BEHAVIOUR OF PARTIAL REPLACEMENT OF PUMICE STONE IN CONCRETE

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***ABSTRACT*: Concrete made with natural light weight aggregate originating from hard rock has a density within a narrow range (300kg/m^3-1840kg/m^3) because of their low specific gravity while that of normal concrete lies between (2200kg/m^3-2600kg/m^3).Lightweight concrete (LWC) has been used for more than 2,000 years (ACI 213R) (American Concrete Institute [ACI], 2003). Early notable LWC structures include the Port of Cosa, the Pantheon Dome, and the Coliseum. In modern times, structural LWC structures are widely used but to a much lesser extent than normal weight concrete. The essential characteristics of light weight aggregates are its high porosity, which results in a low apparent specific gravity. Some light weight aggregates occurs naturally; others are manufactured from natural materials or from industrial by-products.**

I.INTRODUCTION

1.1 GENERAL

Lightweight concrete (LWC) has been used for more than 2,000 years (ACI 213R) (American Concrete Institute [ACI], 2003). Early notable LWC structures include the Port of Cosa, the Pantheon Dome, and the Coliseum. In modern times, structural LWC structures are widely used but to a much lesser extent than normal weight concrete.

1.2 LIGHT WEIGHT CONCRETE

Concrete made with natural light weight aggregate originating from hard rock has a density within a narrow range (300kg/m^3-1840kg/m^3) because of their low specific gravity while that of normal concrete lies between (2200kg/m^3-2600kg/m^3).

The light weight concrete having low density helps in the reduction of dead load, increases the progress of buildings, and lowers haulage and handling cost. The weight of a building on the foundation is an important factor in design, particularly in the case of weak soil and tall structures. If the floors and walls are made up of light weight concrete it will result on considerable economy. Another most important characteristic of light weight concrete is the relatively low thermal conductivity, a property which improves with decreasing density.

1.3 CLASSIFICATION OF LIGHT WEIGHT CONCRETE

It is convenient to classify the various types of lightweight concrete by their method of production. These are:

1. By using porous lightweight aggregate of low apparent specific gravity, i.e. lower than 2.6. This type of concrete is known as lightweight aggregate concrete.

2. By introducing large voids within the concrete or mortar mass; these voids should be clearly distinguished from the extremely fine voids produced by air entrainment. This types of concrete is variously knows as aerated, cellular, foamed or gas concrete.

3. By omitting the fine aggregate from the mix so that a large number of interstitial voids are present; normal weight coarse aggregate is generally used. This concrete as no-fines concrete.

1.4 LIGHT WEIGHT AGGREGATES

The essential characteristics of light weight aggregates are its high porosity, which results in a low apparent specific gravity. Some light weight aggregates occurs naturally; others are manufactured from natural materials or from industrial by-products.

1.4.1 NATURAL AGGREGATE:

These types of aggregates are naturally available. They are classified into two types.

➢ **Inorganic Natural Aggregates**:

Diatomite, pumice, scoria and volcanic cinders are natural, porous volcanic rocks with a bulk density of 500 - 800 kg/m^3 which make a good insulating concrete

➢ **Organic Natural Aggregates:**

Wood chips and straw can be mixed with a binder to provide a lightweight natural aggregate. These are cellular materials which have air trapped within their structures once they have low moisture content.

1.4.2 MANUFACTURED AGGREGATE

They are obtained by heating suitable raw materials in a rotary kiln to incipient fusion when the expansion of the materials takes place due to the generation of gases which becomes entrapped in a viscous pyro plastic mass. Vermiculite, Perlite, Clinker aggregate are some of the examples of manufactured aggregate.

The coarse aggregate selected in this project is pumice stone.

1.5 PUMICE

Pumice stone is a natural lightweight aggregate which is formed by the sudden cooling of molten volcanic matter. Pumice is formed during the volcanic eruption of viscous magma, mostly siliceous and rich in dissolved volatile constituents, especially water vapor.

Pumice is light enough and yet strong enough to be used as light weight aggregate. Their lightness is due to the escaping of gas from the molten lava when erupted from deep beneath the earth’s crust. The pumice can float long periods of time- some time years- before it finally becomes water logged and size of its light weight and porous structure.

