamed concrete block of size 17 m x 17 m x 6 m was cast in three stages in order to allow a maximum height of 2 m per cast. The completed foamed concrete block serves to protect the diaphragm wall when the tunneling machine is coming out into the junction box (Lee et al., 2005). Summary of the most common applications are shown in Table 2.2.

Table 2.2: Application of Foamed Concrete
(Source: Neville, 1985)

Density (kg/m³)	Application
300 - 600 kg/m³	Lightweight and insulating cements for floors foundation, for heat insulation and slope for flat roofs, rigid floors foundation, tennis courts foundation, interspace concrete filling, raceways insulation; thermo insulating blocks, steel structures fireproofing, tunnels and pipelines compensating mass, dumps' foundation and coverings land reclamation and consolidation underground cavities infill and all types of infill where an elevated thermal insulation is required.
600 - 900 kg/m³	Stables and pig-sties foundations; industrial foundations, partition and tampooning slabs, ceiling slabs, concrete + Lightweights Concrete mixed panels.
900 - 1200 kg/m³	Blocks for outside walls, slabs for partitions, concrete and light weight concrete mixed panels for covering, foundations for elastic floors.
1200 – 1700 kg/m³	Prefabricated panels for civil and industrial buildings plugging; walls casting, gardens ornaments.

2.4 Advantages and Disadvantage of Foam Concrete

Lightweight foam concrete (LWC) have main advantage is it consists of lighter weight compare to others concrete. It reduces the dead load of the structures which indirectly reduce the cost of the project and make the design of foundation or supporting structures more economic. Table 2.3 shows the summary of advantages and disadvantages of using lightweight foam concrete as a structure.

Table 2.3: Advantages and Disadvantage of Foam Concrete
(Source: Neville, 1985)

<table>
<tr><th>Advantages</th><th>Disadvantages</th></tr>
<tr><td>Rapid and relatively simple construction</td><td>Very sensitive with water content in the mixtures</td></tr>
<tr><td>Economical in terms of transportation as well as reduction in manpower</td><td rowspan="2">Difficult to place and finish because of the porosity and angularity of the aggregate. In some mixes the cement mortar may separate the aggregate and float towards the surface</td></tr>
<tr><td>Significant reduction of overall weight results in saving structural frames, footing or piles</td></tr>
<tr><td>Most of lightweight concrete have better nailing and sawing properties than heavier and stronger conventional concrete</td><td>Mixing time is longer than conventional concrete to assure proper mixing</td></tr>
</table>

2.5 Properties of Foam Concrete

Chemical, mechanical and physical properties are some of most important parameter for the performance of foamed concrete measured. Foamed concrete is a versatile material with attractive properties and characteristics and as a result, it widely used in construction applications (Jones et.al., 2005).