“EXPERIMENTAL STUDY TO FIND STRENGTH PROPERTIES OF LIGHTWEIGHT FOAM CONCRETE”

A PROJECT

Submitted in partial fulfilment of the requirements for the award of the degree of

BACHELOR OF TECHNOLOGY

IN

CIVIL ENGINEERING

Under the supervision of

Mr. Abhilash Shukla

Assistant Professor

By

Kunal Bhardwaj

(131614)

Shalav Sharma

(131664)

JAYPEE UNIVERSITY OF INFORMATION TECHNOLOGY

WAKNAGHAT, SOLAN – 173234

HIMACHAL PRADESH, INDIA

May, 2017

CERTIFICATE

This is to certify that the work which is being presented in the project report titled "**EXPERIMENTAL STUDY TO FIND STRENGTH PROPERTIES OF LIGHTWEIGHT FOAM CONCRETE"** in partial fulfillment of the requirements for the award of the degree of Bachelor of Technology in Civil Engineering and submitted to the Department of Civil Engineering Jaypee University of Information Technology, Waknaghat is an authentic record of work carried out by Kunal Bhardwaj (131614) and Shalav Sharma (131664) during a period from July 2016 to May 2017 under the supervision of **Mr. Abhilash Shukla**, Assistant Professor, Department of Civil Engineering, Jaypee University of Information Technology, Waknaghat

The above statement made is correct to the best of our knowledge.

Date :- ……………

Dr. Ashok Kumar Gupta	Mr. Abhilash Shukla	External Examiner
Professor & Head of Department	Assistant Professor	
Civil Engineering Department	Civil Engineering Department	
JUIT Waknaghat	JUIT Waknaghat	

ACKNOWLEDGEMENT

The success of every project whether big or small is largely due to effort of number of people who have always given their valuable advice and lend a helping hand. I sincerely appreciate the inspiration, support and guidance of those who helped me to choose and carry out this project.

At the very outset, I would like to express my deep gratitude to my Project Guide **Mr. Abhilash Shukla,** laboratory staff and library staff for their co-operation and for giving me the opportunity to work on this ambitious project.

I would also like to thank **Dr. Ashok Kumar Gupta** and all the faculty members of Civil Engineering Department (JUIT) who helped me in giving shape to my ideas, help me understand the various aspects of the project.

Kunal Bhardwaj [131614]   Shalav Sharma [131664]

CIVIL ENGINEERING DEPARTMENT (JUIT)

CONTENTS

	Abstract		**i**
	List of Tables		**ii**
	List of Figures		**iii**
Chapter 1	**Introduction**		**1**
	1.1	Introduction	1
	1.2	Advantages and Applications of Lightweight Concrete	2
	1.3	Objective of Study	3
	1.4	Layout of Report	4
Chapter 2	**Literature Review**		**5**
	2.1	Historical Development	5
	2.2	Research Papers	6
Chapter 3	**Experimental Work**		**9**
	3.1	Preparation of Materials	9
	3.2	Testing of Materials for Mix Design	10
	3.3	Mix Design	12
	3.4	Mixing	17
	3.5	Casting and Demolding	18
	3.6	Curing	18
	3.7	Testing of Samples	18
Chapter 4	**Results & Discussion**		**20**
	4.1	Specific Gravity Tests	20
	4.2	Foam Density	21
	4.3	Compressive Strength Tests	22
Chapter 5	**Conclusion**		**28**
	References		**29**

ABSTRACT

Concrete is the most versatile and essential construction material in the world. Variations in composition and addition of additives is done to engineer the properties of conventional concrete for specific environments and purposes. Lightweight Foam concrete is a concrete in which foam is mixed in cement slurry to make it lighter with cellular voids.

The strength of foam concrete is relatively lower than conventional concrete. High water content, required to enable mixing of foam with slurry. Compaction can also not be done on this concrete. Due to these reasons the concrete made is of low density and strength.

The focus of this project is to study strength properties of foam concrete with different mix proportions and different densities.

Following materials have been used to prepare specimen:

- Portland Pozzolana Cement (PPC)
- Sand
- Foaming Agent

To study the strength properties specimen have been prepared with variations in density and water cement ratio. These specimen have been tested to check the effect of change in these parameters on the compressive strength of specimen.

List of Tables

Table 3.1: Mix proportions for different design density 15

Table 3.2: Mix proportions for different design density and w/c ratio 16

Table 3.3: Mix proportions for different design density and w/c ratio 17

Table 4.1: 7-Day Compressive strength 22

Table 4.2: 14-Day Compressive strength 22

Table 4.3: 28-Day Compressive strength 23

Table 4.4: 7-Day Compressive strength 25

Table 4.5: 14-Day Compressive strength 25

Table 4.6: 28-Day Compressive strength 26

List of Figures

Figure 4.1: 7 day compressive strength of specimen 23

Figure 4.2: 14 day compressive strength of specimen 24

Figure 4.3: 28 day compressive strength of specimen 24

Figure 4.4: Comparison of Compressive Strength of samples with constant density of 1000 kg/m^3 but different water cement ratio. 26

Figure 4.5: Comparison of Compressive Strength of samples with constant density of 800 kg/m^3 but different water cement ratio. 27

Figure A.1: Compressive Test being performed on specimen 31

Figure A.2: Casting of Specimen 32

Figure A.3: Specimen after 24 hours for demolding 32

CHAPTER 1

INTRODUCTION

1.1 Introduction

Concrete is the most popular material in construction industry all over the world. It is a mixture of a binding agent, usually cement, coarse and fine aggregates, and water. The mixture produces a brittle material on hardening which may be designed for specific purposes by modifying the proportions or by adding of additives or admixtures. Different types of cements are also industrially produced to cater to specific needs in different types of environments.

