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Quality Improvement on Properties of Concrete by using Lightweight Aggregates

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Abstract: ***This paper presents an investigation to make the study on workability and strength properties of concrete which is made by Lightweight Aggregates {i.e. Palm Oil Shell (POS) and Pumice Aggregate (PA)}as coarse aggregate. A series of tests conducted in lab containing Slump test, Compaction Factor test, Schmidt Hammer test and Compressive Strength test was led on concrete made by ordinary aggregate as normal weight sample and concrete formed by different ratios of POS and PA separately i.e. 10% to 50% of dry weight of coarse aggregate. All the specimens were underwater for 3, 7 and 28 days as curing stage. In this experimental study, an effort has been made to concentrate the properties of a lightweight concrete M30 using the lightweight aggregate (POS and PA) as a partial replacement to coarse aggregate. The test results indicate that with the increasing amounts of normal aggregates replaced by POS and PA, the slump test, compaction factor test and strength of the Lightweight Aggregate Concrete (LWAC) has reduced gradually. As water absorption of the LWAC has been increased step by step with the increasing amounts of aggregates replaced by POS and PA. Lastly, it is concluded that the use of POS has great future than compared to PA in the construction of structural lightweight concrete.***

Index Terms: ***Palm Oil Shell (POS), Pumice Aggregate (PA), Slump test, Compaction Factor test (CFT), Schmidt Hammer test and Compressive Strength test.***

I. INTRODUCTION

Highlight Nowadays concrete trade is the main consumer of limited natural resources, such as water, sand, gravel and crushed rock [1]. Concrete is strong in compression and has good resisting properties. The production of concrete by means of normal weight aggregates such as; gravel and granite has led to a decrease in natural rock deposits and to continuous exploration of the deposits, which could lead to environmental damage and ecological imbalance, the need to investigate and appropriate replacement material is to replace the coarse aggregates in the production of concrete [2]. According to [3], the overall volume of concrete is occupied by aggregate is between 70% to 80%. In concrete huge amount of aggregates are occupied, so it is expected that aggregates have a deep impact on the properties of concrete and its performance. Aggregates plays a vital role in making concrete into an engineering material. Their volumetric stability tends to provide concrete, and also have a common influence over deformity- related humidities such as concrete shrinkage. Concrete is an artificial material which is used for different structural purposes and it is similar to stone. The density of Normal Weight Concrete (NWC) is 2400 kg/m^3. Concrete with the ranges of 500 kg/m^3 to 2000 kg/m^3 can be considered as LWC. Concrete made by using palm oil shell and pumice aggregate could be characterized as LWC. On the other hand, LWAC was made using aggregates of volcanic origin such as Pumice and agriculture waste such as palm oil shell are shown in Fig 1 and Fig 2. LWAC are of different types, depending upon the formation of the mortar mix, the aggregates are used. The characteristics of the aggregates differ significantly, depending on their raw materials and performance. The use of LWAC is increasing day by day, various research and expansions are going on the global to develop high performance in LWAC [4]. This paper will focus on important material properties related with the workability and strength as well as the performance of the material when introduced as a LWAC. A brief review on LWAC materials associated with the current strength properties from the available studies are presented below: As per Bryan, Dennis S.P (3) Natural lightweight aggregates (NLWA) may be defined as basically low bulk density and natural mineral materials. In construction trade, the main control is on weight reduction because it equates to cost savings. NLWA products contain lightweight Portland cement concrete and lightweight concrete masonry units due to their lower density. Also, some NLWA take part in standard weight building aggregates for use on the road and common backfill material based on the location. Mannan and Ganapathy [4] led a test on the mix design of the LWC with POS aggregates. They determined that methods for the mix design of POS concrete differ widely with crushed stone aggregates from those of normal concrete. The design depending on the characteristics of the aggregates was also revealed. Owens, P.L. (5) had declared that since from long period the LWC was used for structural purposes. According to his study, the LWAC is a material with low bulk density and often made with sphere-shaped aggregates.

