Engineering Properties and Construction Availability of Light Weight Concrete

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Abstract- *Concrete is second mostly used material in the world today. This is attributed mainly to low cost of materials and maintenance. Therefore it is not surprising that much advancement in concrete technology have occurred now days. Considering these two driving forces, so many researchers are working on light weight concrete. LWC is formed by entraining large air quantity using foaming agent, light weight aggregates (Vermiculite) and water crystal balls. The density of these concrete varies from 750 kg/m3 and 2050 kg/m3. This less density enhances reduction of dead load which results much economical structures in the field construction. The reduction in concrete weight is due to voids present in LWC with is also reduces Thermal conductivity which increases fire resistance of the construction. And also decreases problems related to fire protection and sound reflection and sound absorbing interior, As well as several other problematic issues.*

Keywords- Foaming agent, Water Crystal Balls, Vermiculite, Light Weight Aggregate, and Foamed Concreter.

I. INTRODUCTION

Lightweight concretes have been used as construction materials since the days of the Roman Empire. The earliest types of lightweight concrete were made by using Grecian and Italian pumice as lightweight aggregates. Developments in light weight concrete production started in the 20th century. During the World Wars lightweight concrete was employed in the construction of ships and barges Optimizes use of available materials

Structural lightweight aggregate concrete is defined as concrete which: Is made with lightweight aggregates conforming to ASTM C 330, has a compressive strength in excess of 2,500 psi (17.25 MPa) at 28 days of age when tested in accordance with methods stated in ASTM C 330, and Has an air dry density not exceeding 115 pcf (1,840 kg/m3) as determined by ASTM C 567. Job specifications often allow unit weights up to 120 pcf (1,920 kg/m3) or more.

Cellular Concrete is a cementitious paste of neat cement or cement and fine sand with amultitude of micro/macroscopic discrete air cells uniformly distributed throughout the mixture to create a light weight concrete. It is commonly manufactured by two different methods.

Method A

It consists of mixing a pre-formed foam [surfactant] or mixfoaming agents mixture into the cement and water slurry. As the concrete hardens, the bubbles disintegrate leaving air voids of similar sizes.

Method B

It is 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 powder 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 mold 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. Similar to baking a cake. 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.

Method C

Recently, a direction to concrete compositions prepared by using aqueous gels [aquagels] is being considered as all or part of the aggregate in a concrete mix. Aqua gel spheres,particles, or pieces are formed from gelatinized starch and added to a matrix. Starch modified or unmodified such as wheat, corn, rice, potato or a combination of a modified or unmodified starches are examples of aqueous gels. A modified starch is a starch that has been modified byhydrolysis or dextrinizaton. Agar is another material that can create a pore or cell in concrete.During the curing process as an aqua gel loses moisture, it shrinks and eventually dries up to form a dried bead or particle that is a fraction of the size of the original aqua gel in the cell or pore in the concrete. This results in a cellular, lightweight concrete.

On the other hand, aerated concrete is also known as cellular concrete, cellular aerated concrete, gas concrete or foamed concrete. This type of concrete is essentially an aerated cement paste or mortar made by entraining air or gas in the form or small bubbles with diameter from0.1 to 1.0mm into a plain cement paste or mortar mix during the mixing process (Tam et. al.,1987). The air bubbles are uniformly distributed in the plain cement paste and are retained in the matrix on setting and hardening to form a cellular structure (AAC 1.1, 1990). The classification of aerated concrete is based upon the method of formation (Narayanan & Ramamurthy, 2000b)and it can be, basically, divided into two types that are foamed concrete and gas concrete.

Significance of Study

The significances of this study are as follows:

1) Incorporating light weight aggregate vermiculite as partial and 100% sand replacement material in the mix as to encourage the use of alternating construction material besides limited river sand to create a more sustainable environment and light weight concrete.

2) Developing the mix proportion to produce lightweight concrete incorporated with different materials and studies the engineering properties and fresh properties of lightweight concrete.

3) Using foaming agent in the mix as to encourage the use of alternating construction material besides conventional construction materials to reduce the weight of concrete which reduce the dead load of structure as a result reduces the construction cost.

4) Using crystal water balls as additional material in the mix of sand and cement as to encourage the usage of this kind of concrete where water is limited for curing.