While conventional concrete has good compressive strength, it is heavy and significantly increases the dead load of the building. The density of this concrete was then reduced to create a lighter concrete with better insulating properties. This was done by either using lightweight aggregates or by entraining air to create cellular voids. The latter produces a concrete known as foamed concrete.

Conventional concrete which is made with natural aggregate originating from hard rock has a high density lying within the range of 2200 to 2260 kg/m^3 and represents a large proportion of the dead load on a structure. According to BS: 8110: Part 2: *1985* classifies lightweight concrete as one with a density of 2000 kg/m^3 or less.

Lightweight foamed concrete is a class of aerated concrete. Aerated concrete can be classified according to the methods and agents used to introduce air in the concrete. Aerated concrete can be produced by introducing air entraining agents, gas forming chemicals or directly mixing preformed foam. Concrete which is aerated using foam is known as lightweight foamed concrete. Foaming agents used to create foam can be synthetic based or protein based.

Lightweight foamed concrete was first used as precast bricks in the early 19^{th} century prepared by curing aerated concrete bricks at high temperatures (300° C) in an autoclave (AAC) in both Denmark and Sweden.

Foamed concrete is a material which has many practical aspects owing to it's a low weight, good acoustical properties and low thermal conductibility. Due to these properties, foamed concrete is widely used for building insulating walls, bricks and as a filling material. The applications of foamed concrete as building material for load bearing structures is limited due to its low compressive strength

Lightweight foamed concrete can be prepared with density from 400 kg/rn^3 to 1800 kg/m^3 on the basis of which classification is done. Properties of foamed concrete depend mainly on its mix design. But a number of general properties such as good freeze/thaw resistance, good acoustical properties, low shrinkage and thermal insulation are common to all mixes.

1.2 Advantages and Applications of Lightweight Concrete

There are many properties and advantages offered by lightweight foam concrete over conventional concrete. Due to its low compressive strength, the use of foamed concrete is prevalent for making of non-load bearing structures. But due to its lower density, using lightweight concrete leads to reduced dead load and hence smaller size of load bearing members, smaller footing and hence reduced cost of construction.

Another advantage offered by foam concrete is its high thermal insulation due to its highly porous structure. High thermal insulation ensures that the interior of the building is insulated against outside temperature. This is widely incorporated in construction of green buildings by indirectly saving the energy used for air-conditioners and heaters.

More advantages offered by lightweight foam concrete over conventional concrete include its good acoustical properties and high degree of workability offered. High workability makes this concrete an optimum choice as filler material fro insulation.

Application scope of lightweight foamed concrete in civil engineering works is very broad. It can be used in almost every part of the building; from the superstructure right down to the substructure, including wall panels and roofing. Any conventional panels or masonry units used for structural load and non-load bearing walls using conventional concrete can be replaced by foamed concrete panels and units. Lightweight foamed concrete can be used for thermal and sound insulation panels, filtering media and floating blocks for fishery purposes.

Lightweight foamed concrete can also be used to cast elements for architectural purposes, pottery, void filling, trench reinstatement, foundation raising and construction of swimming pool. In highway construction, lightweight foamed concrete can also be applied as soil filling for sub-base, bridge abutments and bridge embankment.

1.3 Objective of Study

The objective of study is:

a. To produce lightweight foamed concrete with different densities.
b. To obtain optimum w/c ratios for various types of lightweight concrete.
c. To determine the compressive strength of lightweight concrete.

1.4 Layout of Report

This report consists of 5 chapters.

Chapter 1 :This chapter gives a brief introduction of the project and current status of lightweight foam concrete. It also entails objectives of the research, significance of research and the layout of report.

Chapter 2 : This chapter entails the summary of all the essential research papers and articles studied to get a detailed information on the subject.

Chapter 3: This chapter discusses all methodologies used in this study. The material preparation, method to get the mix proportion and mixing procedure are discussed in this chapter. Besides, the testing methods used in testing the specimens are also discussed in this chapter

Chapter 4: This chapter entails the results of all tests performed on samples as well as a discussion and analysis of the information provided.

Chapter 5: The conclusion gives the results of the analysis and a discussion to justify the inferences derived.

CHAPTER 2

LITERATURE REVIEW

2.1. Historical Development of Lightweight Foam Concrete

Romans in the second century where 'The Pantheon' has been built utilizing pumice, the most well-known kind of total utilized as a part of that specific year (Samidi, 1997). From that point forward, the utilization of lightweight frothed concrete has been generally spread crosswise over different nations, for example, USA, United Kingdom, Sweden and India. In UK, 10 years back the utilization of lightweight frothed concrete has developed more quickly than some other "exceptional" solid item. Lightweight frothed cement can be characterized as a sort of cement incorporating an extending specialist in that it builds the volume of the blend while giving including qualities, for example, unsteadiness and reduced the dead weight (Zakaria, 1978). Lightweight frothed cement is 87% to 23% lighter than the traditional cement with. a dry thickness from 300 kg/m3 up to 1840 kg/m3 The fundamental claims to fame of lightweight frothed cement are its low thickness and warm conductivity. Its points of interest included lessening of dead load, quicker building rates in development and lower haulage and taking care of expenses.

2.2 Research Paper

-*Ameer A. Hilal, Nicholas H. Thom, and Andrew R. Dawson* reported; enhanced the properties of Pre-Formed Foam Concrete using two types of additives i.e. silica fume and fly ash which replaces fine sand and Portland Pozzolana Cement. Contrasted with different reviews on foamed concrete, the outcomes from the mixes explored in this review demonstrated higher strengths, higher moduli of elasticity and higher tensile to compressive strength proportions.