Pumice is a light colored, froth like volcanic glass with a bulk density in the range of 500 to 900kg/m^3. It is free from volcanic dust or clay. Pumice makes a satisfactory concrete with a density of 800 to 1800kg/m^3 and with good insulating characteristics but having high absorption and high shrinkage. It has a high thermal insulation. Its strength is about 15 to 40 Kg/cm^2.

The abundant vesicles in pumice and the thin walls between them give the rock a very low specific gravity. It typically has a specific gravity of less than one, giving the rock and ability to float on water. Normally the specific gravity of pumice stone is 0.67.

1.5.1 USES

- Pumice is widely used to makjhue lightweight concrete or insulated low density cinder blocks.
- It is also used as an abrasive, especially in polishes, pencil erasers, cosmetic exfoliants and the production of stone-washed jeans.
- When used as an additive for cement, a fine grained version of pumice called pozzolan is mixed with lime to form a light weight, smooth, plaster-like concrete.
- It is used as aggregate in light weight concrete, as landscaping aggregate, and as an abrasive in a variety of industrial and consumer products.
- The pumice is used as a decorative ground cover in landscaping and planters.
- It is used as drainage rock and soil conditioner in plantings.
- It is used as a traction material on snow covered roads.
- It is used as a traction enhancer in tire rubber and absorbent in cat litter.
- It is used as a light weight filter for pottery clay and also used as a fine grained filter media.

1.5.2 ADVANTAGES OF PUMICE STONE

- Excellent mechanical strength to weight ratio; Although approximately 30% lighter than traditional concrete, pumice stone features high strength values with significant benefits for the structure’s cost efficiency and behavior (reduced dead loads and transportation cost)
- All types of light weight concretes can be manufactured by altering the pumice stone’s granularity and the concrete composition;
  - ➢ Structural: compressive strength greater than 15 Mpa, density less than 2000kg/m^3.
  - ➢ Structural and thermal insulating: compressive strength greater than 3.5Mpa density less than 1400kg/m^3.
  - ➢ Thermal insulating: compressive strength greater than 0.5Mpa density less than 1000kg/m^3
- Lightweight concrete using pumice stone has good sound dampening properties. This is due to the pumice stone’s porous structure that traps air and high sound proofing to weight ratio.
- Pumice stone products are non-combustible and thus enhance the structures fire resistance
- Pumice stone products feature good seismic behavior. Pumice stone light weight concrete is ideal for
- Filling interior floors and shaping final elevations and inclinations before lying marble, tiles or asphalt membrane.
- Insulations as either the final layer to form insulations or thermal insulation for roofs or thermal sound insulation of interior flooring.
- Construction and repairs, where reduced permanent loads and improved seismic behavior are required.

1.6 CHARACTERISTICS OF LIGHT WEIGHT CONCRETE

➢ DENSITY

The density of light weight concrete varies from 300- 1200kg /m^3

➢ WORKABILITY

Due to low density and the characteristics texture of porous aggregates especially in the crushed state, the workability of concrete needs special attention. In general, placing compacting and finishing light weight aggregate requires relatively loss effort; even 50 or 75mm slump may be sufficient to obtain workability of the type that is shown by 100 to 125mm slump of normal-weight concrete.

➢ UNIT WEIGHT

Unit weight and strength are two properties generally sought from light weight concrete. With given materials, it is generally desired to have the highest possible strength/ unit weight ratio with the lowest cost of concrete. The air -dried unit weight of concrete is limited to a maximum of 18.40 KN/m^3. The use normal sand to control the proportions of hardened concrete tends to increase the unit weight, although this tendency is partially offset from the balancing effect of entrained air, which is invariably prescribed for improving the workability. Most structural light weight concrete weigh between 16.00 to17.60 KN/m^3; however job specifications in special cases may allow higher than18.40 KN/m^3.

➢ STRENGTH

Design strength of 20 to 35Mpa, 28 day compressive strengths are common although by using a high cement content and good quality light weight aggregate of small size (9 to 13 mm maximum) has made it possible, in some precast and pre stressing plants, to produce 40 to 48 Mpa concrete. Lightweight aggregates with controlled micro porosity have been developed to produce 70 to75 Mpa lightweight aggregate which generally weight 18.40 to 20.00KN/m^3. The ratio between the splitting tensile strength and compressive strength decreases significantly with increasing strength of light weight concrete.

