LABORATORY INVESTIGATION OF LIGHT WEIGHT CONCRETE WITH NATURAL PERLITE AGGREGATE AND PERLITE POWDER

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Abstract *– In this study the structural lightweight concrete was designed by the inclusion of natural perlite aggregate, which provides the beneficiary advantage of reducing the dead weight and therefore we obtain an economical structural Lightweight concrete. Moreover perlite powder is also added as a replacement of the cement. In this process six mixes were made with different amount of cement with or without perlite powder added. Two groups were made of those six mixes.*

In 1st group an amount of 200kg/m3 cement was added while in the second 300kg/m3 cement. The water-cement ratio in both the cases was 0.50 and 0.40 respectively. Moreover each group had 3 sub-mixes with different amount of perlite powder added as 0%, 15% and 30% respectively.

In this study the structural lightweight concrete was designed by the inclusion of natural perlite aggregate which provides it with a beneficiary advantage of reducing the dead weight and therefore we obtain an economical structural Lightweight concrete.

Moreover perlite powder is also added as a replacement of the cement. In this process six mixes were made with different amount of cement with or without perlite powder added. Two groups were made of those six mixes.

As per the experimental results, it was found out that natural perlite aggregate can be actively used to produce lightweight aggregate concrete. And from more results of strength and density it was possible to deliver lightweight with 20MPa cylindrical compressive strength. Moreover the use of perlite powder reduces the dead weight further and therefore increases performance.

KEYWORDS: **Perlite Powder, perlite aggregates, superplasticizer, light weight concrete, Compressive Strength, Tensile Strength, Slump Test and Density etc.**

1. INTRODUCTION

Structural lightweight aggregate concrete as we know is a versatile material which shows lot of charactered technical and environmental advantages and is thought to become a decisive material in future. Its varied applications are shell roofs, bridges, multi storey buildings, curtain walls, building frames, pre-cast and pre-stressed elements.

It is predominantly used to reduce dead weight of structure and reduces the risk of earthquake damages as well. Reduction in mass of a structure becomes utmost important to reduce the risk of earthquakes.

Structural advantages of lightweight aggregate therefore are its high strength/ weight ratio, better tensile strain capacity, better sound and heat isolation characteristics and lower thermal expansion coefficient due to air voids present in the aggregate.

Perlite is an volcanic rock that has a relatively high water content, typically formed by the hydration of obsidian. It occurs naturally and expands unusually when exposed to sufficient heat. Perlite is a commercial product as well as industrial mineral mainly useful for its low density after dispensation.

1.1 CONCRETE

Concrete is a composite material that consists of a cement paste within which various sizes of fine and course aggregates are embedded. It contains some amount of entrapped air and may contain purposely-entrained air by the use of air-entraining admixtures. Various types of chemical admixtures and/or finely divided mineral admixtures are frequently used in the production of concrete to improve or alter its properties or to obtain a more economical concrete.

1.2 Concrete Making Materials

1.2.1 Cement

Cement is a generic term that can apply to all binders. There is a wide variety of cements that are used to some extent in the construction and building industries, or to solve special problems. The chemical composition of these cements can be quite diverse, but by far the greatest amount of concrete used today is made with portland cements

The mixture of cement and water is called "cement paste". The function of the cement paste in a concrete is to cover the surfaces of the aggregate particles, to fill the spaces between the particles and produce a compact mass by binding the aggregates particles

1.2.2 Aggregates

Aggregates generally occupy 70 to 80 percent of the volume of concrete and can therefore be expected to have an important influence on its properties. They are granular materials, derived for the most part from natural rock (crushed stone or natural gravels) and sands, although synthetic materials such as slag and expanded clay or shale are used to some extent, mostly in lightweight concretes. In addition to their use as economical filler, aggregates generally provide concrete with better dimensional stability and wear resistance

Moderate fines contents are useful for cohesion of concrete and finish ability of concrete. Excessive fines contents increase water demand and may interfere with the aggregate-cement paste bond. Occasionally, impurities are associated with aggregates. At best, impurities impart no benefit to concrete if present in sufficient quantities, their effects can be detrimental. Aggregate is essential to the economy, stability and durability of concrete

1.2.3 Water

Water is a key ingredient in the manufacture of concrete. It is also material on its own right. Understanding its properties is helpful in gaining and understanding of its effects on concrete and other building materials.