-*Chen Bing; Wu Zhen; and Liu Ning* reported; The point of this review is to create structured foamed cements by utilizing fly ash, silica fume and polypropylene fiber by completely replacing sand to deliver foamed concrete. Fine silica smoke and polypropylene fiber were utilized to enhance properties of foamed cement. The outcomes demonstrate that frothed concrete with a thickness of 800–1500 kg/m^3 and compressive quality of 10–50 MPa can be made by utilizing silica fume and polypropylene fiber. Fine silica smoke and polypropylene fiber extraordinarily enhanced the compressive strength of foamed cement. Likewise, including polypropylene fiber essentially enhanced the part rigidity and drying shrinkage resistance.

-*Jihad Hamad Mohammed, Ali Jihad Hamad* reported; It has noteworthy applications on the structure, the including daintily gives a few capacities in of thermal and insulation and lessen the heaviness of the structure, which prompts diminished basic components and steel fortification, consequently bring down the cost of the development. This paper introduces an audit of the order of lightweight solid, where the lightweight solid arranged into two sorts as per generation techniques and use reason. Additionally, it concentrates on the materials used to get lightweight concrete.

-*Ali J. Hamad* reported; Circulated air through lightweight cement have many favorable circumstances when contrasted and regular cement, for example, propelled quality to weight proportion, bring down coefficient of warm development, and great sound protection thus of air voids inside circulated air through cement. This paper is thoughtfulness regarding ordered of circulated air through lightweight cement into foam concrete and autoclaved concrete.

Ashish S. Moon, Dr. Valsson Varghese, S. S. Waghmare reported; A green building is a naturally cognizant building, planned, developed and worked to limit the aggregate ecological effects. Foam concrete is another creative innovation for manageable building and common development which satisfies the criteria of being a Green Material. This paper reasons that Foam Concrete can be a powerful feasible material for development and furthermore concentrates on the cost viability in utilizing Froth Concrete as a building material in supplanting with Mud Block or different blocks.

E. K. Kunhanandan Nambiar1 and K. Ramamurthy reported; shrinkage conduct of preformed foam concrete for the impacts of essential parameters, density, dampness content, structure like filler-cement proportion, levels of supplanting of sand with fly ash and foam volume. Shrinkage of foam concrete is lower than the relating base blend. Shrinkage increments extraordinarily in the scope of low dampness content. Despite the fact that expulsion of water from similarly greater simulated air pores won't add to shrinkage, counterfeit air voids may have, to some degree, an impact on volume dependability by implication by permitting some shrinkage; this impact was more at a higher froth volume.

E. K. Kunhanandan Nambiar1 and K. Ramamurthy reported; the impact of a blend composition on the properties of foam concrete at the fresh state. The security of the base blend regarding the water–solids proportion for getting a steady froth concrete mix of outline thickness was resolved for various blend parameters and their impact on the water–solids proportion necessity was examined. The consistency of the froth solid blend was measured as far as the spread percent utilizing a stream cone test and stream time utilizing a Marsh cone test. The fresh state properties of froth cement, viz;

(i) stability of foam concrete and

(ii) consistency of the foam concrete, were particularly influenced by the water content in the base blend and the measure of froth included alongside the other strong fixings in the blend.

Relapse conditions for anticipating the spread stream estimation of the froth concrete in light of the test results were accounted for. This will help in landing at the water substance of a froth solid blend for a given consistency prerequisite. A suitable estimation of consistency for getting a steady and workable froth cement was additionally proposed.

CHAPTER 3

EXPERIMENTAL WORK

3.1. Preparation of Materials:

3.1.1 Foaming Agent

A foaming agent is used to create foam for mixing in foam concrete. The foaming agents when added into the water and mixed, produce discrete bubbles cavities which become incorporated in the cement paste. The quality of the foam is critical in governing the properties of foamed concrete. Foam agent can be classified according to types of foaming agent:

i) Synthetic based for densities of 1000kg/m^3 and above.

ii) Protein based for densities from 400kg/m^3 to 1600 kg/m^3.

Foams derived from protein-based agents have a unit weight of around 80g/l. Protein-based foaming agents come from processing animal proteins made out of horn, blood, bones of cows, pigs and other remainders of animal carcasses. This leads not only to occasional inconsistencies in quality, due to the differing raw materials used in different batches, but also to a repulsive odour of such foaming agents. Synthetic foams have a density of about 40g/l.

Synthetic foaming agents are purely chemical products. They are very stable at concrete densities above 1000kg/m^3 and give good strength. Synthetic foam has finer bubble size as compared to protein but they generally give lower strength of foamed concrete especially at densities below 1000kg/m^3.

Foaming agent used for our tests was Profo-1000, which is a protein based foaming agent. Protein based foaming agent (**PROFO**) is a foam-forming agent based on highly-active, foam-forming proteins. The specially developed manufacturing process for foam stabilization guarantees optimum foam-forming characteristics and foam stability.

It is manufactured by Maruti Protect. Samples were procured from their store at Sonipat.

3.1.2 Cement:

Cement used was **Jaypee Cement** provided by the university. The cement was **PPC (fly ash based)** conforming to Part 1 of IS 1489:1991.

3.1.3 Fine aggregates

Locally available sand was used as fine aggregate.

3.2. Testing of Materials for Mix Design

3.2.1 Cement Testing

Jaypee Portland Pozzalana Cement provided by university was tested to find its Specific Gravity, Initial Setting Time(IST) and Final Setting Time(FST).

Specific Gravity

Specific Gravity of cement was found out by using a 50 ml Specific Gravity Bottle. Specific Gravity is the ratio of density of a given substance to the density of water. Since cement reacts with water, kerosene was used to find the relative density of cement to kerosene and then compared with water to get Specific Gravity of cement.

Specific Gravity of Cement (SGC) was found to be 3.07.