II. TYPES OF LIGHTWEIGHT CONCRETE

Lightweight concrete can be prepared either by injecting air in its composition or it can be achieved by omitting the finer sizes of the aggregate or even replacing them by a hollow, cellular or porous aggregate. Particularly, lightweight concrete can be categorized into three groups:

i. No-fines concrete
ii. Lightweight aggregate concrete
iii. Cellular concrete

- Aerated/Foamed concrete
- Autoclaved aerated concrete using hydrogen peroxide
- Aqua gel concrete –water jelly beads

NO-FINES CONCRETE

No-fines concrete can be defined as a lightweight concrete composed of cement and fine aggregate. Uniformly distributed voids are formed throughout its mass. The main characteristics of this type of lightweight concrete is it maintains its large voids and not forming laitance layers or cement film when placed on the wall. Figure 2 shows one example of No-fines concrete.

No fines concrete usually used for both load bearing and non-load bearing for external walls and partitions. The strength of no-fines concrete increases as the cement content is increased. However, it is sensitive to the water composition. Insufficient water can cause lack of cohesion between the particles and therefore, subsequent loss in strength of the concrete. Likewise too much water can cause cement film to run off the aggregate to form laitance layers, leaving the bulk of the concrete deficient in cement and thus weakens the strength.

LIGHTWEIGHT AGGREGATE CONCRETE

Porous lightweight aggregate of low specific gravity is used in this light weight concrete instead of ordinary concrete. The lightweight aggregate can be natural aggregate such as pumice, scoria and all of those of volcanic origin and the artificial aggregate such as expanded blast-furnace slag, vermiculite and clinker aggregate. The main characteristic of this lightweight aggregate is its high porosity which results in a low specific gravity.

The lightweight aggregate concrete can be divided into two types according to its application. One is partially compacted lightweight aggregate concrete and the other is the structural lightweight aggregate concrete. The partially compacted lightweight aggregate concrete is mainly used for two purposes that is for precast concrete blocks or panels and cast in-situ roofs and walls. The main requirement for this type of concrete is that it should have adequate strength and a low density to obtain the best thermal insulation and a low drying shrinkage to avoid cracking.

Structurally lightweight aggregate concrete is fully compacted similar to that of the normal reinforced concrete of dense aggregate. It can be used with steel reinforcement as to have a good bond between the steel and the concrete. The concrete should provide adequate protection against the corrosion of the steel. The shape and the texture of the aggregate particles and the coarse nature of the fine aggregate tend to produce harsh concrete mixes. Only the denser varieties of lightweight aggregate are suitable for use in structural concrete.

AERATED CONCRETE

Aerated concrete does not contain coarse aggregate, and can be regarded as anaerated mortar. Typically, aerated concrete is made by introducing air or other gas into a cement slurry and fine sand. In commercial practice, the sand is replaced by pulverized fuel ash or other siliceous material, and lime maybe used instead of cement.

There are two methods to prepare the aerated concrete. The first method is to inject the gas into the mixing during its plastic condition by means of a chemical reaction.

The second method, air is introduced either by mixing-in stable foam or by whipping-in air, using an air-entraining agent. The first method is usually used in precast concrete factories where the precast units are subsequently autoclaved in order to produce concrete with a reasonable high strength and low drying shrinkage. The second method is mainly used for in-situ concrete, suitable for insulation roof screeds or pipe lagging.

The differences between the types of lightweight concrete are very much related to its aggregate grading used in the mixes, aggregate suitable for the different types of lightweight concrete

III. METHODOLOGY

Raw Materials

The specimen production for lightweight foamed concrete consist of five types of raw material, namely ordinary Portland cement, vermiculite, water jelly beads, hydrogen peroxide, super plasticizers, sand, water and foam.

Ordinary Portland cement

The Ordinary Portland Cement (OPC) which is produced by Deccan cement under the brand name of “DECCAN 53 GRADE” was used throughout the study. The OPC was sieved through 600µm sieve and was stored in an airtight container in order to maintain the quality of cement such as to prevent air moisture contact as hydrated cement particle would affect the formation of calcium silicate hydrate gel. According to ASTM C150 (2005), the OPC used throughout this research is complied with Type I Portland Cement and the details chemical composition of OPC is given in Table

Physical properties of cement:

Physical properties	Test result
Consistency limit	32% by weight of cement
Setting time (vicat apparatus Initial setting time Final setting time	115 minutes 200 minutes
Compressive strength of cement	49.27 KN/M3
Fineness of cement	5%

Water crystals beads

Water crystal is kind of super water absorption polymer. It can absorb water up to several hundred times ,its weight in a short time and turns into gel form , the slowly release the water.

