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STRENGTH OF LIGHTWEIGHT SINTERED PULVERIZED FUEL ASH AGGREGATE CONCRETE WITH HYBRID FIBRES

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Abstract

Worldwide commercial demand of lightweight strong aggregate has increased because of its less self-weight than normal weight aggregate, for also structural applications. Lightweight strong aggregates are available naturally in limited quantity. Synthetic lightweight aggregate can be produced from fly ash. Fly ash is a byproduct while burning coal for electricity, since other sources for electricity, hydropower and nuclear power are limited in resources. Fly ash is pollutant. Hence, its disposal is of increasing concern all over the world. Synthetic lightweight aggregate produced from fly ash is a viable source of structural aggregate material and it will be a solution for these environmental challenges. In this study, artificial lightweight aggregates made from pulverized fuel ash are used instead of granite aggregates in concrete along with steel fibres, polyester fibres and results are presented here. The compressive strength of M20 lightweight aggregate concrete (LWAC) is around 27.75N/mm^2. With 0.75 percent steel fibre (LS75P0), it is 35.30 *N/mm^2 and with 0.75 percent steel fibre and 0.3 percent polyester fibre (LS75P3), it is 40.60 N/mm^2. On adding steel fibre and polyester fibre to LWAC, the compressive strength of concrete increases by 31.20 percent. The findings of this study include the respective Youngs Modulus.*

Keywords: Lightweight aggregate, Steel fibres, Polyester fibres, fly ash, Strength

1. Introduction

The planet is facing Climate change and other environmental impact challenges at everywhere and they lead to frequent occurrence of Flood, Earthquake, Cyclone, Hurricane, Tsunami and other natural calamities which affect the life of human beings and other life supporting system. The future viability of the concrete industry will be determined by its response to the global issue of sustainability [1]**.** Burning coal for electricity is inevitable since other sources like hydropower and nuclear power are limited in resources and there are also other technical drawbacks. In the thermal power production, waste flyash disposal is of increasing concern all over the world. Also fly ash is pollutant. There is a need to develop novel reuse applications for fly ash that provide both environmental and economic benefits. India is utilizing only 5 percent out of 85 million tones per year fly ash production whereas Denmark and Netherlands are utilizing 90 and 100 percent in various ways including artificial aggregates[2]. In recent years there has been renewed interest in lightweight aggregate concretes, in particular for production of high strength concretes that can be used for bridge construction and other special applications such as off-shore structures [2-7]. Unplanned exploitation of rocks may lead to landslides of weak and steep hill slopes [8]. On the other hand, there is worldwide environmental, economic and technical impetus to encourage the structural use of LWAC [9-10]. Y.ke et al studied the influence of volume fraction and characteristics of LWA (expanded shale and expanded clay) on the mechanical properties of concrete and state that tensile strength of aggregates controls the lightweight aggregate concrete [11]. Low volume of steel fibre increases cylinder splitting tensile strength and modulus of rupture, although it has little effect on compressive strength, wherein silica fume is also used in LWAC [12]. The scope of this study includes the compressive strength of lightweight aggregate concrete with the addition of steel fibre and polyester fibre without silica fume.

2. Experimental Investigations

2.1. Materials

2.1.1. Cement

Ordinary 53 grade Portland cement is used in this study. Its specific gravity is 3.15 and finess (blaine) is 290 m^2/kg. Its chemical composition are given in Table 1

Table 1. Characteristics of cement

Chemical characteristics	In percentage
Silica (SiO_2	21.90
Alumina (Al_2O_3)	6.56
Ferric oxide (Fe_2O_3)	4.13
Calcium oxide (CaO)	61.93
Magnesium oxide (MgO)	1.40
Sodium oxide (Na_2O)	0.36
Potassium oxide (K_2O)	0.42
Sulphuric anhydride (SO_3)	2.00
Loss on ignition (LOI)	1.30

2.1.2. Aggregates

Lightweight aggregates manufactured from pulverized fuel ash as raw material is used in the production of Lightweight concrete. The size of the aggregate is ranging from about 1mm to 14mm. Bulk specific gravity for aggregate is 1.23 and apparent specific gravity for aggregate is 1.74. The analysis of the elements is given in Table 2.