Initial Setting Time(IST) and Final Setting Time(FST)

Initial setting time is defined as the time taken for a cement mix in a Vicat's mould to gain enough stiffness to prevent the penetration of Vicat needle within the range of 5 mm to 7 mm from the bottom of the mould. It is time period when water is first mixed in the dry mix and it just starts losing its plasticity.

Final setting time is that time period between the time water is added to cement and the time at which 1 mm needle makes an impression on the paste in the mould but 5 mm attachment does not make any impression. This test is done to gauge the time taken for cement mix to completely lose its plasticity. The test was performed in accordance to IS:4031(Part 5):1988.

IST of Cement = 55 minutes

FST of Cement = 6 Hours 35 minutes

3.2.2 Fine Aggregate Testing

Specific Gravity

Specific Gravity of cement was found out by using a 50 ml Specific Gravity Bottle, similar to finding specific gravity of cement. Water is used as sand is insoluble in water.

Specific Gravity of FA was found out to be 2.48

3.3. MIX DESIGN

The mix proportion is designed as per the guidelines given in ASTM C796, similar to one used by Nambiar and Ramamurthy (2006). As the standard deals with only cement slurry, the procedure was modified to include cement–sand components.

3.3.1 Foam Volume

In ASTM C796 foam volume being generated from foam generator is measured with time, and appropriate quantity of foam is added to the mix. The foam generator fills foam in a container with known volume in excess. The excess part is struck off and an estimate of foam generated with time is made. The container is further used to find density of foam being created.

Foam was generated using hand held motor with attachment, as mixer. A 20 litre bucket with markings was used as large container for mixing of foaming agent and water with dilution factor of 1:20. 100 ml of foaming agent was added to 2000 ml of water.

Initially foam generated had large bubbles and was unstable but after mixing for 2-3 minutes a stable consistent foam was formed.

The foam was filled in a borosil beaker of known volume and weighed to find density of foam generated.

For adding of measured quantity of foam to mix, the bucket markings were used.

Foam with average density of 43.6 g/l (kg/m^3) was obtained.

3.3.2 Water Cement Ratio

ASTM C796 specifies w/c ratio of 0.58 for Type I cement and w/c ratio of 0.64 for Type III cement. However, if a particular cement or foaming agent used with these values of w/c does not produce a satisfactory mix, a trial mix or mixes may be made using the cement and foaming agent to achieve a satisfactory mix with required design density.

In the first part of the project, all mix designs were made using a fixed w/c. ratio of .64.

In the second part of the project w/c ratio

3.3.3 Mix Proportions

ASTM C796 specifies design density as

$$D_d = \frac{W_w + W_c + W_f}{\frac{W_w}{1000} + \frac{W_w}{SGC \times 1000} + V_f}$$

This was modified to incorporate fine aggregate

$$D_d = \frac{W_w + W_c + W_f + W_{FA}}{\frac{W_w}{1000} + \frac{W_c}{SGC \times 1000} + \frac{W_{FA}}{SGFA \times 1000} + V_f}$$

Step 1: **Selection of design density**

Design density of 600 kg/m^3 was selected.

D_d =600 kg/m^3

Step 2: **Selection of w/c ratio and FA proportion**

For PPC, using a w/c ratio of 0.64

And using Cement: FA ratio as 1:1.5

Step 3: **Finding volume of foam required**

Using trial batch with weight of cement W_c = 400 kg

Therefore, weight of fine aggregate W_{FA} = 600 kg

Weight of water required W_w = 256 kg

Weight of foam = Volume of foam x Density of Foam

= V_f x 43.6

Hence using Equation 4, Volume of foam required V_f =1.58 m^3

Weight of foam required W_f =1.58x 43.6 =68.8 kg

Step 4: **Mix Proportions for 1 m^3 of concrete**

Total Volume in above mix = $\frac{W_w}{1000} + \frac{W_c}{SGC \times 1000} + \frac{W_{FA}}{SGFA \times 1000} + V_f$

=2.208 m^3

Therefore, for 1 m^3

Weight of Cement	(W_c)	= 181.16 kg
Weight of Sand	(W_{FA})	= 271.74 kg
Weight of Water	(W_w)	= 115.94 kg
Weight of Foam	(W_f)	= 31.16 kg
Volume of Foam	(V_f)	= 0.71 m^3

Similarly mix proportions for obtaining design density of 800 kg/m^3, 1000 kg/m^3 and 1200 kg/m^3 were designed and are tabulated below

Table 3.1: Mix proportions for different design density

Mix Designation	M1	M2	M3	M4
Design Density(**Kg/m^3**)	600	800	1000	1200
w/c ratio	0.64	0.64	0.64	0.64
Cement (kg)	181.16	245.70	310.56	376.65
Sand (kg)	271.74	368.55	465.84	564.97
Water (kg)	115.94	157.25	198.76	241.05
Weight of Foam (kg)	31.16	26.78	22.34	17.82
Volume of Foam (m^3)	0.714	.614	.512	.409

Table 3.2: Mix proportions for different design density and w/c. ratio

Mix Designation	M5	M6	M7	M8
Design Density(**Kg/m^3**)	1400	1600	1000	1000
w/c ratio	0.64	0.64	0.55	0.50
Cement (kg)	441.50	506.97	320.46	324.55
Sand (kg)	662.25	760.45	480.69	486.82
Water (kg)	282.56	324.46	176.2	162.275
Weight of Foam (kg)	12.12	7.03	22.6	23.8
Volume of Foam (m^3)	0.306	.204	.518	.545

Table 3.3: Mix proportions for different design density and w/c. ratio

Mix Designation	M9	M10	M11	M12
Design Density(**Kg/m^3**)	1000	800	800	800
w/c ratio	0.45	0.55	0.50	0.45
Cement (kg)	330.85	253.48	257.57	261.78
Sand (kg)	496.28	380.23	386.34	392.67
Water (kg)	148.88	139.42	128.78	117.80
Weight of Foam (kg)	23.68	27.25	27.51	27.81
Volume of Foam (m^3)	.543	.625	.631	.638

3.4. Mixing

Mixing was done in buckets manually. Initially cement, sand and water slurry is made to which pre-formed foam in calculated quantity is added. Foam is generated in a separate bucket. After mixing for 2 minutes after the addition of foam, the mix is immediately poured in molds.