One small packet of 10 gm. will
produce about 500gm of beads.

Vermiculite

Vermiculite is a light-weight and cheap product that, because of its thermal resistance has become a valuable insulating material. Used as an aggregate with Portland cement it forms an ultra light weight concrete with an open structure ideal for void filling, suitable for use in most light industrial and domestic applications where thermal insulating and fireproof properties are required.

Sand

In this study, only fine sand (zone II) was used in the production of cement based aerated concrete. The sand was dried in an oven at the temperature of 105 °C ± 5 °C for at least 24 hours to remove the moisture in it. Then, the dried sand was sieved through a 600 µm sieve before it stored in airtight container to prevent atmospheric humidity contact.

Water

In this study, tap water was used in the production of lightweight concrete. The tap water used must not contain any impurities as the impurities may affect or harmful to the hydration process of cement and durability of concrete.

Super plasticizer

High range water reducing admixture type sulphonated melamine formaldehyde condensate which is known commercially as was used. The material was prepared as a solution in water which is used in concrete mix. 0.5% of super plasticizer is used for each mix design with respect to water content used in mix design.

Foaming Agent

Foam is a form of stable bubbles, produced in foam generator by mixing foaming agent and water with a specific ratio in order to produce desired density of foam. In this study, the ratio offoaming agent to water are 1:30, 1:25 and 1:20 by volume is used and the foam produced with density of 25 kg/m3. Foaming agent is used by entraining the preformed stable foam into the fresh lightweight concrete in order to control the density of lightweight concrete and achieve

IV. RESULTS AND DISCUSSION

This chapter discusses the results about the compressive strength and densities of lightweight concrete using vermiculite, foam and crystal water balls. The densities and compressive strength for each mix were discussed. The specimens for each mix proportions were cured inwater for 7, 14 and 28 days before carrying out compression test. The test results were represented in tabular forms below and the variation strength with respect to age of curing were represented through graphs. The strength variation with respect to densities of mixes using vermiculite, foaming agent and crystal water balls were also mentioned in tabular forms as well as in graphs. The compressive strengths and densities for different mixes with different water content were also shown in tabular forms.

Compressive Strengths:

Using vermiculite:

Mix Design (By volume)	Water content	Compressive Strength(MPa)		
		7 days	14 days	28days
Vermiculite(1C:2L:6V)	1.107	1.92	2.5	3.96
	1.15	2.03	2.64	4.2
	1.22	1.98	2.38	4.01
Vermiculite (2C:1L:8V)	1.1	3.45	4.6	6.7
	1.15	2.84	3.69	5.6
Vermiculite(1C:1S:1V)	0.6	14.69	15.1	16.3
	0.65	10.5	12.3	15.67
Vermiculite (1C:1S:2V)	0.75	6.73	7.89	10.05
	0.8	5.7	6.83	9.55

Using foaming agent:

Mix Design (By volume)	Water content	Compressive Strength(MPa)		
		7 days	14 days	28days
1C:2S (1FA:20W)	0.6	9.43	11.24	14.79
	0.7	5.16	6.38	9.15
	0.8	4.65	5.19	6.67
	0.9	4.45	4.91	5.98
1C:2S (1FA:25W)	0.45	16.29	17.58	21.23
	0.5	11.77	13.3	19.34
	0.7	5.26	7.18	10.5
1C:2S (1FA:30W)	0.45	21.33	24.04	27.07
	0.5	12.65	14.07	20.07

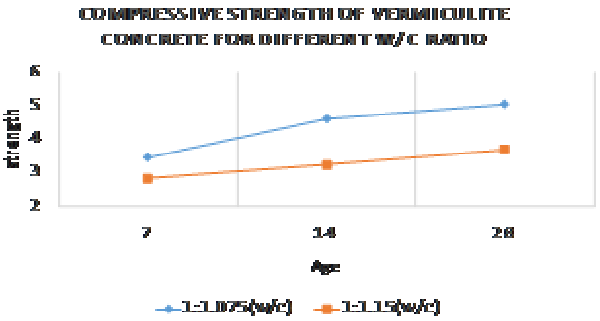
Using water crystal balls

Mix Design (By volume)	W/C	Compressive Strength(MPa) (Normal curing with water)			Compressive Strength(MPa) (No curing)		
		3 days	7days	28 days	3 days	7days	28 days
1C:2S:1.5WB	0.17	11.04	14	19.8	8.03	11.28	16.75
1C:2S:1WB	0.18	17.51	18.97	23.12	14.68	16.41	21.89
1C:2S:0.6WB	0.2	20.13	23.7	`28.37	18.33	20.63	25.05