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The structural LWAC ranges in density from 1400 kg/m^3 to 2000 kg/m^3 compared to NWAC for 2400 kg/m^3. Hossain [5] considered that POS aggregate has porous nature, high absorption and low volume density. Due to a low density of bulk, the hardened concrete in relation to conventional granite concrete was found to be lighter This decreases the total dead load on the structure, which means that the total construction costs are saved significantly. In countries where the existence of an earthquake is unavoidable, there the harmful inertia forces influence the structures to reduce forces ultimately, as these forces are proportional to the weight of the structure, hence in that particular case the lightweight nature of resulting concrete plays a crucial role. Pumice aggregates have higher water absorption i.e. of value about 37% than the palm oil shell. In general, most LWA generally have higher absorption values than conventional aggregates.

II. METHODOLOGY

Submit This study focuses on the compressive strength and workability of LWAC. Mix designs of the concrete with the different percentage of POS and Pumice aggregates were developed separately. Slump test and compaction factor test was led to measure the workability of the mix designs [6]. Upon preparation of the lightweight aggregate concrete samples, they were cured in underwater for particular ages of 3, 7 and 28 days. Compressive strength test was conducted to measure the strength of the lightweight aggregate concrete and comparisons is made with normal weighted concrete.

III. MATERIALS AND MIX DESIGN

The M30 concrete mix design was made using IS:10262-2009 method for the adoption of ordinary concrete constituents In the sequence of present study, the NWC has been replaced in equal proportions of five percentages i.e., 10%, 20%, 30%, 40% and 50%. Different specimens have been cast and tested for studying the properties of concrete. Throughout the investigation process the water cement ratio of 0.49 is kept constant.

The preliminary part of the study has been programmed in the consecutive steps.

Step-1: The main ingredients of the concrete viz., fine aggregate, coarse aggregate (granite), cement, water and LWA (pumice and palm oil shell) have been acquired from various places.

Step-2: Materials testing of lightweight concrete has to be done based on mix proportions.

Step-3: Following tests to be studied in this step i.e. Slump test, Compaction factor test, Schmidt hammer test and Compressive strength test.

The detailed description of each material that were required for this study is discussed below:

A. Cement: - Conforming to ISI standards, Zuari Cement (OPC) of 43 grade Cement Brand was locally available [7]. Different tests according to IS 8112- 1989 have been carried out. It has been determined,

- Specific gravity of cement = 3.10
- Standard consistency, % = 34
- Initial and final setting time, in minutes = 43 and 128

B. Fine Aggregate: - Natural sands available on site are obtained and are found to conform to Table IS 383- 1970 grading zone- III. It has been found that several tests were performed in accordance with the procedure given in IS 383(1970).

- Specific Gravity of fine aggregate is 2.60

C. Coarse Aggregate (Granite): - From the laboratory a crushed stone aggregate was obtained which confirms IS 383-1970 with 10 mm and 20 mm aggregation sizes. It was tested on different properties, for example

- Specific Gravity = 2.24.
- Fineness modulus = 6.7
- Bulk density, kg/m^3 = 1800
- Water absorption, % = 0.71

D. Light Weight Aggregate

(a) Pumice: - Pumice is an environmentally friendly material and naturally abundant aggregate resource around the world. Since long ago for the time being pumice is utilized in lightweight concrete. Concrete structures are usually designed to use their compressive strength. LWA (pumice) is procured from Mumbai, which was shown in Fig. A.

- Size of LWA is 10mm and 20mm
- Specific Gravity of pumice = 1.06
- Bulk density, kg/m^3 = 574.5
- Water absorption, % = 46.23

Figure A. Pumice Aggregate

(b) Palm oil Shell (POS): - POS were used to replace the coarse aggregate. They were collected from Palm oil mill owned by Godrej Agro vet Ltd, A.P, which was shown in Fig. B.

- Specific gravity of palm oil shell is 1.15
- Bulk density = 590 kg/m^3
- Water absorption, % = 33.30

Figure B. Palm oil shell

E. Water reducers (SP): - Super plasticizers (Conplast SP430) was used in the concrete to improve the workability of the fresh LWA concrete. Conplast SP430 is a water reduction admixture of high- quality concrete.
It is a highly effective dual action superplasticizer for producing free- flowing concrete or as a significant water-reduction agent to promote high early and ultimate strength.

