Mechanical Properties of Light Weight Engineered Cementitious Composites

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***Abstract* - In the recent years the consumption of concrete is keep on increasing by the construction industry throughout the world and facing shortage in natural resources due to abundant usage. The scarcity as well as rising cost of raw materials, the concrete technologists are hunt for some alternative materials to manufacture the concrete. In this study an attempt has been made to utilize the waste products in production in concrete. The paper presents the feasibility of utilization of stone waste and industrial by-product such as fly ash for construction work. Here the artificial manufactured light-weight aggregate by pelletization process using industrial by-product such as fly ash and utilization of stone waste such as Cuddapah stone. The industrial by product such as fly ash is a promising material to produce light weight aggregate. This led to the wide spread research on using viable waste materials from industrial by-products. Along with light weight aggregate, Cuddapah stone waste is utilized in this project. In this experimental study various combinations of artificial aggregates were used to produce concrete mixes. The results concluded that the higher compressive strength values were obtained from Cuddapah stone incorporated designed concrete mixes of 50% and 100% replacement of natural coarse aggregate. Whereas the fly ash, sintered fly ash with replacement of fine and coarse aggregate have lesser weight than the normal concrete but they provide lesser strength. The UPV for normal and Cuddapah stone includes great quality higher than the cold bonding fly ash admixture containing medium quality.**

Keywords - Fly ash aggregate, Cuddapah stone, pelletizer, light weight aggregate concrete.

I. INTRODUCTION

Concrete is a widely accepted and demand-full construction material around the world for its various functional requirements. A composite material of concrete composed of cement, fine aggregate, coarse aggregate, water, and other admixtures like pozzolanas and chemical admixtures. These modern days concretes are developed for focused applications. So the use of concrete is unavoidable. The fast urbanization around the cities raised consumption of natural material and have directed fast decline in available natural resources. At the same time abundant usage of natural aggregates led scarcity of coarse aggregate and greatly influenced the increased demand on searching new type of alternatives.

The end products such as fly-ash, silica fume and steel slag were considered as waste materials by industry and these by-products have been successfully utilized as partial or full replacement in concrete as form of binder or aggregates to improve the construction process.The industrial waste has been encouraged and consumed in lot by construction industries because it contributes to reduce the usage of natural resources and preserve from adverse impact on environment.

Light weight concrete (LWC) has been successfully used since the ancient Roman and it had gained its popularity due to its lower density and superior thermal insulation properties (Chandra, S. and Berntsson - 2002). Lytag is an artificial product used as coarse aggregate in producing lightweight concretes. Compared to normal weight concrete are the improved durability properties, fire resistance and the low thermal conductivity.

The manufacturing of light weight aggregate, using fly ash, has been frequently reported in literature (Moss 1976; Anon 1978; Buttler 1987). However, the production of other types of lightweight aggregate similar to Lytag has also been reported (Wainwright et al 2002; Boljanac et al 2007). Several researchers have reported theproperties of Lytag concrete (Swamy &Lambert 1983; Bamforth 1987; Wainwright& Robery 1997; Bai et al 2004; Zhang 2011). The use of light weight aggregates concrete in structures offers many advantages over the conventional normal weight concrete, including an increased strength weight ratio and improved thermal and sound insulation and fire resistances properties (K.Dhir and et.al, 1984). In concrete construction field, the concrete represents a very large proportion of the total load on the structure and there are clearly considerable advantages in reducing its density. One of the ways to reduce the weight of a structure is the use of light weight concrete (Mouli and Khelali, 2008). Light weight aggregate concrete has been used successfully for structural purposes for many years, because of their improved properties such as the workability, strength, less dead load and resistance to freezing and thawing of light weight concrete (Khonsari and et.al, 2010). In the coming section the methodology to observe the potentiality of waste for constriction works is presented.Mustafa Karasshin and Serdal Terzi (2007) were conducted the studies on marble waste. It shows overall cost is minimized compared to conventional concrete. Hankfi Binci et.al. (2008) reported the concrete behavior made with aggregate of marble waste, granite and ground blast furnace slag (GBFS). It's reported that concrete mix enhances the mechanical properties. Kursat Esat Alyamac and Ragip Ince (2009) studied the marble powder utilization in SCC. It's used to improve the fresh and harden concrete properties. Both Bahar Demirel (2010) and Nagabhushna and Sharada bai (2011) has conducted the experimental work on concrete. In this work the waste marble dust (WMD) was used as replacement for sand. They observed that the replacement is possible up to 40% without reduction of concrete strength.Artificial aggregates can be formed by different process like autoclaving, cold bonding or sintering (Bijen, 1986; Baykal and Doven, 2000; Mangialardi, 2001). Research studies show better results on usage of various waste products as artificial aggregates. Some of which are mining residues, heavy metal sludge (SuChen Huang et al., 2007), sewage sludge (Cheeseman and Virdi, 2005; Mun, 2007), bottom ash (Geetha and Ramamurthy, 2010, 2011; Kim and Lee, 2010). Here, in this pilot study, fly ash aggregates are formed by cold bonded technique. Cold bonding is nothing but normal water curing.