3.5 Casting and Demolding

Molds of 10cm X 10cm X 10 cm were first properly cleaned and then oiled. Concrete was slowly poured with only light tapping on the sides to remove large bubbles which create large voids with unstable walls. The top surface is levelled with a trowel.

Test cubes should be demolded between 20 to 24 hours after casting. If still the cubes have not achieved sufficient strength , they must be delayed for some time. Since molds were still soft they were removed after 24 hours.

When removing the cubes from the mold care should be taken to remove it completely. A chisel and a hammer may be used for proper demolding. No damage should be caused to the cube as it may reduce the compressive strength of the specimen.

After demolding, each cube should be marked on the surface using ink to identify. The mold must be cleaned after demolding. Ensure that dirt does not collect between the faces of the flanges as the two halves will not fit together properly and there will be leakage through the joint and an irregularly shaped cube may result.

3.6. Curing

Specimen are cured by immersing them in water for 7, 14 and 28 days. Specimen were cured separately to ensure that no damage occurs to them.

3.7. Compressive Strength Test

The cubes are casted with the given mix and compressive strength is checked in 14, 28 days in compression testing machine.

Procedure:

(i) Remove the specimen from water after specified curing time and wipe out excess water from the surface.

(ii) Take the dimension of the specimen.

(iii) Clean the bearing surface of the testing machine.

(iv) Place the specimen in the machine in such a manner that the load shall be applied to the opposite sides of the cube cast.

(v) Align the specimen centrally on the base plate of the machine.

(vi) Rotate the m ovable portion gently by hand so that it touches the top surface of the specimen.

(vii) Apply the load gradually without shock and continuously at the rate of 140kg/cm^2/minute till the specimen fails.

(viii) Record the maximum load and note any unusual features in the type of failure

CHAPTER 4

RESULTS AND DISCUSSIONS

4.1 Specific Gravity Tests

Specific Gravity of Cement

Weight of empty bottle (W_1) = 24.25 g

Weight of bottle filled with kerosene (W_2) = 43.85 g

Weight of bottle with cement (W_3) = 31.50 g

Weight of bottle filled with cement and kerosene (W_4) = 49.00 g

Weight of bottle filled with water (W_5) = 49.35 g

Specific gravity of Cement = $\frac{(W3 - W1)}{(W2 - W1) - (W4 - W3)} \times \frac{W2}{W5}$

Hence Specific Gravity of Cement (SGC) was found to be 3.07

Specific Gravity of Fine Aggregates

Weight of empty bottle (W_1) = 30.40 g

Weight of bottle filled with water (W_2) = 79.40 g

Weight of bottle with FA (W_3) = 80.40 g

Weight of bottle filled with sand and water (W_4) = 109.6 g

Specific gravity of FA = $\frac{(W3 - W1)}{(W2 - W1) - (W4 - W3)}$

Hence Specific Gravity of FA was found out to be 2.48.

4.2 Foam Density

The foam was filled in a borosil beaker of known volume and weighed to find density of foam generated.

Readings:

Volume of beaker: 1300 ml

Weight of empty beaker: 300 g

Sample 1

Weight of beaker with foam: 360g

Density of foam: 46.2 g/l

Sample 2

Weight of beaker with foam: 355g

Density of foam: 42.3 g/l

Sample 3

Weight of beaker with foam: 355g

Density of foam: 42.3 g/l

Hence foam with average density of 43.6 g/l (kg/m^3) was obtained.

4.3 Compressive Strength Tests

Cube Size: 10cm X 10cm X 10 cm

Table 4.1

Compressive strength test on cubes 10cm*10cm*10cm after 7 days		
Sample	Max load(kN)	Compressive Strength(MPa)
M1	8	0.8
M2	9	0.9
M3	11	1.1
M4	13	1.3
M5	18	1.8
M6	20	2.0

Table 4.2

Compressive strength test on cubes 10cm*10cm*10cm after 14 days		
Sample	Max load(kN)	Compressive Strength(MPa)
M1	12	1.2
M2	15	1.5
M3	17	1.7
M4	19	1.9
M5	25	2.4
M6	31	2.7

Table 4.3

Compressive strength test on cubes 10cm*10cm*10cm after 28 days		
Sample	Max load(kN)	Compressive Strength(MPa)
M1	15	1.5
M2	20	2.0
M3	23	2.3
M4	26	2.6
M5	35	3.5
M6	41	4.0