1.3 Light Weight Concrete

Lightweight aggregate concrete is not a new invention in concrete technology. It has been known since ancient times, so it is possible to find a good number of references in connection with the use of LWAC. It was made using natural aggregates of volcanic origin such as pumice, scoria etc. Sumerians used this in building Babylon in the 3rd millennium B.C. The Greeks and the Romans used pumice in building constructions. Some of these magnificent ancient structures still exists, like St. Sofia Cathedral or Hagia Sofia, in Istanbul, in Turkey, built by two engineers, Isidore of Miletus and Anthemius of Tralles, commissioned by the Emperior Justinian in the 4th century A.D.; the Roman temple, Pantheon, which was erected in the years A.D. 118 to 128; the prestigious aqueduct, Pont du Gard, built ca. A.D. 14; and the great Roman amphitheatre, Colosseum, built between A.D. 70 and 82. With the increase in the demand for LWAC and unavailability of aggregates, technology for producing lightweight aggregates has been developed.

1.4 Lightweight Aggregate Concrete

Lightweight aggregate concrete has a lower compressive strength than normal concrete with the same w/c ratio based on the assumption that the lightweight aggregate particles have lower strength than the hardened cement paste. There are several advantages in using lightweight aggregates. These are due to their bond with the cement paste and closeness of their coefficients of thermal expansion and the modulus of elasticity compared to those of the dry cement paste. As a composite material, this type of concrete leads to a more homogenous and coherent material with a minimum of micro-cracking. Another advantage is that compatibility between the aggregates particles and the cement paste does not need to be taken into account for mix design, unlike normal concrete. At mix design, cement may be partially replaced by natural pozzolan. All these influence the properties of fresh and hardened concrete.

1.5 OBJECTIVE

In this project objective is to examine the performance of structural lightweight aggregate concrete with the use of natural perlite aggregate and to achieve the more economical structural lightweight aggregate concrete mixture while using the cement replacement with perlite powder.

Two groups of concrete mixtures were formed with different cement contents and water/cementitious-materials ratio (w/cm). Each group has three sub mixes with some percentages of perlite powder as cement replacement. Two were produced by using 0%, 15% and 30% of perlite powder as cement replacement. And One of the other sub-mixes was without perlite powder. Superplasticizer was used in all mixtures to obtain the required slump and workability.

For the mixtures formed, properties of fresh concrete like: slump, density, air-content and setting time were examined. And for hardened concrete, compressive strength and tensile strength were examined.

More than this, the properties of fresh and hardened concrete was investigated due to the effect of perlite powder. The optimum value for the percentage of perlite powder used as cement replacement was also searched.

2. LITERATURE REVIEW:

Malek Jedidi et al. (2015): He evaluated in this paper, an experimental study was carried out in order to provide more data on the effects of expanded perlite aggregate (EPA) dosage on the compressive strength and thermophysical properties of lightweight concrete at different ages. The first part of this experimental study was devoted to the choice of the proper mixing procedure for expanded perlite concrete (EPC). Thereafter, six sets of cubic specimens and six sets of parallelepiped specimens were prepared at a water-to-cement ratio of 0.70 with varying replacement percentages of sand by EPA ranging from 0% to 80% by volume of sand. Compressive strength, thermal conductivity and thermal diffusivity were determined over curing age. Unit weights for the mixtures prepared varied between 560 and 1510 kg/m^3. Compressive strength was decreased when perlite content was increased. The test results indicated that replacing natural aggregate by EPA increased the thermal resistance of the lightweight concrete and consequently, improved thermal insulation.

Anju Ramesan et al. (2015): She established and explore the suitability of recycled plastics (high density polyethylene) as coarse aggregate in concrete by conducting various tests like workability by slump test, compressive strength of cube and cylinder, splitting tensile strength test of cylinder, flexural strength of R.C.C as well as P.CC. beams to determine the properties and behaviour in concrete. Effect of replacement of coarse aggregate with various percentages (0% to 40%) of plastic aggregate on behaviour of concrete was experimentally investigated and the optimum replacement of coarse aggregate was found out. The results showed that the addition of plastic aggregate to the concrete mixture improved the properties of the resultant mix.

Plastic aggregate is a lightweight material with specific gravity 0.94. The workability of concrete increased by 50%, for a mix containing 40% plastic aggregate. Compressive strength and splitting tensile strength of concrete increased till 30% replacement of natural aggregate with plastic aggregate and on further replacement they tend to decrease but not below the target mean strength. Compressive strength increased by 9.4% and splitting tensile strength by 39% for a mix with 30 % replacement of natural aggregate by plastic aggregate when compared to control mix. Flexural strength of PCC beam and breaking load of RCC beam increased till 40% replacement. There was an improvement of 20% and 31% strength respectively. The optimum percentage replacement of natural coarse aggregate using plastic aggregate was obtained as 30%.