Table 2. Elements analysis

Element	Weight%	Atomic%
Na	1.35	1.89
Mg	3.39	4.51
Al	21.18	25.38
Si	40.57	46.70
K	4.32	3.57
Ca	7.34	5.92
Ti	1.68	1.13
Fe	10.19	5.90
Cu	4.65	2.36
Zn	5.35	2.64
Total	100.00	-

2.1.3. Fine Aggregate

For all the concrete mixes normal weight sand is used. The river sand has the specific gravity of 2.64, confirming to grading zone II as per IS: 383-1970.

2.1.4. Water

Potable water is used for mixing lightweight aggregate concrete.

2.1.5. Polyester fibre

The Polyester fibres having filament diameter 30microns, 12mm length, and specific gravity 1.36 are used in this research as shown in Figure 1. The tensile strength of fibres is 4GPa and the melting point is above 250^{o}C.

Figure 1: Polyester fibres

2.1.6. Steel fibre

The diameter of the fibre is 0.55mm. Cold drawn wire fibres of 35mm length with hooked ends, glued in bundles having an aspect ratio of 64 are used as shown in Figure 2. Fibre wire tensile strength is 1100 N/mm^2 and fibres confirming to ASTM A820 Standards.

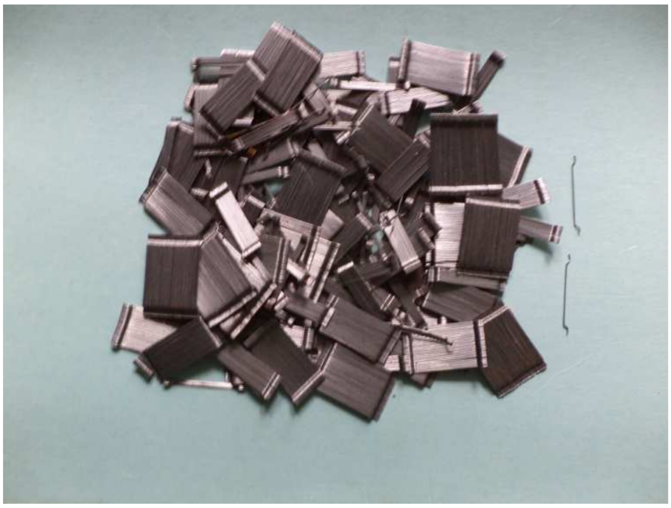

Figure 2: Steel fibres

2.2. Lightweight aggregate properties

A portfolio of tests is conducted on the lightweight aggregates. The aggregate is almost spherical in shape. The Void content in the aggregate is 34% which is determined by the rodding. Angularity number (AN) is 1. The microstructure of the aggregate is analyzed by microscopic methods. Thin section and powdered form are first analyzed by petro graphic microscopy. For higher resolutions a Scanning Electron Microscope (SEM) with a field emission gun is utilized. The SEM analysis is performed under low vacuum mode with a low nitrogen pressure. Micro chemical analysis is carried out by a micro X-ray fluorescence spectrometer (MXRF) and by the EDX system attached to the SEM with five numbers of iterations. The SEM micrographs of the Fly ash based aggregate is shown in Figure 3[13].

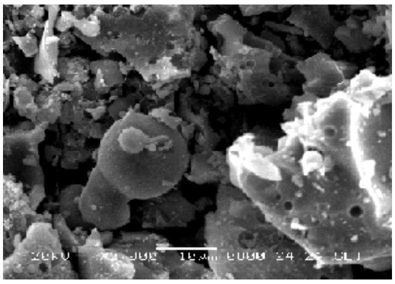

Figure 3: Scanning Electron Microscope (SEM) analysis of ash aggregate

The elemental composition of the aggregate was always rich in silica, aluminum, potassium and calcium as noticed in Figure 4 and Table 2.