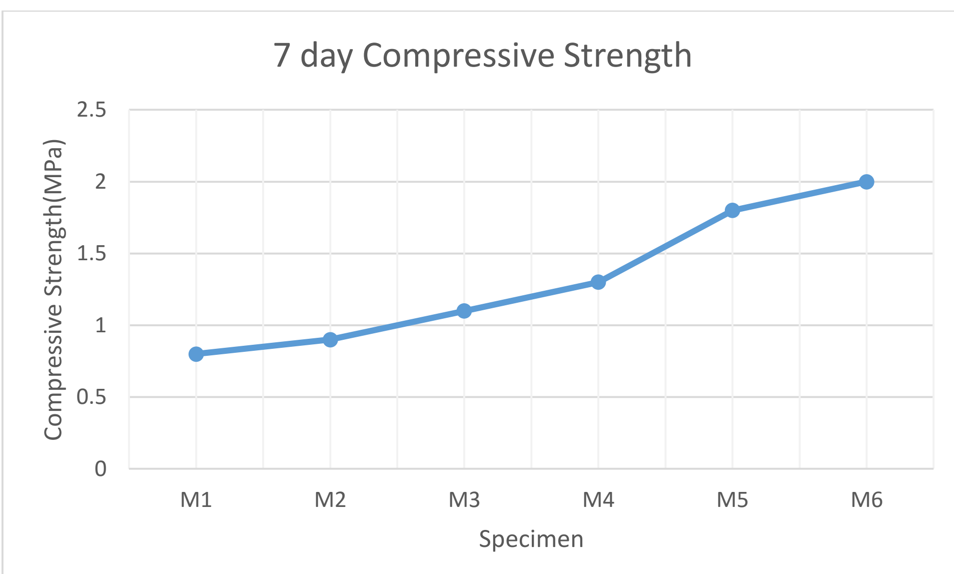

Figure 4.1: 7 day compressive strength of specimen

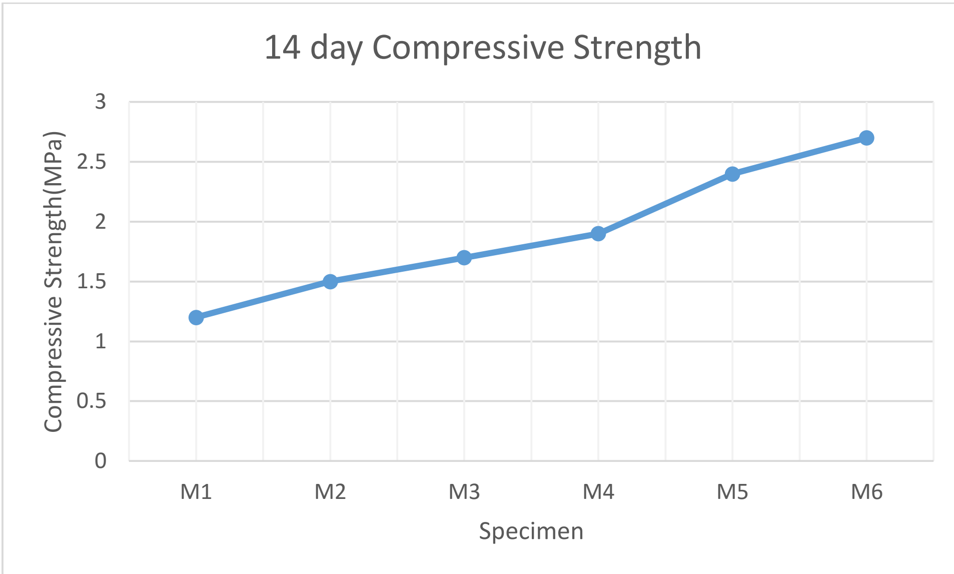

Figure 4.2: 14 day compressive strength of specimen

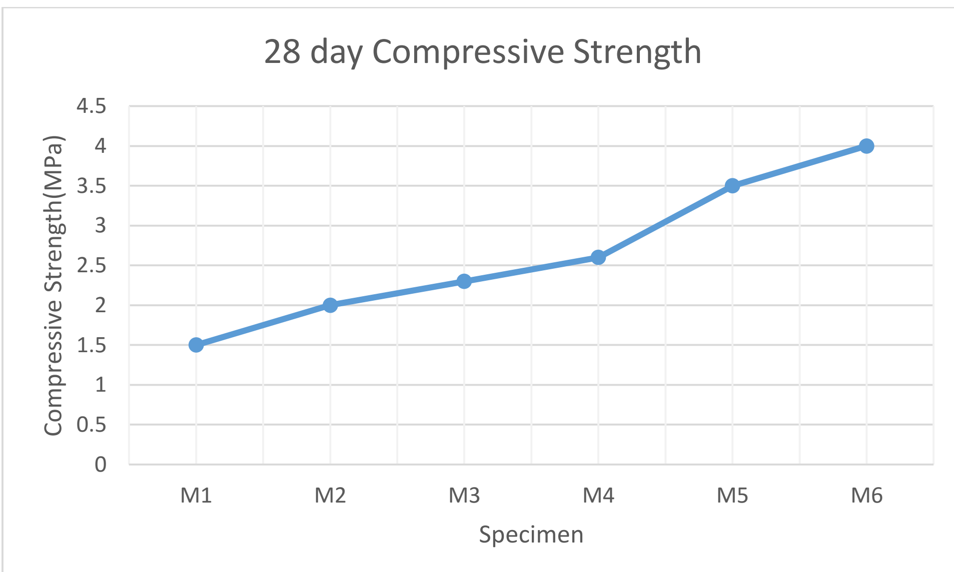

Figure 4.3: 28 day compressive strength of specimen

Three cubes each of specimen M1, M2, M3, M4, M5, and M6 were casted and cured. The compressive strength was then checked for each specimen after 7, 14, 28 days. From above results it is evident that compressive strength varies linearly with density. Compressive strength is higher for concrete with higher densities.