N. sarath kumar (2016): He described in this study that the comparative studies on partial replacement of expanded perlite as coarse aggregate. Perlite is basically the mineral obsidian. It is naturally occurring siliceous volcanic rock. Utilization of natural resources of environment is essence of any development in concrete. Perlite gives excellent insulating properties at temperature varying from very low and very high. Using expanded perlite aggregate in concrete the total amount of cement content 70% and fly ash 30% replacement of cement. The combination reduces the effect of thermal conductivity in light-weight concrete. In light weight concrete addition of perlite is reduced the density of concrete. The flexural and compressive response of concrete to be determined and 0% to 30% replacement of fine aggregate using expanded perlite. Optimum percentage of partial replacement of aggregates were obtained by conducting various strength tests such as compression and flexural strength on the casted specimens such as cubes, cylinders, prisms and beams.

T. parhizkar al. (2011): In this study, he investigates on the properties of volcanic pumice lightweight aggregates concretes. To this end, two groups of lightweight concretes (lightweight coarse with natural fine aggregates concrete, and lightweight coarse and fine aggregates 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 lightweight aggregate concretes. The compressive strength of LCNF concretes is 20 to 40 % lower than control concrete, whereas they are about 30 % lighter than control concrete. The compressive strength of LCF concretes is about 50 % lower than control concrete, whereas they are about 40 % lighter than control concrete. Only mixes with high amount of cement, meet the strength requirements of structural lightweight concrete. Therefore, these lightweight aggregates are suitable for structural lightweight concrete construction. The cement content is a prominent factor in the physical/mechanical and durability properties of lightweight aggregate concretes. Increasing the cement content leads to a lower water/cement ratio in the transition zone; hence increases the mechanical and durability properties, and decreases capillary absorption, chloride content and sulfate expansion In lightweight aggregate concretes the rate of capillary absorption and the water absorption are not directly related. For these concretes the rate of capillary absorption and the water absorption are respectively lower and higher than control concrete

Dr v. Bhaskar desai et al. (2014): He present experimental investigation an attempt is to be made to study the strength properties of light weight cinder aggregate cement concrete in different percentage proportions of 0, 25, 50, 75 and 100 by volume of light weight aggregate concrete can be prepared. By using this the properties such as compressive strength, split tensile strength, modulus of elasticity, density and shear stress etc., are studied by casting and testing around 105 samples consisting 15 no of plain cube specimens of size 150 x 150 x 150mm, 60 no of (Double Centered Notch) DCN specimens of size 150x150x150mm and 30 no of cylinders of size 150mm dia. and 300mm height.

Kamran Aghaee et al. (2014): In the present study, waste steel wires taken from steel reinforcement and formworks which were previously used in buildings and infrastructures projects, were blended with structural lightweight concrete. The scope was to replace the industrial steel fibers of controlled quality with recycled ones. Compressive, tensile, flexural and impact tests were performed observing the mechanical properties of a 28-day reinforced concrete (RC) specimen to compare with the same apparatus of RC with mixed steel wires, mixed steel fibers as well as plain concrete. The percentage of fibers on all fiber reinforced concrete (FRC) specimens was 0.25%, 0.5% and 0.75% in volume fraction of the concrete. Varying the fiber content, a similar trend in all types of FRCs was observed. It was concluded that the waste wires could be used as a suitable and promising alternative to steel fibers in structural lightweight concrete.

Kok Seng Chia et al. (2007): He have investigated the water permeability and chloride penetrability of high-strength lightweight aggregate concrete and compared to that of high-strength NWC with or without silica fume. The LWA used in this study was expanded clay and the fine aggregate used was natural sand. Three series of concrete mixes were prepared with w/c ratios 0.55 and 0.35 and with 10% silica fume as cement replacement with w/c ratio 0.35 (Table 3.10). The results indicated that a significant improvement in the permeability of the NWC from the strength level of about 40 MPa to 80 MPa due to reduced w/cm from 0.55 to 0.35; on the other permeability of the LWCs was similar at different w/cm ratios. The incorporation of 10% silica fume as cement replacement reduced the water permeability (Table 3.11) of the concrete further compared with that of the control concrete with equivalent w/cm. According to rapid chloride penetrability test (Table3.12), the resistances of concretes to chloride ion penetrations were increased with the reduction of w/c and with incorporation of silica fume.