➢ THERMAL INSULATION

It is about 3-4 times more than that of bricks and about 10 times than that of concrete.
●Fir resistance is excellent.
● Sound insulation is poor.

➢ DURABILITY

Aerated concrete is slightly alkaline. Due to this porosity and low alkalinity the reinforcement may be subjected to corrosion and as such, require special treatments.

➢ REPAIRABILITY

Lightweight cellular element can be easily sawn, drilled or nailed which makes for each construction and repairs

➢ ECONOMY

Due to light weight and high strength to mass ratio, the cellular products are quite economical.

1.7 ADVANTAGES OF USING LIGHT WEIGHT CONCRETE

- Decreased dead load: less mass is required to support additional weight. Structural reinforcement can be less demanding
- Higher seismic resistance: in lower densities concrete can actually absorb shock. Light weight concrete is often used in ballistic tests because of this ability. Hammer blows can be absorbed without fracturing the concrete
- Lower water permeability: greatly reduced due to the diffusion of closed cells which prevent sponging. Also reduces problems caused by rusting rebar by eliminating the problem at its sources.
- Greater insulation: Enhanced R-values, especially in the lower density Range. Again, this is more sound absorption: The transmission of sound is inversely related to the number of air/solid interfaces. Light weight concrete has a high number of these interfaces, thus more due to the increased number of air/solid interfaces.
- Increased fire resistance: Greatly improved due to low thermal conductivity. Spalling is reduced or eliminated. Adaptability: Lighter weight increases options for on-site casting. Forming can be swifter and easier due to less supported weight Simplicity: ordinary tools can be used for alterations. It can be easily sawn and sculpted, and nailed or screwed without pre-drilling.
- Handling capabilities are vastly improved. Concrete does not need to be cold, damp, dense and hard to work with.

1.8 DISADVANTAGES OF LIGHTWEIGHT CONCRETE

- Very sensitive with water content in the mixtures.
- 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.
- Mixing time is longer than conventional concrete to assure proper mixing.

1.9 APPLICATIONS OF LIGHTWEIGHT CONCRETE

- Low density cellular concrete is used for precast floor and roofing units.
- Load bearing walls using cellular concrete blocks.
- As insulation cladding to exterior walls of structures.

1.10 METHODOLOGY

- Study on basic characteristic
- Testing of material
- Mix design
- Casting of cubes
- Testing of cubes
- Analysis of results

II. LITRATURE REVIEW

I. Application of pumice aggregate in structural lightweight concrete

T. Parhizkar, M. Najimi and A.R. Pourkhorshidi

This study, presents experimental investigation on the two groups of light weight concrete are built and the physical/mechanical and durability aspects of them are studied. The results of compressive strength, tensile strength and drying shrinkage show that these lightweight concretes meet the requirements of the structural lightweight concrete. Also, the cement content is recognized as a paramount parameter in the performance of Light weight aggregate concretes.

II. Pumice aggregates for structural lightweight and internally cured concretes

Samuel Green, Nicholas Brooke and Len McSaveney

This paper presents research on the utilization of New Zealand's abundant resources of pumice aggregates for producing structural lightweight and internally cured concretes. Mixture designs were developed for lightweight concrete containing both partially saturated and fully saturated pumice aggregates. A vacuum saturation system was developed to completely saturate the normally partially saturated aggregates and consequently avoid a loss of workability attributed to the high absorption capacity of pumice. Shear strength and bond strength of pumice concrete was investigated, as well as the application of saturated fine pumice aggregates as an internal curing

Media for both high performance concrete and ready-mixed full scale thin concrete slabs with a low water cementations materials ratio. The research presented demonstrates the potential to commercially produce structural lightweight concrete containing naturally occurring pumice aggregates, while meeting the requirements of New Zealand Concrete Design Standards

III. The effects of different fine and coarse pumice aggregate/cement ratios on the structural light concrete properties without using any admixtures.