A. Research significance

Present experimental study has been focused on concrete with partial and full replacement of conventional coarse aggregate by pelletized aggregate and Cuddapah stone aggregates and cement by fly ash. The main objective of the work was to investigate performance characteristics of the natural and artificial coarse aggregates made by industrial by products. In this project three different types of coarse aggregate concrete was prepared namely normal aggregate concrete, concrete made with Cuddapah stone, and artificial light weight aggregate concrete from fly ash.

The variations of various combinations of natural and artificial light weight aggregates were investigated through compressive strength. The compressive strength test and ultrasonic pulse velocity test on cubes and split tensile test were conducted. The analysis of the results has been done to investigate mechanical behavior of fly ash light weight aggregate and black stone aggregate with comparison natural aggregates as follows and then compared the results accordingly.

II. EXPERIMENTAL PROGRAM

A. Materials

The constituent of materials used in present investigation for making concrete and the properties of materials investigated as shown in Table I as follows.

1) Cement

In market available ordinary Portland cement of 53 grade with specific gravity of 3.15 is used as binder material to the concrete.

2) Fly Ash

A waste by-product Fly ash consists of very fine particles compared to cement particles. Because of its extreme fineness, it reveals effective pozzolanic properties and is used in concrete to improve its fresh and hardened properties. It has been well proved that fly ash improves compressive strength, bond strength, and abrasion resistance and durability. The physical properties of fly ash are shown in Table I.

3) Aggregates

Locally available fine and coarse aggregate has been used in this project. The sand is free from clayey matter, silt and organic impurities. Sand passing through 4.75 mm IS sieve was used. The coarse aggregates passing through 20 - 10 mm were used and washed before preparing the concrete. The aggregates were used in saturated surface dry condition. The properties of concrete aggregates are shown in Table I.

4) Cuddapah stone

Geographically some part of Rayalaseema region, the Anantapur, Kurnool and Cuddapah district areas of Andhra Pradesh (State) is much potential for natural black stone i.e. Cuddapah stone. In these areas the layered stone are exploring form the quarry and making into finished goods for flooring and ornamental purpose. During this stage of converting into finished goods the waste is generating and this is dumping in and around the stone industry and road side. It is causing to inconvenience to the public who are residing near the industry and beside the road. In our project stone collected from cuddapah district and preparation of aggregate as shown in Figure1.

Fig. 1. Preparation of aggregate

5) Sodium hydroxide (NaOH)

Sodium hydroxide is also known as lye and caustic soda which is used as a binder in preparation of fly ash aggregate with water with 12 molarity.

6) Water

The potable drinking fresh water was used for preparation of concrete and curing. This was free from concentration of acids and organic substances.

TABLE I: Mechanical properties of materials

S.No	Name of the material	Properties of material	Result
1	Ordinary Portland cement-53 Grade	Specific gravity	3.15
		Initial setting time	35min
		Final setting time	420min
		Fineness	2%
		Normal consistency	27%
2	Fine aggregate passing 4.75mm sieve	Specific Gravity	2.6
		Fineness modulus	2.84
3	Natural coarse aggregate passing 20-10mm	Specific Gravity	2.68
		Fineness modulus	6.36
		Bulk density compacted	1630Kg/m^3
4	Cuddapah stone passing 20-10mm	Specific Gravity	2.68
		Fineness modulus	2.96
		Bulk density compacted	1378Kg/m^3
		Water absorption	0.49%
5	Cold bonding fly ash aggregate passing 20-10mm	Specific Gravity	1.63
		Fineness modulus	7.98
		Bulk density compacted	913Kg/m^3
		Water absorption	18.1%
6	Water	Locally available potable water which is free from concentration of acids and organic substances has been used in this work.	