Table 4.4

Compressive strength test on cubes 10cm*10cm*10cm after 7 days		
Sample	Max load(kN)	Compressive Strength(MPa)
M7	12	1.2
M8	13	1.3
M9	11	1.2
M10	10	1.0
M11	11	1.1
M12	10	1.0

Table 4.5

Compressive strength test on cubes 10cm*10cm*10cm after 14 days		
Sample	Max load(kN)	Compressive Strength(MPa)
M7	17	1.7
M8	18	1.8
M9	17	1.7
M10	16	1.6
M11	17	1.7
M12	15	1.5

Table 4.6

Compressive strength test on cubes 10cm*10cm*10cm after 28 days		
Sample	Max load(kN)	Compressive Strength(MPa)
M7	24	2.4
M8	26	2.6
M9	23	2.3
M10	21	2.1
M11	23	2.3
M12	20	2.0

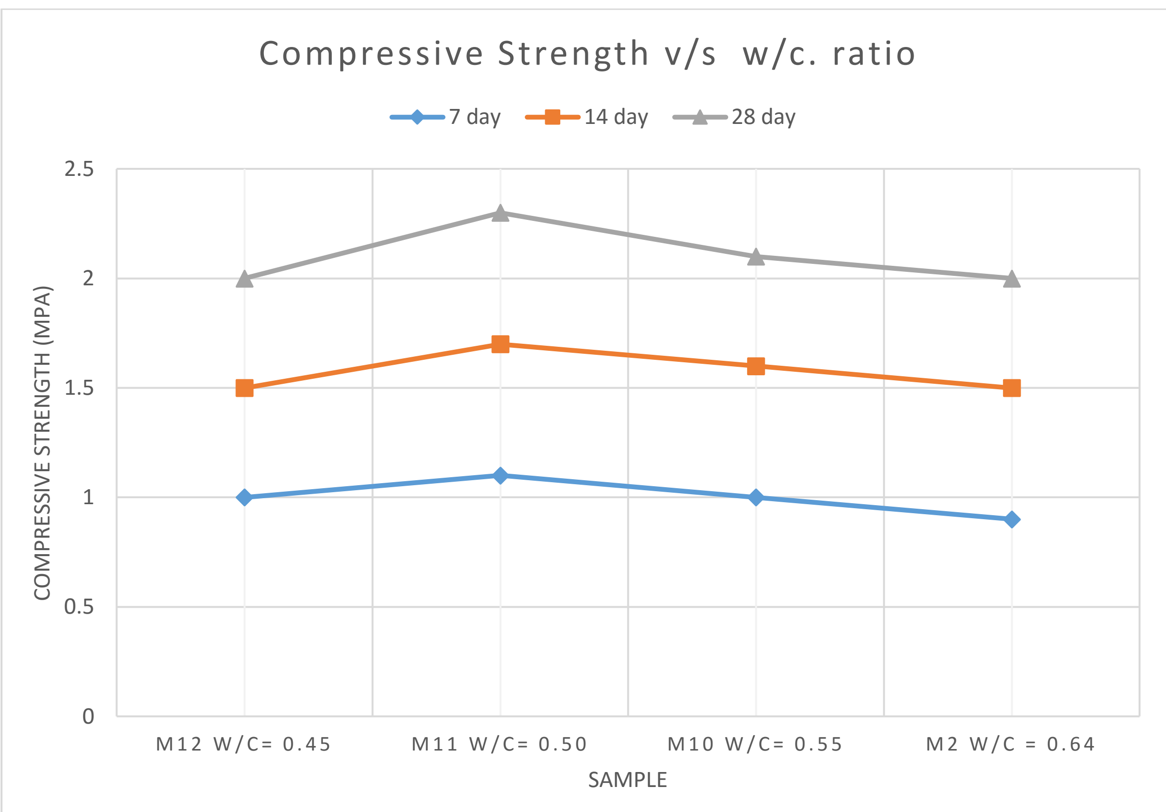

Figure 4.4: Comparison of Compressive Strength of samples with density 1000 kg/m^3 but different water cement ratio.