L. Gunduz, I.Ugur

Structural lightweight concrete solves weight and durability problems in buildings and structures. In order to produce the high strength concrete in the civil engineering applications, lightweight concrete mixtures containing the fine pumice aggregate (FPA) from Nevehir region in Turkey and coarse pumice aggregate (CPA) from Yali Island in the Eastern Mediterranean were tested and the research findings were discussed in this paper. To analyses the effects of FPA and CPA/cement ratios on the structural concrete engineering properties, the range of different pumice aggregate/cement (A/C) ratios of 2:1, 2 1/2:1, 3:1, 3. 1/2:1 and 4:1 by weight and cement contents of 440, 375, 320, 280 and 245 kg/m^3, respectively, were used to make pumice aggregate lightweight concrete (PALC) mixture testing samples with a slump of from 35 to 45 mm. The experimental research findings showed that PALC has strengths comparable to normal weight concrete, yet is typically 30-40% lighter. PALC showed the design flexibility and substantial cost savings by providing less dead load due to its lower density values. The properties, which increase in value and indicate the increasing quality with lower A/C ratios (high cement contents), are compressive strength, modulus of elasticity and density. Properties, which decrease in value and indicate the increasing quality, with lower A/C ratios are water absorption and carbonation depth. In all cases, lowering the A/C ratio (higher cement content) increases quality. The research showed that structural lightweight concrete can be produced by the use of fine and coarse pumice aggregates mixes without using any additions or admixtures.

IV. Effect of prewetting methods on fresh and hardened properties of concrete with coarse aggregate

Nihat Kabay, Fevziye Akoz

One of the major problems in lightweight aggregate concrete production is the high water absorption characteristic of the aggregates due to their porous structure. This problem is usually overcome by rewetting the lightweight aggregates or increasing the amount of mixing water. Since aggregate rewetting methods significantly affect fresh and hardened lightweight concrete properties, it is important to take this into account before the concrete production process.

This study is focused on the effects of three presetting methods on some fresh and hardened properties of pumice lightweight concrete. Pre-soaking, water-soaking and vacuum-soaking methods were applied to pumice lightweight aggregate prior to mixing. Test results showed that fresh and hardened

Properties of concretes with vacuum-soaked and water-soaked lightweight aggregate were significantly better than that of concretes with pre-soaked lightweight aggregate. Vacuum-soaking and water-soaking of pumice aggregate improved workability, compressive strength and drying shrinkage of pumice lightweight concrete.

V. Effect of coarse aggregate type and loading level on the high temperature properties of concrete.

Minho Yoon, Gyuyong Kim, Gyeong Choel Choe, Youngwook Lee, Taegyu Lee

When concrete is exposed to temperature changes, its durability is reduced because of the decomposition of cement metrics generation of cracks within its structure as its component materials undergo different volumetric changes. Coarse aggregates play an important role in such behavior of concrete.

We thus evaluated the influence of coarse aggregates on the fire resistance performance of a concrete structure by conducting a fire experiment under loading on two types of concrete, one with a granite-based coarse aggregate (NWC: normal weight concrete) and the other consisting of a clay-ash lightweight aggregate (LWC: lightweight concrete). LWC displayed a higher residual compressive strength than NWC under thermal load condition. NWC suffered from a large number of cracks at its interior at high temperatures, while the interior of the LWC demonstrated fewer cracks because of the voids in its interior to the mitigation of thermal expansion stress. When a load equivalent to 20% of its room temperature compressive strength was applied, both NWC and LWC demonstrated quasi-equilibrium between the thermal expansion strain and the loading-induced shrinkage strain. Whereas the 40% loading condition, the specimen exhibited shrinkage strain and its compressive strength was observed to undergo a sharp decrease from 500 °C.

VI. Laboratory Investigation of Lightweight Concrete Properties

H. Celik Ozyildirim, Ph.D., P.E.

The purpose of this study was to evaluate the density (unit weight), splitting tensile strength, and elastic modulus of LWC mixtures under different curing conditions to achieve a better understanding of the LWC properties that are essential for long-lasting and cost-effective structures. Further, the study examined the correlation between the results of the rapid chloride permeability test and the surface resistance test using the Wenner probe to investigate whether the latter could be used to predict the permeability of LWC mixtures, as it is faster and more convenient. The scope of the study was limited to LWC mixtures having different lightweight aggregates prepared and tested in the laboratory.