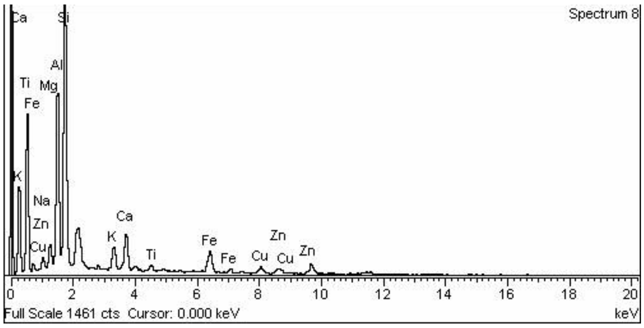

Figure 4: Chemical composition of the ash aggregates in the corresponding spectrum

The presence of Hazardous elements is almost within tolerable limits. The ash based aggregates are lighter and more porous in nature. The unit weight of aggregate, determined in an oven- dry condition is 748 kg/m^3. Bulk specific gravity for aggregate is 1.23 and apparent specific gravity for aggregate is 1.74. Percentage of water absorption is 24% which is several times more than that of granite. This phenomenon may help to reduce the drying shrinkage cracks in concrete [13].

2.3. The preparation of test specimens

To mix the concrete ingredients thoroughly, a laboratory type pan mixer is used. For each batch, quantities of ingredients are weighed as per M20 mix design[14,15] and also to suit to the capacity of the pan mixture which is shown in Figure 5. Steel moulds are used to cast the cube specimens of size 100mm x 100mm x 100mm and cylinder specimens of size 150 mm diameters x 300mm height. SP is added and the cohesive concrete mix is compacted in steel moulds using a table vibrator. The specimens are demoulded after completion of 24 hours of casting and they are immersed in water for the curing process

Figure 5: Laboratory type pan mixer

2.4. Tet Setup

The test set up for modulus of elasticity of concrete, consists of computerised universal testing machine and other accessories which is shown in Figure 6. Extensometer was attached with the specimen. The machine displays the data like peak displacement, displacement at peak load etc.,. The machine is also used for compressive strength determination.

Figure 6:. Test setup

3. Results and discussion

The concrete specimens without fibres and with different types of fibres are tested in Universal testing machine for compressive strength at 7 days and 28 days and for modulus of elasticity of concrete at 28 days. The test results are discussed as below.

3.1. Compressive strength

The results of compressive strength at 7 days and 28 days are given in Table 3 and plotted as in Figure 6&7. The additions of steel fibres and Polyester fibres to lightweight aggregates concrete increase the compressive strength of lightweight aggregate concrete.

Table 3. Compressive strength

Sl. No.	Steel Fibre (%)	Polye-ster Fibre (%)	Cube design.	7 days Strength in (N/mm^2)			Average Strength (N/mm^2)	28 days Strength in (N/mm^2)			Average Strength (N/mm^2)
				cube1	cube2	cube3		cube1	cube2	cube3	
1	0	0	LWC00	22.20	21.70	21.20	21.70	28.00	28.25	27.00	27.75
2	0	0.3	LS0P3	24.10	24.60	23.90	24.20	30.75	29.75	30.25	30.25
3	0.75	0	LS75P0	28.60	27.20	29.10	28.30	35.90	35.20	34.80	35.30
4	0.75	0.3	LS75P3	31.50	32.70	32.10	32.10	39.50	41.30	41.00	40.60