F. Concrete Mix Design

The mixture proportioning which is commonly called mix design. Mix design is a process to let engineer to select the appropriate constituents of the concrete and defining their relative amounts with the quantities of

Table: I Mix Proportions for (M30) Grade for POS

Mix No.	Content kg/m^3				
	POS	OPC	Water	F. A	C.A
1(0%)	0.00	395	197	650	1185.0
2(10%)	118.5	395	197	650	1066.5
3(20%)	237.0	395	197	650	948.0
4(30%)	355.5	395	197	650	829.5
5(40%)	474.0	395	197	650	711.0
6(50%)	592.5	395	197	650	592.5

making concrete of certain lesser characteristics, especially consistency, strength as economically as possible. They were soaked 24 hours in the water and dried air in the lab. Eight concretes were produced for each type of concrete mix proportions and were tested at ages of 3, 7 and 28 days [8]. Hence, total of 56 cubes were produced for the tests. Ordinary Portland (Type I) and the uncrushed aggregate (20 mm) were used in this study. The mix proportions for LWA are shown in Table I and Table II.

Table: II Mix Proportions for (M30) Grade for Pumice

Mix No.	Content kg/m^3				
	PA	OPC	Water	F. A	C.A
1(0%)	0.00	395	197	650	1185.00
2(10%)	123.76	395	197	650	1113.84
3(20%)	185.64	395	197	650	1051.96
4(30%)	247.52	395	197	650	990.08
5(40%)	309.40	395	197	650	928.20
6(50%)	371.28	395	197	650	866.32

IV. RESULTS AND ANALYSIS

A. Slump Test

Slump is a measurement of consistency. The slump is the distance between a 12- inches (300 mm) truncated cone of concrete and the slump down when the moulding cone is removed. The slumps for the concretes of POS and Pumice ranged from 79.0 mm to 162.5 mm and 91.5 mm to 162.5, according to Table III and Table IV. The 10 % to 30 % slumps can be categorized as high workability because they are in between of 145.0 mm to 160.5 mm for POS and 148.5 mm to 160 mm for Pumice. The mix with 40 % can be categorized as medium workability. From the results, [9] the slumps decrease when the percentage of POS and Pumice aggregate replacement with the coarse aggregate is increased, which was shown in Fig. C of slump heights with different percentages of LWA.

Table III: Slump Test for different % of POS

Palm Oil Shells (POS)	Coarse Aggregate	SLUMP (mm)		
		1	2	Avg.
0 %	100%	160	165	162.5
10 %	90%	161	160	160.5
20 %	80 %	168	170	169.0
30 %	70 %	145	145	145.0
40 %	60 %	90	92	91.0
50 %	50 %	78	80	79.0

Table IV: Slump Test for different % of Pumice

Pumice Aggregate	Coarse Aggregate	SLUMP (mm)		
		1	2	Avg.
0 %	100%	160	165	162.5
10 %	90%	162	158	160.0
15 %	85 %	157	152	154.5
20 %	80 %	149	148	148.5
25 %	75 %	112	110	111.0
30 %	70 %	91	92	91.5