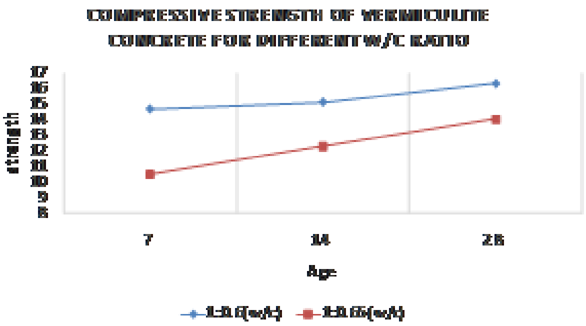
Comparison of Strength and densities of different Mixes Mix Design

Mix Design	Water content	Strength	Wet Density(Kg/m3
Vermiculite (1C:2L:6V)	1.075	3.96	1177
	1.15	4.2	1116
	1.225	4.01	1056
Vermiculite (2C:1L:8V)	1.10	6.7	1245
	1.15	5.6	1214
Vermiculite (1C:1S:1V)	0.6	16.3	1775
	0.65	15.67	1744
Vermiculite (1C:1S:2V)	0.75	10.05	1704
	0.8	9.55	1679
Vermiculite (1C:6V)	1.6125	3.14	875
LWWBC 1C:2S:1.5WB	0.17	19.8	1892
LWWBC 1C:2S:1WB	0.18	23.12	1950
LWWBC 1C:2S:0.6WB	0.2	28.37	2030
1C:2S 1FA:20W	0.6	14.79	1645
	0.7	9.15	1119
	0.8	6.67	972
	0.9	5.98	757
1C:2S 1FA:25W	0.45	21.23	1887
	0.5	19.34	1780
	0.7	10.5	1380
1C:2S 1FA:30W	0.45	27.05	1901
	0.5	20.05	1850