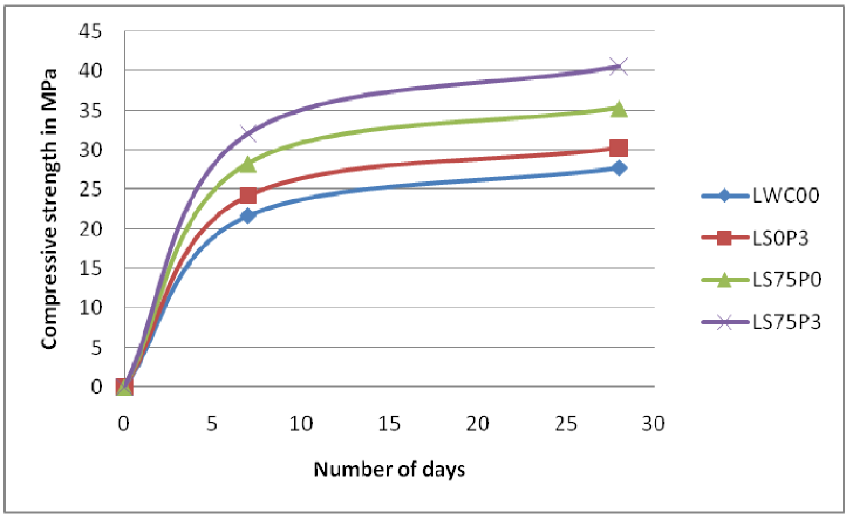

Figure 7: Compressive Strength of LWC with and without different types of fibres

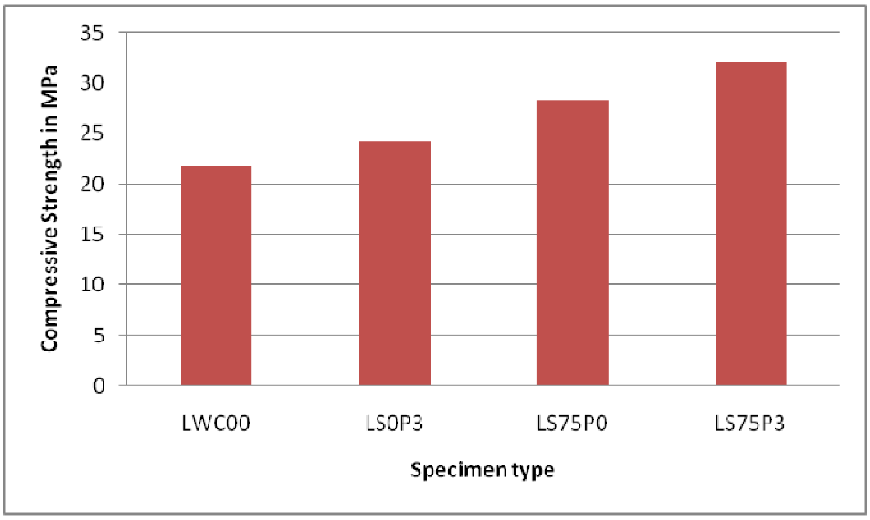

Figure 8(a): Comparison of 7 days compressive strength

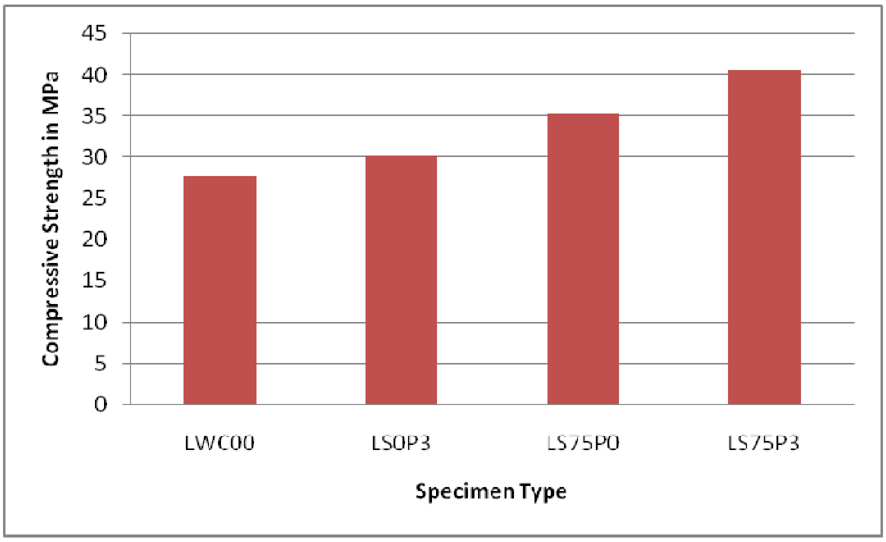

Figure 8(b): Comparison of 28 days compressive strength

The seven days compressive strength of lightweight aggregate concrete with 0.25 percent steel fibre (LS75P0) is 23.32% more than that of lightweight aggregate concrete (LWC00). But compressive strength of lightweight aggregate concrete with 0.3 percent Polyester fibre (LS0P3) is only 11.52% more than LWC00. The compressive strength of lightweight aggregate concrete with combination of both the fibres namely 0.75 percent steel fibre and 0.3 percent Polyester fibre (LS75P3) is 32.40% more than that of LWC00. The hybrid fibre reinforced concrete gives more compressive strength than individual steel fibre reinforced concrete or Polyester fibre reinforced concrete.

The 28 days ultimate compressive strength of LS75P0 is 21.39 % more than that of lightweight aggregate concrete (LWC00), whereas LS0P3 is 8.26 % more than that of lightweight aggregate concrete. The hybrid fibre reinforced concrete (LS75P3) gives more compressive strength than individual steel fibre reinforced concrete; polyester fibre reinforced concrete and LWC00 in terms of measurement are 13.05%, 25.49% and 31.20% respectively.