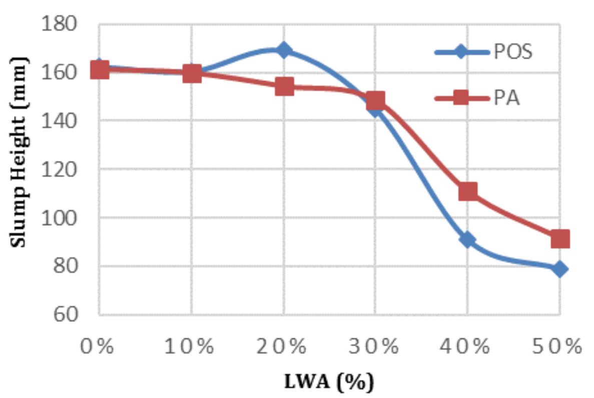

Figure C. Slump Heights for different % of LWA

B. Compaction Factor Test

The compaction factor of the POS and Pumice aggregate concrete ranged from 0.83-0.80 and 0.88-0.81. The compaction factor lies between 0.8 to 0.92 for the standard range of concrete [10]. This test is mainly suitable for dry mixes for which the slump test is not agreeable. For normal kind of workability, the sensitivity of compaction factor is reduced at outside of the concrete and is normally inadequate for compacting factor greater than 0.92. Currently, to regulate the workability of concrete this test is commonly replaced by the slump test. The compaction factor test's result is ranged from 0.83 to 0.80 which can be considered as a kind of medium workability according to Fig. D.

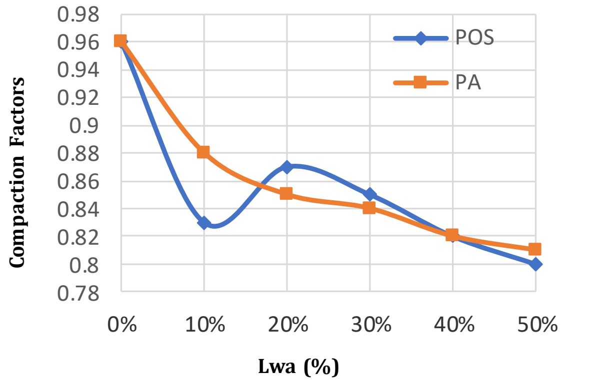

Figure D. Compaction factor for different (%) of LWA

C. Schmidt Hammer Test

Rebound hammer also named as Schmidt hammer which is normally used for testing the quality of hardened concrete in a structure. Fig. E and Fig. F shows the Rebound hammer test results for LWA (POS & Pumice) concrete specimens as strength of the specimens increases with age [11]. The difference in results of Rebound hammer test and compressive strength test maybe due to a surface area affected by the irregularity of the concrete surface due to the presence of LWA (POS & Pumice) on the specimens.

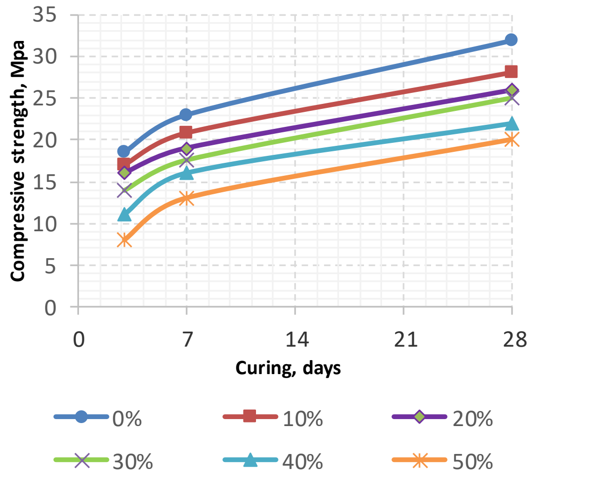

Figure E. Rebound hammer strengths of POS in Different curing days

The rebound number is not that accurate due to the different point to test the strength. The rebound hammer may hit the aggregate which is strong adequate and indicates higher rebound number.