III. PELLETIZING AND COLD BONDING PROCESS

One of the common techniques while producing the lightweight aggregate is by agglomeration technique. In agglomeration technique of pelletization is a process to make balls in two ways either by agitation granulation and compaction (Bijen, 1986). Pelletization of fly ash is done by using rotating drum with fixed blades and adjusting inclination. The dosage of binding agent is more important for making the fly ash balls. Initially 20% of water is added in the binder and remaining water is sprayed during the rotation period because while rotating without water in the drum the fly ash and binders (NaOH and Cement) tend to form lumps and does not increase the even distribution of particle size. The pellets are formed approximately in duration of 6 to

7 minutes. Ordinary Portland cement is used as the binder material. Fly ash and the binder are mixed well initially for 2 minutes in pelletizer and then water with NaOH is sprayed in to it. Spraying should be done carefully to make sure that the water has been sprinkled not in the same place to avoid slurry muddy balls. The fresh pellets formed were then kept at room temperature for a day to attain initial strength and then water cured for 28 days. The usage of sodium hydroxide gave better initial strength to the pellets which helps in easy handling. The manufacture of fly ash light weight aggregate pellets in Disc pelletizer machine is as shown in Figure 2.

Fig. 2.Disc pelletizer machine

IV. MIX DESIGN OF CONCRETE

The medium strength M25 grade concrete mix has been designed as per IS 456-2000 [35], 10262 – 2009 [36]. The mix proportion obtained is 1:1.6:2.907 with constant water cement ratio 0.43. To obtain slump in the range of 150-190mm water reducing admixture brandSP430 from force with a dose of 0.3 % by weight of cementshall be used. The derived final mix proportions have shown in Table II.

1. Control mix
2. 35% with cement replaced by fly ash
3. 50% coarse aggregate replaced by Cuddapah stone
4. 100% coarse aggregate replaced by Cuddapah stone
5. 50% coarse aggregate replaced by cold bonding fly ash
6. 100% coarse aggregate by cold bonding fly ash

TABLE II: Final control mix proportions

Cement	Water	Sand	20mm	10mm	Admixture
400	172	635	619	564	1.2
1	0.43	1.6	1.547	1.36	0.003

A. Details about test specimens

The following are the details of the test specimens conducted

TABLE III: Details of the test specimens

S.No	Test	specimen	Numbers
1	Compressive strength	100X100X100mm cube	54
2	Split tensile strength	100X150mm cylinder	54
3	Ultrasonic pulse velocity test	100X100X100mm cube	36

V. RESULTS AND DISCUSSIONS

The following are the results for the tests conducted.

A. Compressive strength test

The results of compressive strength of values are shown Table V and Table VI. These destructive tests were conducted on 3 days, 7 days and 28 days of age of cubic specimens. The three ages of specimens yielded the compressive strength values are following in same trend. From the Table IV reveals compressive strength results of different mixes involved in the experimental work. According to 28 days strength, among the six mixes the CS100 mix was showing highest compressive strength value compared with control mix concrete. This is because; the Cuddapah stone aggregates are showing good angularity in shape and strong enough equal to natural aggregates. In addition Cuddapah stone aggregate are rich in calcium content (Venkata Ramana et al. 2013) which is impart more strength between aggregate and cement paste. This rough surface and heterogeneous mineralogical particles react with cement paste in presence of water impart good bounding. The 35% of replacement of fly ash with cement was shown lowest value of compressive strength, because of the dormant period for reaction of fly ash with cement paste. The 100% of replacement of cold bonding fly ash aggregate concrete has shown lower values of

When compared to cold bonding fly ash coarse aggregate with natural aggregates, it was yielded lower compressive strength (Hasan Yıldırım et al. 2013). This is due to higher porosity (Kockal et al. 2010) and improper bonding in interferential transition zone between cement paste and smooth surface of pelletized aggregates.

TABLE IV: Notations for Mix proportions of test results

S. No	Mix	Description of concrete
1	CM	Control mix of concrete
2	C65F35	35% replacement of cement by fly ash
3	C50CS50	50% replacement of coarse aggregate by Cuddapah stone
4	CS100	100% replacement of coarse aggregate by Cuddapah stone
5	C50CBF50	50% replacement of coarse aggregate by cold bonding fly ash
6	CBF100	100% replacement of coarse aggregate by cold bonding fly ash

TABLE V: compressive strength test results

S. No	Mix	Compressive strength(MPa)		
		3days	7days	28days
1	CM	11.8	21.3	32.7
2	C65F35	9.3	16.7	25.3
3	C50CS50	11.1	21.6	33.1
4	CS100	11.8	24.2	34.3
5	C50CBF50	7.0	18.2	28.7
6	CBF100	6	17.6	26.4