3. Laboratory Investigation

The structural lightweight aggregate concrete with the use of natural perlite aggregate will provide an advantage of reducing dead weight of structure and to obtain a more economical structural lightweight concrete by the use of mineral admixture perlite powder as a replacement of the cement. Six mixes were produced with different cement content and with or without perlite powder. Six mixes divided into two groups according to their cement content. First group had a cementitious materials content of 200kg/m^3 and second group had cementitious materials content of 300kg/m3; also the w/cm ratios of groups were 0.50 and 0.40 respectively. Moreover, each group had three sub-mixes with 0%, 15% and 30% of perlite powder as a replacement of cement and without perlite power. All mixes had 0.5%-1.8% of accelerator superplasticizer by weight of cement.

TABLE-1 MIX proportions of Concrete

Series	Sub-mixes	C* kg/m^3	PP* kg/m^3	NPA kg/m^3	W / (C+PP)	Super-plasticizer (% of C+PP)
2M	2M1	200	0	1000	0.50	1.0
	2M2	170	30	1000	0.50	1.2
	2M3	140	60	1000	0.50	1.4
3M	3M1	300	0	900	0.40	1.5
	3M2	255	45	900	0.40	1.6
	3M3	210	90	900	0.40	1.8

3.1 Investigations on Fresh Concrete

The slump, density and air-content values of fresh concrete are tabulated in Table given below for different sub-mixes. Although the aggregates were used in the dry state, slump values of fresh concrete were between 50 mm-100 mm. The lightweight aggregate concrete used in this study was very cohesive and workable. The maximum and minimum values of the density of the fresh concrete were 1963 kg/m^3 and 1840 kg/m^3 respectively.

Table-2 Properties in Fresh State

Series	Sub-mixes	W/ (C+PP)	PP (%)	Slump (mm)	Air-content (%)	Density (kg/m^3)
2M	2M1	0.50	0	60	5.70	1870
	2M2	0.50	15	85	4.60	1890
	2M3	0.50	30	100	3.70	1880

3M	3M1	0.40	0	65	3.80	1940
	3M2	0.40	15	97	4.60	1920
	3M3	0.40	30	100	3.80	1925

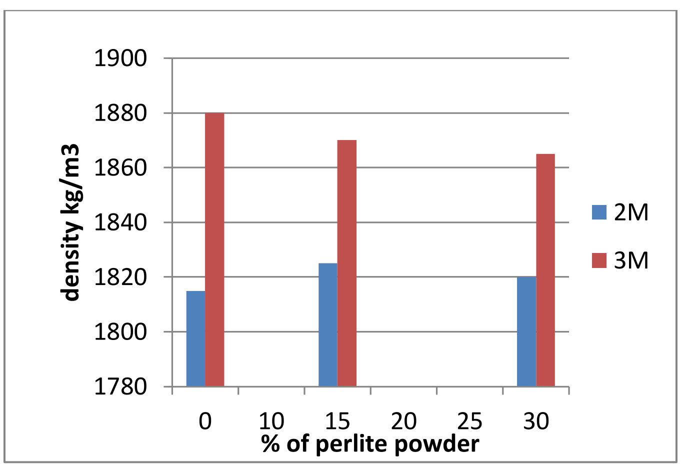
Table-3 Initial and Final Setting Times

Series	Sub-mixes	PP (%)	Setting Times (h:min)	
			Initial	Final
2M	2M1	0	6:10	10:10
	2M2	15	7:15	11:15
	2M3	30	7:35	11:30
3M	3M1	0	3:55	6:15
	3M2	15	3:55	6:15
	3M3	30	3:55	6:20

Table-4 Compressive Strength and Density

Series	Sub mix	w/c	Pp (%)	Compressive strength (Mpa)		Density Kg/m³
				7 D	28 D	
2M	2M1	0.50	0	24	32	1815
	2M2	0.50	15	18	21	1825
	2M3	0.50	30	12	20	1820
3M	3M1	0.40	0	27	38	1880
	3M2	0.40	15	24	37	1870
	3M3	0.40	30	27	35	1865

CHART-1 The effect of perlite powder addition on the density of LWAC.