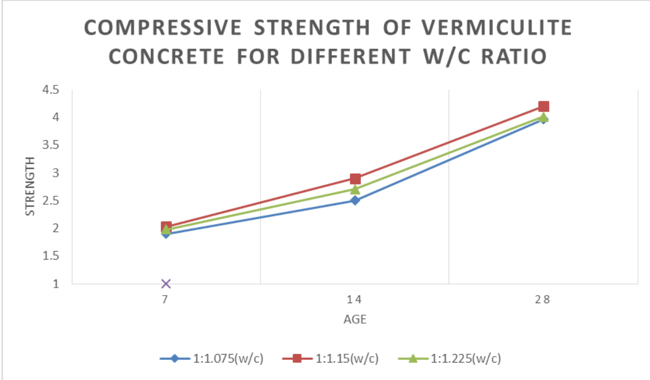
2 Cement:1 Lime :8 Vermiculite



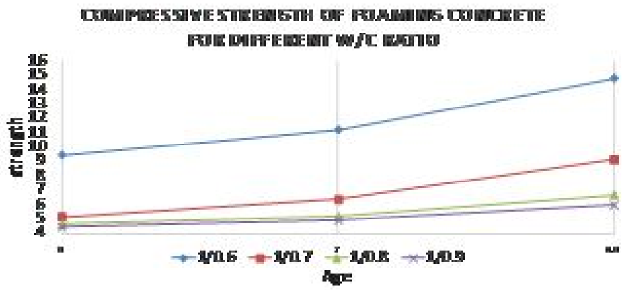
1Cement:1 Sand:1 Vermiculite



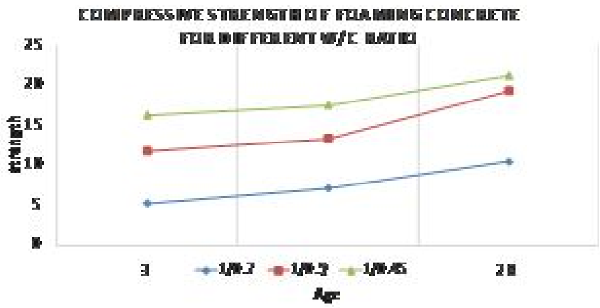
1 Cement; 2 lime; 6 Vermiculite



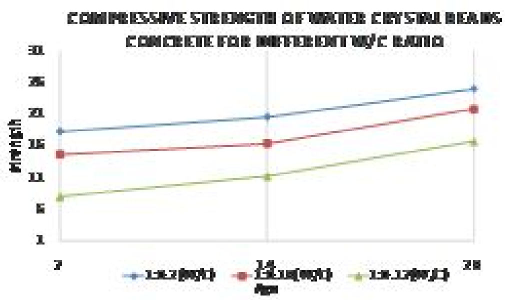
1:20 foam concentration

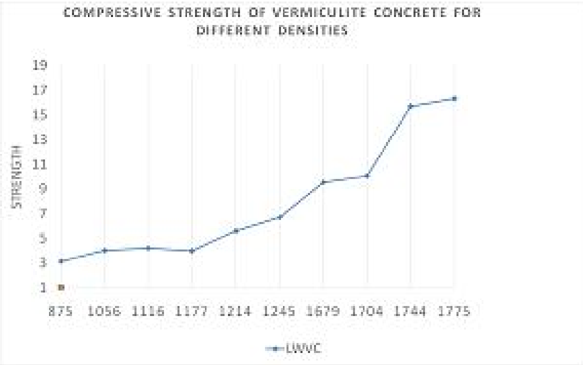


1:25 foam concentration

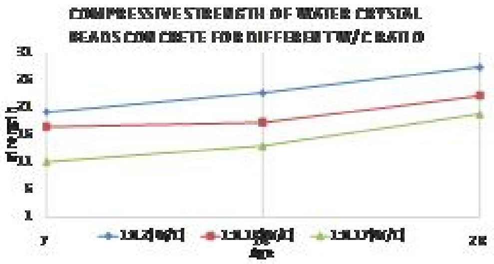


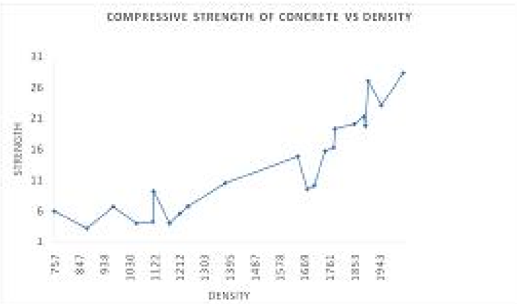
With out curing

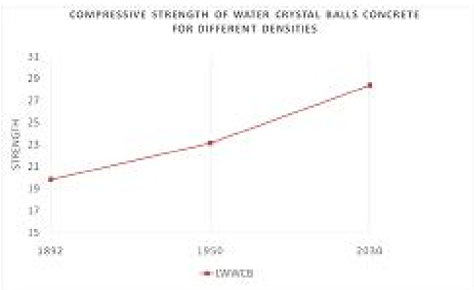




with curing







V. CONCLUSION

Based on the laboratory results and observations, the following conclusions can be drawn.

Foamed concrete

The preparation of foam plays vital role in obtaining better performance of LWFC. The foam has to be stable and dense. The preparation of foam needs special equipment to generate foam with desired specifications. The concentration of foaming agent in water increases, the density of LWFC also increases which leads to decrement of strength of concrete.

Crystal water balls concrete

The amount of crystal water balls increases, the strength of LWWCB decreases along with density.

The strength of concrete, with curing and without curing does not have much variation. As content of crystal water balls increases w/c ratio decreases.

Vermiculite

The vermiculite content in concrete increases, strength and densities decrease. For LWVC as density increases compressive strength also increases.The water absorption percentage increases with vermiculite content in LWVC. As the water absorption of vermiculite is more, this type of concrete is not recommended in places where water scarcity is there. This type of LWC is mostly suitable for insulating materials for increasing fire and sound resistance. It can also be used as filler material in the field of construction. The proportion 1C:1S:1V can be used for structural elements in construction.

Density (Kg/m^3)	Mix design	Strength(Mpa)	Applications
750 to 1250	LWVC - 1C:2L:6V LWVC - 2C:1L:8V LWVC – 1C:6V LWFC- 1C:2S(1FA:20W) (W/C=0.7,0.8,0.9)	1 Mpa to 10 Mpa	Lightweight and insulating cements for floors foundation, for heat insulation and slope for flat roofs, inter space concrete filling; thermo insulating blocks, 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.

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