3.2. Modulus of Elasticity

The Young's modulus (Ec) of lightweight aggregate concrete, LS0P3, LS75P0 and hybrid fibre (LS75P3) reinforced concrete are determined as the secant modulus measured at the stress level equal to 40 percent of the average compressive strength of concrete cylinders. Six cylinders of 150mm x 300 mm are casted for each category. Three of these cylinders are used to determine the elastic modulus. Other three cylinders are tested to determine the compressive strength. All the specimens are capped in accordance with the Indian Standard. The test set-up for measuring the elastic constants shown in Figure 6 and the results are shown in Table 4 and in Figure 9.

Table 4. Modulus of Elasticity of Lightweight concrete

S.No	Steel Fibre (%)	Polyester Fibre (%)	Cube designation	Average in GPa
1	0	0	LWC00	19.9943
2	0	0.3	LS0P3	20.8741
3	0.75	0	LS75P0	23.1810
4	0.75	0.3	LS75P3	25.1720

Young's modulus (E_c) of lightweight aggregate concrete containing steel fibre (LS75P0) is 13.74% more than that of lightweight aggregate concrete (LWC00), whereas Polyester fibres (LS0P3) is 4.40% more than that LWC00. The hybrid fibre reinforced concrete (LS75P3) gives more E_c than individual steel fibre reinforced concrete, polyester fibre reinforced concrete and LWC00 and in terms of measurement are 7.91%, 17.07% and 20.57 % respectively.