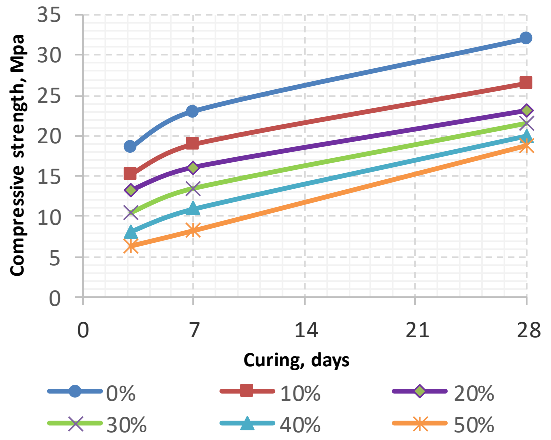

Figure F. Rebound hammer strengths of Pumice in Different curing days

D. Compressive Strength Test

Nowadays the most common method of determining the concrete strength is to test in simple compression [12]. The concrete with 10% POS and Pumice replacement exhibited the best strength which is over 33.2 MPa and 32.0 MPa, and it is 7.6 MPa and 8.8 MPa lesser than the control. In Figs. G & H, Compressive strengths are shown for particular ages of 3, 7 and 28 days. Each three bars show one category i.e. 0% POS 10 % POS etc. similarly 0 % Pumice,10 % Pumice etc. LWA (POS & Pumice) and compressive strength of the concrete specimen are inversely proportional to each other i.e. when percentage of LWA (POS & Pumice) increases, the cube strength of concrete sample decreases. It is also clear that 0% LWA obtains the ultimate strength, as LWA gradually substitutes the coarse aggregate, so the concrete strength is slowly dropped. The fact that LWA materials are lightweight and less strong than the ordinary coarse aggregate can illustrate this [13]. In addition, a decrease in concrete strength resulting from an increase in the additional percentage of LWA could be achieved through irregular LWA shapes. The highest found in the 0 % LWA as coarse aggregate (Control), the average compressive strength is 40.8 MPa. For the replacement of coarse aggregate with LWA (POS & Pumice), the highest compressive strength in 28 days with 10 % POS & 10 % Pumice is 33.20 MPa and 32.0 MPa. Hence from the Figs 7 & 8, the results meet the requirement of structural LWC. Conferring to the specification [1], the least compressive strength in structural LWC for 28 days is 17.0 MPa.

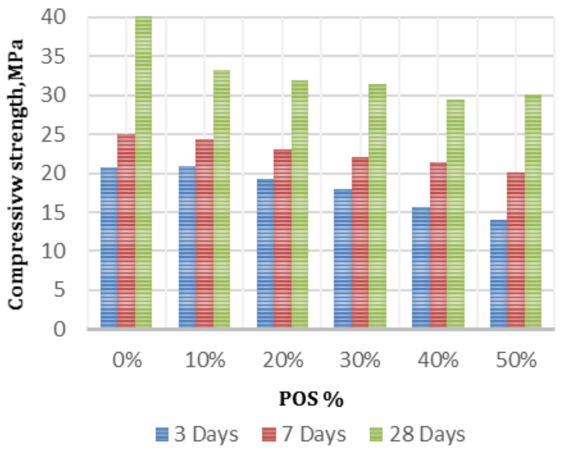

Figure G. Compressive strengths of Different % of POS

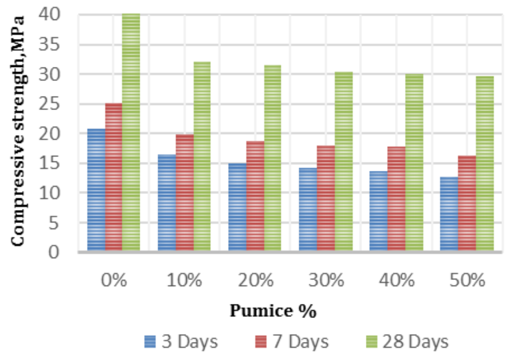

Figure H. Compressive strengths of Different % of Pumice

V. CONCLUSIONS

1) The specific gravity of LWA (POS & Pumice) are 1.15 & 1.06; that shows LWA are approximately 60% lighter than normal coarse aggregates.
2) The 24 hours' water absorption capacity for LWA (POS & Pumice) is 33.30 & 46.23, which is much higher than normal gravel aggregates.
3) Increase in percentage of replacement by LWA (POS & Pumice) decreases workability of concrete.
4) The maximum and minimum compressive strength of concretes with LWA 10 % and LWA 50 %, respectively, shows that the compressive strength of specimens of LWA concrete depend on the sample amount of LWA. However, the strength of the samples depended on the two variables, i.e. The minimum structural requirement required for lightweight concrete was met for LWA (POS & Pumice) and curing period.

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