The results indicated that measured densities are different than those calculated from batch weights; curing conditions affect the splitting tensile strength and elastic modulus values; and the correlation between the results of the rapid chloride permeability test and the surface resistivity test for a given lightweight aggregate was good. The study recommends that fresh concrete densities be used in designing for dead load computations of LWC structures; that the curing condition be stated for the hardened concrete properties; and that the surface resistivity test be permitted for screening or acceptance of LWC specimens for permeability after the test is standardized by the American Association of State Highway and Transportation Officials.

VII. Some mechanical properties of pumice lightweight aggregate concrete incorporating rise husk ash

Kawkab H. Al-Rawi, Mazin T. Al-Kuttan, Rawa'a A. Al-Niemey

In this work to investigate the possibility of using local pumice rocks (available in the north of Iraq) for the production of structural lightweight aggregate concrete.

In this investigation, two types of lightweight concrete (LWC) were produced using pumice stone as a coarse aggregate with natural sand and also with fine pumice aggregate, the effect of incorporating high range water reducing admixture (HRWRA) synergistically with 8% rice husk ash (RHA), as a partial replacement by weight of cement, on the mechanical properties of LWAC were investigated.

Hardened unit weight, compressive strength and splitting tensile strength were investigated for all types of lightweight aggregate concrete and at various ages of curing. The inclusion of 8% RHA, as a partial replacement by weight of cement, with the optimum dosage of HRWRA (6% by weight of cement) showed considerable increase in mechanical properties at all ages of curing compared with the reference concrete.

LWAC containing fine pumice aggregate has lower air-dry density than that of sanded-LWAC. LWA concretes containing fine pumice aggregate have lower compressive strength and splitting tensile strength at all ages of curing compared to sand-LWAC.

VIII. Experimental study on light weight aggregate concrete with pumice stone, silica fume and fly ash as a partial replacement of coarse aggregate

Lakshmi Kumar Minapu, M K M V Ratnam, Dr. U Rangaraju

In this study, an attempt has been made to study the Mechanical Properties of a structural grade light weight concrete M30 using the light weight aggregate pumice stone as a partial replacement to coarse aggregate and mineral admixture materials like Fly Ash and Silica Fume. For this purpose along with a Control Mix, 12 sets were prepared to study the compressive strength, tensile strength and flexural strength. Each set comprises of 4 cubes, 2 cylinders and 2 prisms. Slump test were carried out for each mix in the fresh state. 28-days Compressive test, Tensile Strength and Flexural Strength tests were performed in the hardened state. The study is also extended for blending of concrete with different types of mineral admixtures. The test results showed an overall strength & weight reduction in various trails.

By using 20% of light weight aggregate as a partial replacement to natural course aggregates the compressive strength is promising. The density of concrete is found to decrease with the increase in percentage replacement of natural aggregate by pumice aggregate. The compressive strength of concrete is found to decrease with the increase in pumice content. With the addition of mineral admixtures, the compressive, split-tensile and flexural strengths of concrete are increased. Light weight aggregate is no way inferior to natural coarse aggregate and it can be used for construction purpose.

IX. High strength natural light weight aggregate concrete with silica fume

A.Yenigobali,, K.G.Sobolev, S.V.Soboleva, M.Tokyay.

In Turkish standards highest strength classes for light weight aggregate and pumice concretes are 30 and 16MPa. In this research selected samples of these light weight rocks were used to produce high strength light weight aggregate concretes. The binding medium was made of ordinary Portland cement, silica fume and super plasticizing admixture. For each concrete mixture properties such as unit weight, workability, compressive strength at various ages, as well as splitting tensile strength, modulus of elasticity and thermal conductivity values were determined to find the optimum quantities of materials to be used.

Tests show that it is possible to produce a natural lightweight aggregate concrete with a 28 day compressive strength of 55MPa, a dry unit weight in the range of 1700-2100kg/m^3 and coefficient of thermal conductivity value of about0.55W/m^2K. Results showed that the bleeding and shrinkage of the light weight aggregate concrete was very much less when compared to that of the conventional concrete. The usage of silica fume improved the compressive strength, split tensile strength and modulus of elasticity.