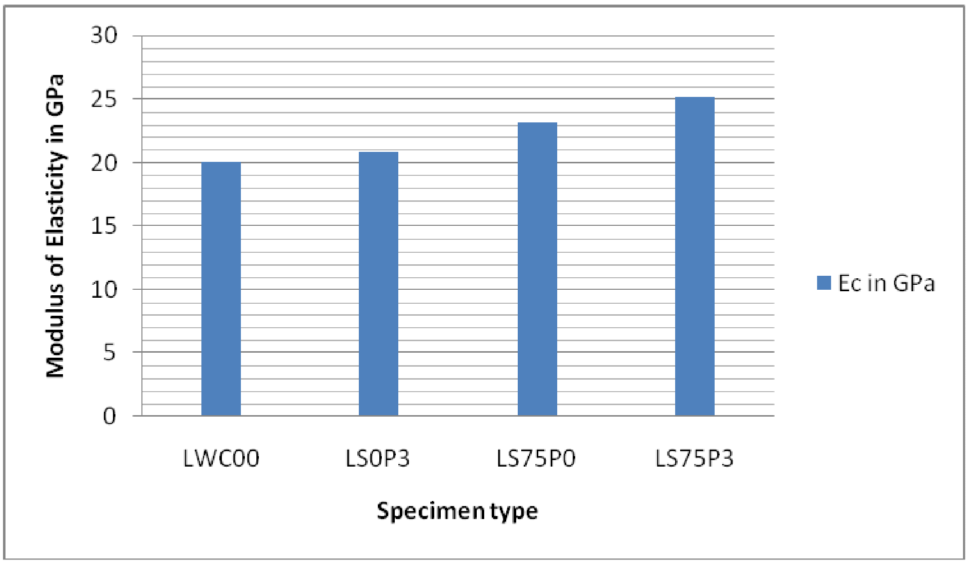

Figure 9: Comparison of The Modulus of Elasticity of LWC

4. Conclusions

The following conclusions are drawn from this experimental work. The compressive strength of concrete increases it with addition of fibres. In both 7 days and 28 days, lightweight aggregate concrete with containing 0.75 % steel fibre (LS75P0) exhibits more compressive strength than the lightweight aggregate concrete (LWC00) and the lightweight aggregate concrete with 0.3 percent Polyester fibre (LS0P3). The hybrid fibre reinforced concrete (LS75P3) gives more compressive strength than individual steel fibre reinforced concrete, Polyester fibre reinforced concrete and LWC00 and in terms of measurement are 13.05%, 25.49% and 31.20% respectively.

Young's modulus (E_c) of lightweight aggregate concrete containing hybrid fibre (LS75P3) is higher than individual steel fibre reinforced concrete, Polyester fibre lightweight concrete LWC00 and in terms of measurement are 7.91%, 17.07% and 20.57 % respectively. Lightweight aggregate hybrid fibre reinforced concrete has excellent properties and may well-suit to manufacture precast concrete products that are needed in rehabilitation and retrofitting of structures after a disaster in addition to conventional construction practice and also structural applications.

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References

[1] John.P.Ries et. al., Lightweight concrete –Two Millennia of proven performance, ESCSI, IS 7001, 2003.
[2] Shenbaga R., Kaniraj and Vasant, G., Havanagi,, Correlation analysis of laboratory compaction of fly ashes. *ASCE Practice Periodical of Hazardous, Toxic, and Radioactive Waste Management*, 5, Paper No. 22158, 25-32, 2001.
[3] Zhang.M.H. and Gjorv. O.E., Amer. Concr. *Inst. Materials J.*, 88(2), 150-158, 1991.

[4] Holm. T.A., Bremmer. T.W., and Newman J.B., *Concrete international*, 6(l), 49-54, 1984.

[5] Slate. F.O., Nilson. A.H., and Martinez. *S., Amer. Concr. Inst. J.* 83(6), 606-613, 1986.

[6] G.C. Hoff, Proc. 2nd. International Symposium on High Strength Concrete, Berkeley, California, AC1 SP-121,619-644, 1990.

[7] Zhang. M.H., and Gjorv. O.E., *Amer. Concr. Inst. Materials J.*, 88(3), 240-247, 1991.

[8] TN Gupta, Building Materials in India: 50 Years: A Commemorative Volume Building Materials and Technology Promotion Council, Ministry of Urban Affairs & Employment, Government of India, India, 1998.

[9] Alduaij. A, Alshaleh.A, Haque.M.N., and Ellaithy. K., Lightweight concrete in hot coastal areas. *Cement and Concrete Composites*, 21, 453–458, 1999.

[10] Haque.M.N., and Al-Khaiat.H., Strength and durability of lightweight concrete in hot marine exposure conditions. *Material Structures*, 32, 533–538,1999.

[11] Ke. Y. et. al., Influence of volume fraction and characteristics of LWA on the mechanical properties of concrete, *Const. and Building Materials*, 23 2821-2828, 2009.

[12] Balendran R.V. et. al., Influeance of steel fibres on strength and ductility of normal and lightweight high strength concrete, *Building and Environment*, 37, 1361-1367, 2002.

[13] Vengatachalapathy.C., and Thirugnanasambandam.S., A new dimension in aggregate: Lightweight aggregate concrete – An overview", ICAMAT, Coimbatore,261-265, 2010.

[14] ACI 211.2-98, Standard practice for Selecting proportions for Structural Lightweight concrete.

[15] IS: 383, Specification for coarse and fine aggregate from natural sources of concrete, (Bureau of Indian Standards), New Delhi, 1970