3.2 Compressive strength at 7 and 28 days

Chart-2 The effect of perlite powder addition on 7 day compressive strength of lightweight concrete

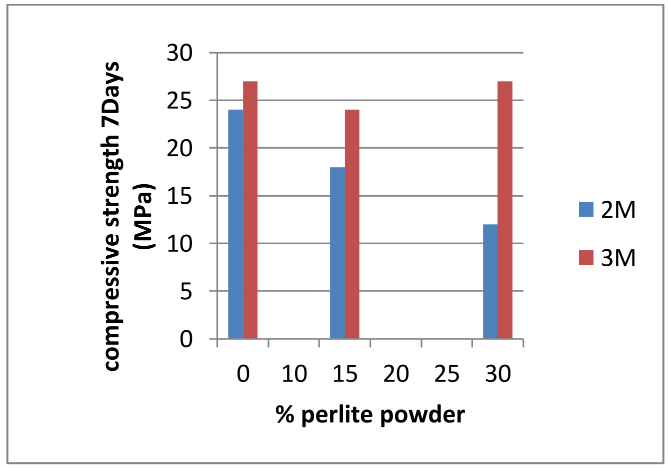
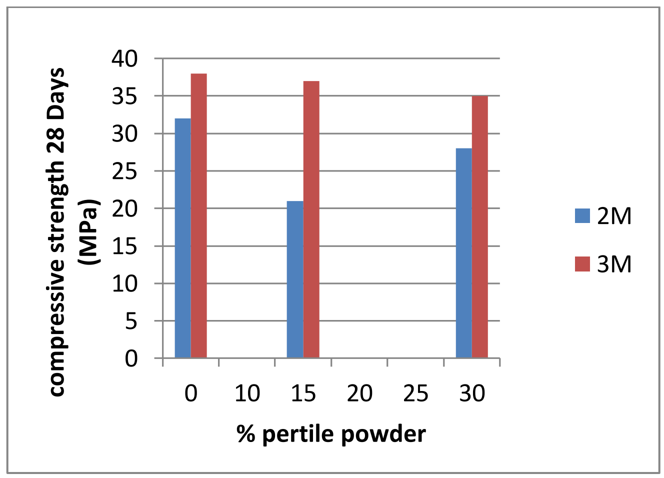


Chart-3 The effect of perlite powder addition on 28 days compressive strength of light weight concrete

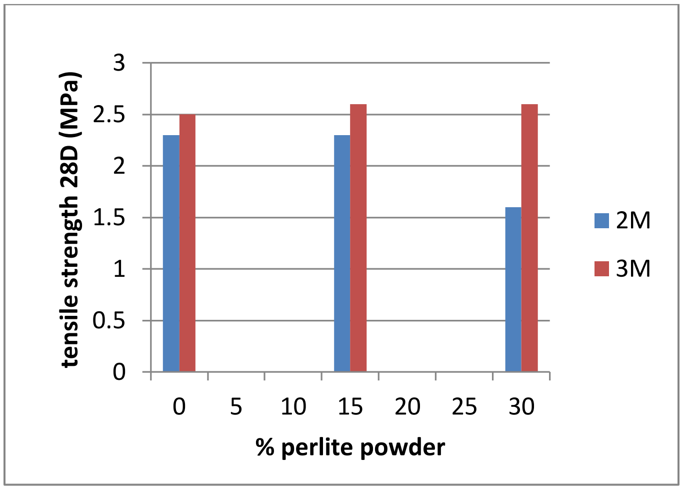


3.3 Tensile strength

Table-5 Tensile strength at 28 days

Series	Sub-mixes	W/ (C+PP)	PP (%)	Tensile Strength (MPa)
				28 D
2M	2M1	0.50	0	2.30
	2M2	0.50	15	2.30
	2M3	0.50	30	1.60
3M	3M1	0.40	0	2.50
	3M2	0.40	15	2.60
	3M3	0.40	30	2.60

Chart-4 The relationship between the % perlite powder and 28 days tensile strength



4. CONCLUSIONS

In the light of laboratory investigation presented herein, the following conclusions have been drawn;

The perlite aggregate can be used as a resource in concrete production and also can be used in low cost construction.

1. Cement with 15% and 30% replacement level of perlite powder which obtained 32, 21, 28 and 37, 39, 35 (Mpa). Compressive strength in 2M and 3M series respectively satisfies the requirement of building material to be used in structural applications.
2. The tensile strength was high at 15% and 30% perlite powder at 28 days.
3. Light weight aggregate with natural perlite aggregate has advantage of reduced density of normal weight concrete is about 2350 Kg/ m^3 and Light weight aggregate has density less than 2000 Kg/m^3.
4. As a result of this perlite aggregates has an advantage of reduced dead weight of the structure and also reduces the earthquake damages as a seismic forces are proportional to the mass of structure.

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