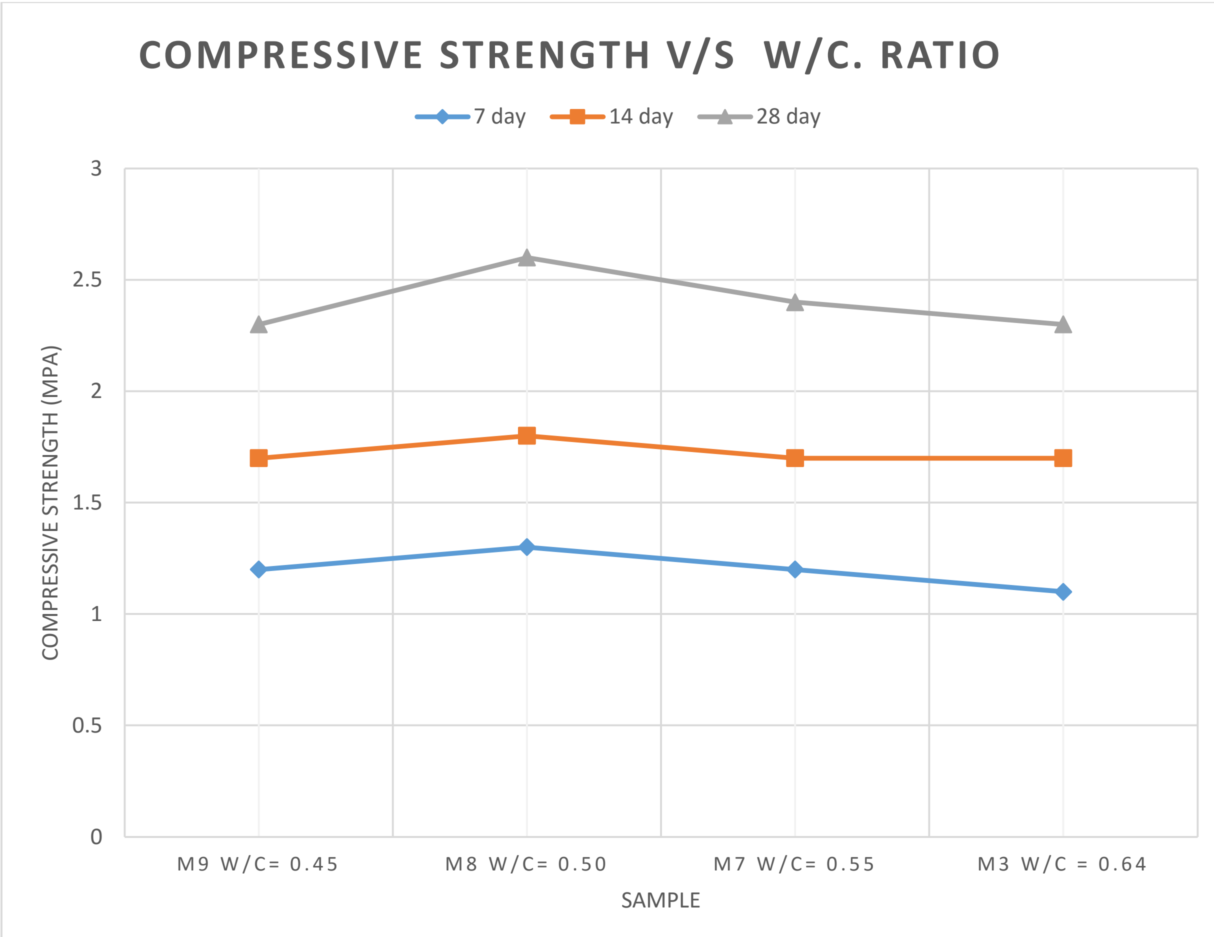

Figure 4.5: Comparison of Compressive Strength of samples with density 800 kg/m^3 but different water cement ratio.

Three cubes each of specimen M7, M8, M9, M10, M11, and M12 were casted and cured. The compressive strength was then checked for each specimen after 7, 14, 28 days. Here specimen M7, M8 and M9 were casted for density of 1000 kg/m^3 and specimen M10, M11 and M12 were casted at design density of 800 kg/m^3. From above results it is observed that compressive strength of specimen at same density is maximum for specimen with water cement ratio of 0.5 which is also more than strength of sample with w/c. ratio as 0.64 specified by ASTM796.

CHAPTER 5

Conclusions

1. Compressive strength of foamed concrete varies linearly with density. Higher density results in higher compressive strength values.

2. Water-cement ratio influences the size, shape, distribution, and connectivity of pores in foam concrete. The effect of w/c ratio on the strength of foam concrete is shown in Figure 7. With the increase in w/c ratio, the compressive strength of foam concrete increased first and then decreased. This result was achieved because, on one hand,when the w/c ratio was smaller than the optimal ratio, a smaller w/c ratio generated higher proportions of small thin-walled, connected, and irregular pores.On the other hand ,the w/c ratio that exceeded the optimal level resultedin a weaker bubble maintaining capability of the paste. Moreover, the bubbles in the paste get easily combined during stirring and result in reduced pores, increased pore diameter, and uneven pore distribution.This occurrence would cause stress concentration on the walls and redundant free water would form capillary channels after the hydration reaction of cementing materials orevap oration ,negating the compactness of the pore walls and consequently reducing the strength of the foam concrete. Optimum water cement ratio for maximum compressive strength is 0.5 for specimen with densities 800kg/m^3 and 1000 kg/m^3.

REFERENCES

[1] Aldridge, D., (2005), Introduction to Foamed Concrete What, Why, and How? *Use of Foamed Concrete in Construction*. London: Thomas Telford, 1005: 1-14.

[2] Aldridge, D., Ansell, T., (2001), Foamed Concrete: Production and Equipment Design, Properties, Applications and Potential. *Proceedings of One Day Seminar on Foamed Concrete: Properties, Applications and Latest Technology Developments*. Loughborough University.

[3] American Society for Testing and Materials (2005). Standard Specification for Portland Cement (ASTM C150 – 05)

[4] American Society for Testing and Materials (2010). Standard Guide for Examination of Hardened Concrete Using Scanning Electron Microscopy (ASTM C1723-10)

[5] Byun, K.J., Song, H.W., Park, S.S. (1998). Development of Structural Lightweight Foamed Concrete Using Polymer Foam Agent. ICPIC-98: 9.

[6] Jones, M.R., McCarthy, A., Dhir, R.K. (2005). Recycled and Secondary Aggregate in Foamed Concrete. WRAP Research Report, The Waste and Resources Action Programme. Banbury, Oxon.

[7] Kearsley, E.P. (1996). The Use of Foamed Concrete for Affordable Development in Third World Countries. Appropriate Concrete Technology. London: E&FN Spon. 233-234.

[8] Kim, H.K., Jeon, J.H., Lee, H.K (2011). Workability, and Mechanical, Acoustic and Thermal Properties of Lightweight Aggregate Concrete with A High Volume of Entrained Air. Construction and Building Material, 29: 193-200.

[9] Neville, A. M. (2010). Properties of Concrete (4th ed.). London: Pearson, 10–17, 65– 71, 83 – 86, 598-599, 688. \

[10] Parra, C., Valcuende, M., and Gomez, F. (2011) Splitting tensile and modulus of elasticity of self-compacting concrete. *Construction and Building Materials*. 25:201-207.

[11] Ramamurthy, K., Kunhanandan Nambiar, E.K., Indu Siva Ranjani, G. (2009). A Classification of Studies on Properties of Foam Concrete. *Cement & Concrete Composite*, 31: 388-396.

[12] Steiger, R.W., Hurd, M.K. (1978). Lightweight Insulating Concrete for Floors and Roof Decks. *Concrete Construction.* 23(7): 411-422.

[13] Valore, R.C. (1954). Cellular Concrete Part 1: Composition and Method of Production, *ACI Journal*, 50: 773-796.

APPENDIX

Figure A.1: Compressive Test being performed on specimen

Figure A.2: Casting of Specimen

Figure A.3: Specimen after 24 hrs prepared for demolding