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Performance of Light Weight Concrete using Fly Ash Pellets as Coarse Aggregate Replacement

Dr. M.Vijaya Sekhar Reddy[1], Dr. M.C. Nataraja[2], K.Sindhu[3], V.Harani[3] and K.Madhuralalasa[3]

[1] Head and Assistant Professor, Department of Civil Engineering, Srikalahasteeswara Institute of Technology, Srikalahasti, Andhra Pradesh, India.

[2]Professor and Head of the Department of Construction Technology and Management, Sri Jayachamarajendra College of Engineering, Mysuru-570 006, Karnataka, India

[3] Lecturers, Department of Civil Engineering, Srikalahasteeswara Institute of Technology, Srikalahasti, Andhra Pradesh, India.

Abstract

Many researchers have been carried out in the area of fly ash utilization in the past. It mainly concentrated on replacement of cement with fly ash but production of artificial aggregates with fly ash helps in utilizing large volume of flyash in concrete. In the present scenario the world is much interested in this part recently due to this large scale utilization which also reduces environmental pollution and dwindling of natural resources. The production of concrete requires aggregate as an inert filler to provide bulk volume as well as stiffness to concrete. Crushed aggregates are commonly used in concrete which can be depleting the natural resources and necessitates an alternative building material. This led to the widespread research on using a viable waste material as aggregates. Fly ash is one promising material which can be used as both supplementary cementitious materials as well as to produce light weight aggregate. This paper mainly focuses on manufacturing process of fly ash light weight aggregates using pelletizer and curing has been done in cold bonded technique. The properties of these fly ash aggregates have been tested and the results indicated that cold bonded fly ash aggregates can be effectively used as a coarse aggregate replacement material in concrete. Artificial manufactured lightweight aggregates can be produced from industrial by-products such as fly ash, bottom ash, silica fume, blast furnace slag, rice husk, slag or sludge waste or palm oil shell, shale, slate, clay. The use of cost effective construction materials has accelerated in recent times due to the increase in the demand of light weight concrete for mass applications. The present experimental investigation aimed in studying workability, strength properties of M40 lightweight concrete made with artificial fly ash aggregates as replacement of coarse aggregates with addition of superplasticizer.

Keywords: Cold Bonded Technique, Compressive Strength, Fly ash Pellets, Light Weight Concrete, Superplasticizer.

INTRODUCTION

In growing need for electricity in India, 70% of power is generated through thermal power plants. The environmental dreads from these plants include air pollution due to particulate emission, water pollution and shortage of land for dumping the fly ash. Further, the poor quality of Indian coal has high ash content, which worsens the disposal problem. Instead of dumping the fly ash as landfills, it can be widely used as cement replacement material. In the present scenario, construction industry is growing very fast manner. The availability of raw materials for the construction is facing many problems in most of the world. The continuous usage of natural resources for the production of the concrete in some locations creates many threatens to the environmental conditions. Researchers have carried out extensive work on this area are trying for new alternative materials for this deficiency in the construction industry. In this condition, the present study focussed on artificial fly ash aggregates in place of coarse aggregates. The coarse aggregates from waste material like fly ash with cement as binder can be used in concrete. Fly ash from thermal plants is creating environmental problems. One of the essential requirements of the green building is to use environmental friendly building materials such as the industrial waste products like fly ash [1].

The concurrent use of the fly ash by products will lead to a range of economic and environmental benefits [2]. The artificial coarse aggregate is produced in a pelletiser by cold bonding processes of minimum energy utilization method. The shape of aggregate produced is round in nature. Though the artificial aggregate production attained attention in research field, in India it is not implemented widely. This may be due to the availability of natural resources, relatively higher initial cost for manufacturing and the energy required for curing. There are also methods like cold bonding which does not require energy for curing of artificial aggregates [3].

LITERATURE REVIEW

Manikandan et al., investigated that the durability properties of concrete made with fly ash aggregate cured by different methods and found that sintered aggregates produce better strength compared to cold bonded aggregates [4].

Priyadarshiny et al.,have observed that the fly ash aggregates produced by normal curing showed comparable results with the aggregates produced with other methods of curing, when the experimental study on cold bonded fly ash aggregates with number of days of curing period is increased [5].