X. Fibre reinforced light weight aggregate (natural pumice stone) concrete

N. Sivalinga Rao, Y.Radha Ratna Kumari, V. Bhaskar Desai, B.L.P. Swami

Steel fiber reinforced concrete (S F R C) is a composite material developed to reduce the brittleness of concrete and dramatically increases its ductility. Steel fiber reinforced concrete (S F R C) is used extensively to line the tunnels and other underground structures, to increase the thickness of pavements, and to repair and strengthen various structures. Increasing utilization of lightweight materials in structural applications is making pumice stone a very popular raw material. More than the target means strength of M 20 concrete is achieved with 20 percent replacement of natural coarse aggregate by pumice aggregate and with 1.5 percent of fibber. Also with 40% pumice and with 0.5% of fibbers average target mean strength of M20 concrete is achieved. The compressive strength of pumice concrete is seen to increase with the fiber content and reaches an optimum value at 1.5% of fiber content and afterwards it gets decreased for various contents of pumice.

From the investigation it is observed that 20% replacement of natural aggregate by 20% pumice and with 1.5% fiber is supposed to be optimum percentage, since for this combination higher number of blows is achieved. Also pumice content of 20% without fiber is supposed to be the recommendable range to achieve optimum impact value.

III. MATERIAL PROPERTIES

CEMENT

- Fineness : 6.5
- Specific gravity : 3
- Standard consistency : 30%
- Setting time test : Initial setting time : 35min and final setting time should not exceed 10 hrs.

SAND

- Specific gravity is 2.67

PUMICE STONE

- Specific gravity of bottom-ash is 0.64

COARSE-AGGREGATE

- Specific gravity of coarse aggregate is 2.74
- Bulk density : 1673.13 kg/m^3

IV. METHODOLOGY

4.1 Mix Design

Mix Proportion

Water	Cement	Fine Aggregate	Coarse Aggregate
206(L)	412 Kg	600.92 Kg	1045.43 Kg
0.5	1	1.50	2.50

4.2 Materials required for one cube of size 150mm×150mm×150mm (w/c = 0.5)

SI No	Cement in Kg	Fine Aggregate in kg	Coarse Aggregate in kg	Water cement ratio	Pumice stone in%	Pumice stone in kg
1	1.0	1.50	2.50	0.5	0	0
2	1.0	1.50	2.0	0.5	20	0.138
3	1.0	1.50	1.50	0.5	40	0.277
4	1.0	1.50	1.0	0.5	60	0.416
5	1.0	1.50	0.50	0.5	80	0.554
6	1.0	1.50	0	0.5	100	0.693

V. TEST FOR CONCRETE

5.1 Test results for hardened concrete

S.NO	% of pumice stone added	Compressive strength		Durability test 1% HCl acid immersion		Tensile strength	
		7 days	28 days	7 days	28 days	7 days	28 days
1	0	23.43	32.80	18.77	27.80	0.74	1.90
2	20	17.21	28.27	15.19	23.22	0.60	1.86
3	40	16.32	26.70	12.11	21.90	0.50	1.71
4	60	13.11	22.19	11.01	18.02	0.47	1.66
5	80	10.09	20.36	7.22	16.85	0.43	1.58
6	100	9.36	17.84	5	12	0.35	1.50

VI. RESULT AND DISCUSSION

Replacement of 0, 20, 40, 60, 80, 100 percentages of pumice stone in coarse aggregate. 0% replacement of pumice stone gives maximum compressive, tensile and durability compared to other composition. After that 20 and 40 % replacement of pumice stone in coarse aggregate gives target m_{20} strength and durability of the concrete. After this 60, 80, 100 percent replacement of pumice stone in coarse aggregate fail to give strength and durability of the concrete.

VII. CONCLUSION

Pumice stone act as a good replacement material for coarse aggregate. It performance is less compared to coarse aggregate but it reached the target M_{20} concrete. By using this can able to prevent the demand in coarse aggregate. Light weight aggregate is no way inferior to natural coarse aggregate and it can used for construction purpose.

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