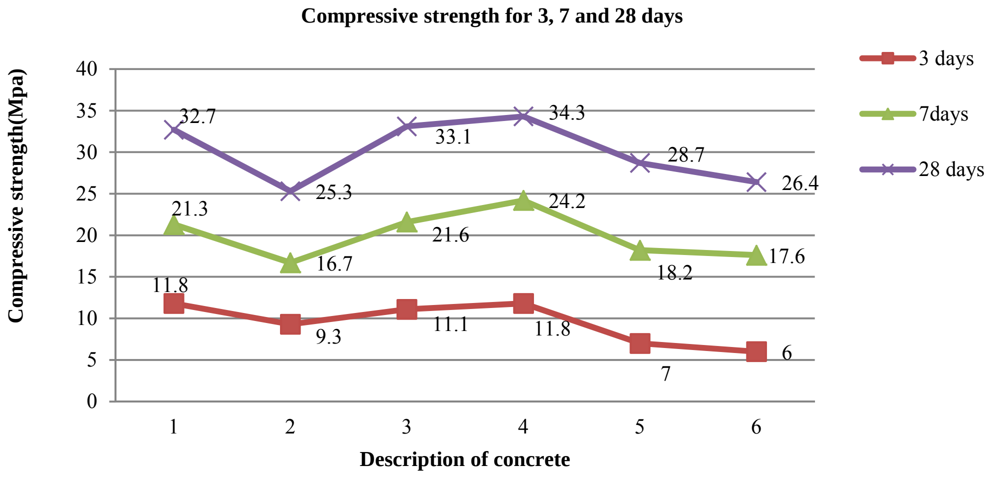

Fig. 3. Compressive strength values

B. Split tensile strength test

The Table VI shows results of Split tensile strength of different mixes involved in the experimental work. Among the six mixes, the 50% CBF aggregate concrete mix is showing highest value for Split tensile strength because in cold bonding process the mineral particles in the binder fuse together to form the crystalline structure (CSH) and results in the higher strength of the aggregate. Whereas the 100% Cuddapah stone aggregates showing lesser value compared to control concrete mix. This is due to the naturally layered morphology of Cuddapah stone aggregates.

TABLEVI: Split tensile strength results

S. No	Mix	Compressive strength(MPa)		
		3days	7days	28days
1	CM	1.3	2.9	4.1
2	C65F35	1.4	3.1	3.9
3	C50CS50	1.2	2.6	3.6
4	CS100	1.3	2.7	3.9
5	C50CBF50	1.6	3.7	4.3
6	CBF100	1.4	4.2	3.9

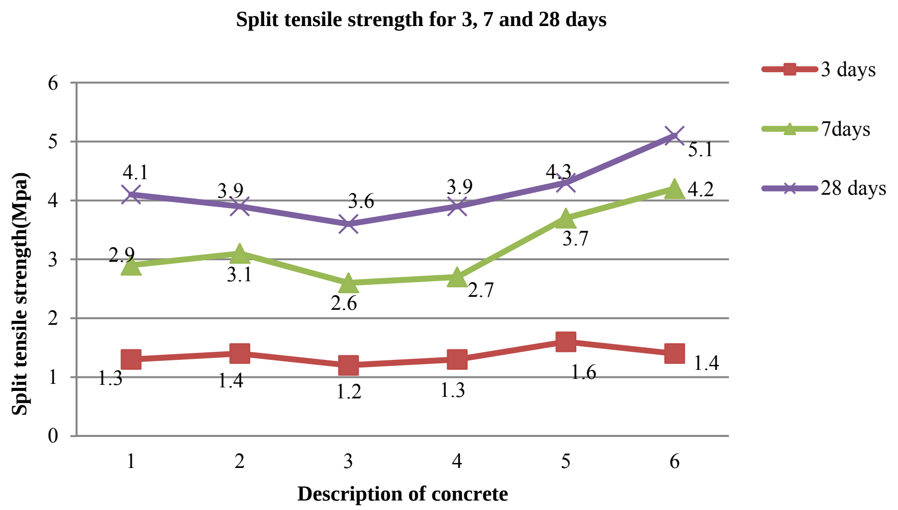

Fig. 4. Split tensile strength values

C. Ultrasonic pulse velocity test

An Ultra-sonic pulse velocity test is an in-situ, nondestructive test to know the quality of concrete. In this test the cube specimens were employed and the test was performed as per directions given by IS 13311 (Part 1): 1992. The UPV velocity criterion for concrete quality grading is based on IS: 13311 – Part 1 is given in Table VII. The assessment of concrete thorough ultrasonic pulse velocity device is showing in Figure 5. Table VII shows the UPV test results on 7 days and 28 days. From the test results of 7 days and 28 days, the CS100 mix has attained maximum UPV velocity values. This is contributed due to dense packing of Cuddapah stone aggregate concrete and solid structure of Cuddapah stone aggregate enables to the travel waves too speed compared to other concretes. It can be also be noticed that for replacement of CBF aggregate concrete has showing the quality grading is medium but the other concrete were performing good in quality grading. The mixes of partially and fully replaced with cold bonded fly ash aggregates showed medium level of quality of grading. This can be due to highly porous nature of CBF.