In conventional concrete, weight of concrete is one of the parameters to compare with weight of fly ash aggregate concrete. Normally density of concrete is in the order of 2200 to 2600 kg/m^3. This heavy self weight makes an uneconomical structural material compared to low self weight of fly ash aggregate concrete. In order to produce concrete of desired density to suit the required application, the self weight of structural and nonstructural members are to be reduced. Hence economy is achieved in the design of supporting structural elements which lead to the development of light weight concrete. This paper is reviewed on the suitability of using fly ash lightweight aggregate in developing light weight concrete of M40 grade to study the workability and strength properties.

MATERIALS AND METHODS

Cement

Ordinary Portland cement Zuari-53 grade conforming to IS: 12269-1987 [6] was used in concrete.

The physical properties of the cement are listed in Table 1.

Table 1: Physical Properties of Zuari-53 Grade Cement

S. No	1	2	3	4	5		
Properties	**Specific Gravity**	**Normal Consistency**	**Initial Setting Time**	**Final Setting Time**	**Compressive Strength (MPa)**		
Values	3.15	32%	60 min	320 min	3 days	7 days	28 days
					29.4	44.8	56.5

Fine Aggregate

Natural sand from Swarnamukhi River in Srikalahasthi with specific gravity of 2.60 was used as fine aggregate conforming to zone- II of IS: 383-1970 [7]. The individual aggregates were blended to get the desired combined grading.

Water

Potable water was used for mixing and curing of concrete cubes.

SUPPLEMENTARY CEMENTING MATERIAL

Fly ash class – C

The disposal of fly ash is a serious environmental problem. In India, 110 million of fly ash is produced and 2-30 percent is used and rest occupies vast tracks of valuable land as a pond. The fly ash is supplied from M/S.Srinivasa Enterprises, Chennai. The chemical properties are represented in Table 2.

Table 2: Chemical Properties of Flyash-C

S. No	Chemical composition	Percentage (%)
1	Silica(SiO_2)	49-67
2	Alumina(Al_2O_3)	16-29
3	Iron oxide(FeO_3)	4-10
4	Calcium oxide(MgO)	1-4
5	Magnesium oxide (MgO)	0.2-2
6	Sulphur(SO_3)	0.1-2
7	Loss of ignition	0.5-3

Clay

Clay is a soft, loose, earthy material containing particles with a grain size of less than 4 micrometers. Clay is an important material in preparation of cold bonded fly ash aggregate because it acts as binding material.

Lime

Calciumoxide (CaO), commonly known as quick lime or burnt lime, is a widely used chemical compound. It is a white, caustic, alkaline, crystalline solid at room temperature. The broadly used term lime connotes calcium containing inorganic materials, in which carbonates, oxides and hydroxides of calcium, silicon, magnesium, aluminum, and iron predominate. Lime is an important material in preparation of cold bonded fly ash aggregates because it acts as binding material.

Superplasticizer

Varaplast PC 432 is a chloride free, superplasticising admixture based on selected synthetic polymers. It is supplied as a brown solution which is instantly dispersible in water and also it can provide very high level of water reduction and hence major increase in strength can be obtained coupled with good retention of workability to aid placement.

METHODS OF PREPARATION OF FLY ASH AGGREGATES

The desired grain size distribution of an artificial lightweight aggregate is either crushed or by means of agglomeration process. The pelletization process is used to manufacture lightweight coarse aggregate. Some of the parameters need to be considered for the efficiency of the production of pellet such as speed of revolution of pelletizer disc, moisture content, angle of pelletizer disc and duration of pelletization [8]. The different types of pelletizer machine were used to make the pellet such as disc or pan type, drum type, cone type and mixer type. With disc type pelletizer the pellet size distribution is easier to control than drum type pelletizer. With mixer type pelletizer, the small grains are formed initially and are subsequently increased in particle size by disc type pelletization [9].

Here, in this pilot study, fly ash aggregates are formed by cold bonded technique. Cold bonding is nothing but normal water curing. Pelletizer of 0.55 m in diameter and 0.250 m depth with a rotating speed of 40 rpm is used in the process of pelletization (Figure 1). An angle of 55^{o} is maintained as per previous studies which give better pelletization efficiency and good grading of pellets [10].

Fig 1: Formation of Fly Ash Pellets

STUDY ON PROPERTIES OF FLY ASH AGGREGATES

Aggregates passing through 12.5 mm and retained in 10 mm sieve were used for both fly ash aggregates for the mechanical tests. The crushing value gives the resistance of aggregate against gradually applied crushing load. Aggregate crushing value, impact value was found using IS 2386 (Part 4): 1963. Specific gravity, water absorption, bulk density were calculated as per IS 2386 (Part 3): 1963 [11].The above mentioned properties of fly ash aggregates are represented in Table 3.

Table 3: Properties of Fly Ash Pellets

Properties	Units	Fly Ash Aggregate	Allowable limit	Reference
Aggregate Crushing Strength	%	21.60	<45%	IS:2386-part 4
Aggregate Impact Value	%	23.40	<45%	IS:2386-part4
Specific Gravity	_	2.12	_	IS: 2386-part 3
Bulk Density	Kg/lit	1.247	_	IS: 2386-part 3
Water Absorption	%	11.83	_	IS: 2386-part 3
Fineness Modulus	_	7.98	_	IS: 2386-part 1

HARDENING PROCESS IN LIGHT WEIGHT AGGREGATE

The flyash aggregates are porous material and to improve the strength of the pellet the binder material like cement, lime is added. The percentage of binder content is taken by the weight of fly ash. Hardening the pellets is done by various process namely cold bonding, sintering and autoclaving. Cold bonded fly ash aggregates are hardened by different curing process namely normal water curing, steam curing and autoclaving. Autoclave and steam curing method is less effective to improve the properties of aggregate as compare to normal water curing method. The curing method is more important to enhance the aggregate strength. Hence, a normal water curing method can be adopted. The fly ash aggregates were taken out from the pelletiser and allowed to dry for a day. The dried aggregates were cured in the water tank for 28 days.

Figure 2: Fly Ash Pellets

MIX PROPORTION

In the present work, a proportion for concrete mix design of M40 was carried out according to IS: 10262-2009 recommendations [12]. The mix proportions are presented in Table 4.

Table 4: Mix Proportions for M40 Concrete.

Normal Mix	Control Mix Concrete	Mix 1 Fly ash Pellets
Superplasticizer (lts/m^3)	0.05	0.025
Cement(kg/m^3)	350	350
Water (lts/m^3)	140	140
Fine aggregate (kg/m^3)	896	896
Coarse aggregate (kg/m^3)	1140	1140

RESULTS AND DISCUSSIONS

Workability Test (Slump Cone Test):

The shape and texture of aggregate affects the fresh property of the concrete. Fly ash aggregate is rounded in shape. Rounded aggregates promotes workability of concrete while the angular nature of natural gravel gives a better bonding property but requires more cement mortar for better workability. The workability results are presented in Table 5 and Fig 3.

Table 5: Workability Test (Slump Cone Test)

Trail Mix	Workability (slump in cm)
Control Mix	24
Mix 1	27

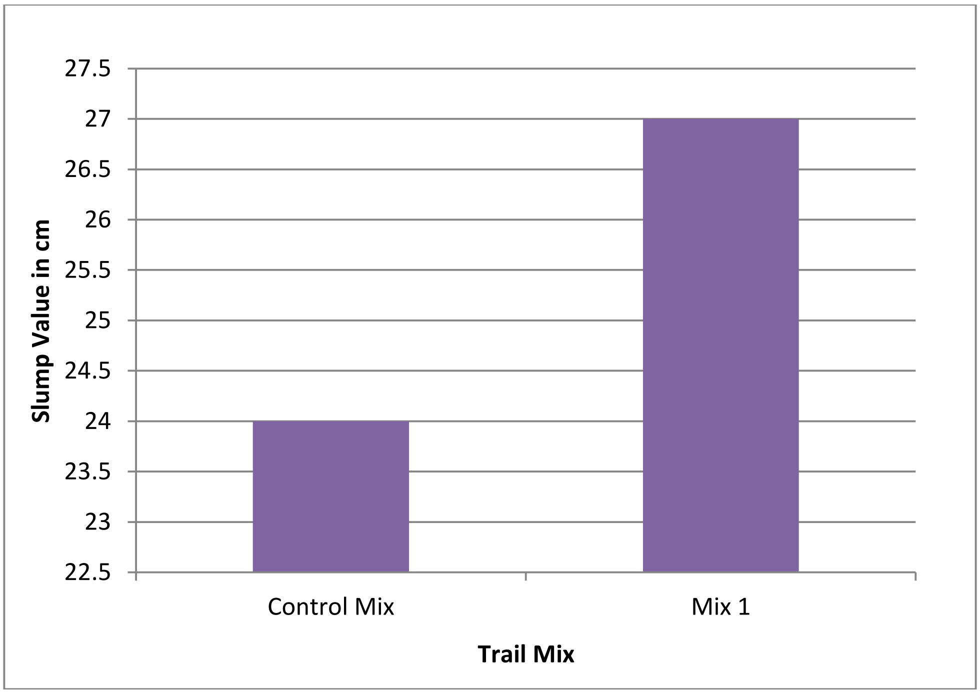

Fig.3: Variation of Slump Value for different trail mixes

Compressive Strength:

The tests were carried out as per IS: 516-1959 [13]. The 150mm size cubes of various concrete mixtures were cast to test compressive strength. The cubes specimens after de-moulding were stored in curing tanks and on removal of cubes from water the compressive strength were conducted at 7days, 28days. The test results were compared with controlled concrete.

Table 5: Compressive Strength for Different Trail Mixes

Trail Mix	Compressive Strength N/mm^2	
	7 Days	28 Days
Control mix	24.68	42.43
Mix 1	27.73	47.45

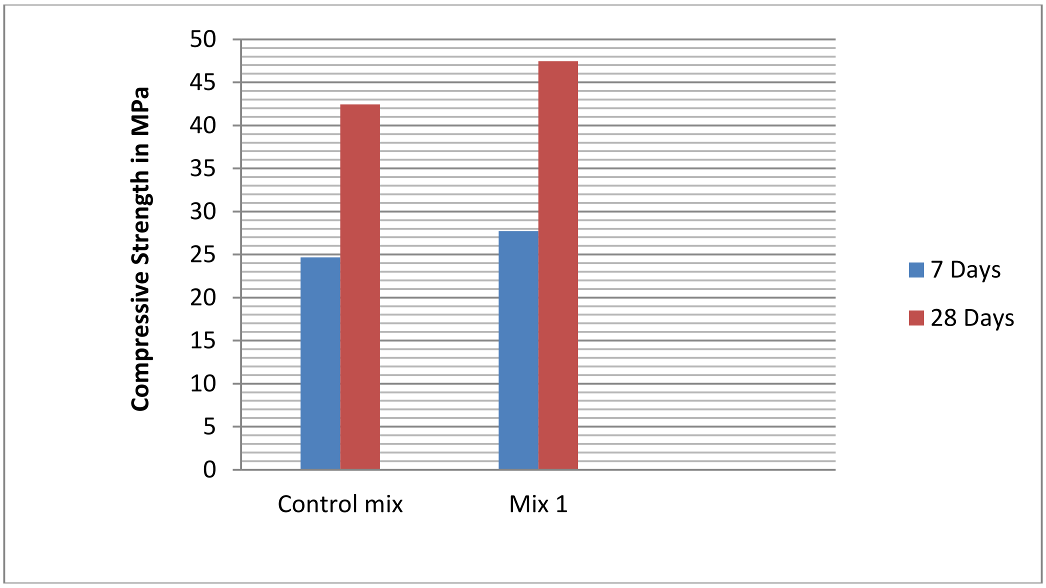

Fig. 4: Variation of Compressive Strength for different trail mixes

When it comes to strength aspect, the compressive strength of normal concrete was 48% greater than the fly ash pellet concrete in the first day, which was reduced to 12% in 28 days. Further, as hydration process of fly ash occurs only on later days, early strength gain will be lesser but it increases gradually with age of curing.

CONCLUSIONS

- The rounded shape of fly ash pellet gives better workability compared to the angular natural gravel.
- Crushing and impact value shows value much lesser than the allowable limit.
- The experimental results show that the maximum compressive strengths for seven and 28 days curing period achieved are 27.73 and 47.45 N/mm^2 respectively with 100% replacement of coarse aggregate by fly ash pellets.

- Low specific gravity compared to natural gravel proves it to be a light weight aggregate material and fly ash has been consumed in large volume when it is used as a coarse aggregate replacement material due to its occupation of large volume in concrete. This in turn reduces the problem of dumping as landfills to greater extent.
- Fly ash aggregates shows better results comparable with natural gravel, so fly ash aggregates can be considered as a replacement material for coarse aggregate. Also, it improves the property of concrete as fly ash is a pozzolanic material. The obtained aggregates can be considered for various applications like wall panels, masonry blocks, roof insulation material, structural load bearing elements.

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