Fig. 5. UPV testing specimen

TABLE VII: UVP test results

S. No	Mix	UPV (m/s)	
		7days	28days
1	CM	3760	4507
2	C65F35	3640	4305
3	C50CS50	3910	4580
4	CS100	4070	4670
5	C50CBF50	2800	3105
6	CBF100	2750	3045

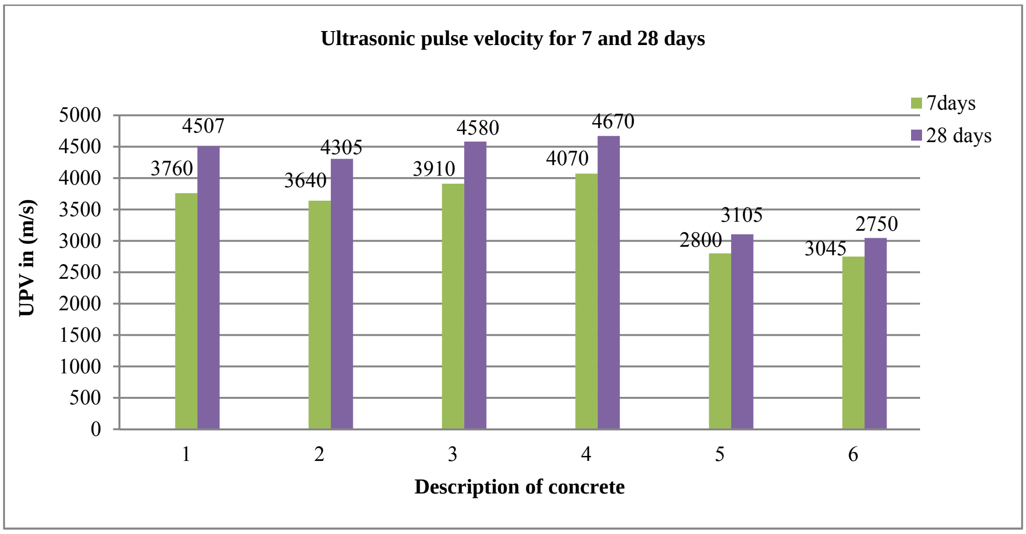

Fig. 6. Ultrasonic pulse velocity values

TABLEVIII: Grading of pulse velocity

Pulse velocity (km/sec)	Concrete quality(grading)
Above 4.5	Excellent
3.5 to 4.5	Good
3 to 3.5	Medium
Below 3	Doubtful

The Table IX Giving the idea about average weight of various mix combinations. From the mix combinations, 100% replacement of CBF aggregates yields lesser weight because of its porous nature. This can archive 17% and 13% less weight compared to normal Cuddapah stone aggregates respectively. The 100% replacement of Cuddapah stone aggregate concrete yields 8% lesser in weight.

TABLE IX: Average weight of various mix combinations

S. No	Mix	Average weight(kg)
1	CM	2.38
2	C65F35	2.27
3	C50CS50	2.28
4	CS100	2.20
5	C50CBF50	2.15
6	CBF100	1.92

VI. CONCLUSIONS

The following conclusions are produced using the above study, which are appropriate to the materials utilized and scope of parameters concentrated on.

i. The production of artificial light weight fly ash aggregate by pelletization process could be an effective way to produce artificial light weight aggregates for concrete production.

ii. From the study it is concluded that the compressive strength, split tensile strength, and Ultrasonic pulse velocity test are decreased continuously with the increasing replacing content of fly ash aggregate in concrete with the natural aggregate. The Cuddapah stone aggregates were obtained almost same results compared to control mix of concrete also increased with increasing curing period.

iii. From the results, it was observed that the higher strength values were attained by 50% and 100% replacement of Cuddapah stone aggregates with natural coarse aggregate concretes.

iv. Whereas the fly ash, cold bonding fly ash with replacement of fine and coarse aggregate have lesser weight than the normal concrete but they provide lesser strength.

v. According to pulse velocity values the normal aggregate concrete and Cuddapah stone aggregate concrete mixes were shown good agreement with IS code values higher than 4.5. The cold bonded fly ash aggregates were shown the values more than 3, so it indicates the quality of concrete is medium.

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