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Use of Fly Ash Aggregates in Concrete and its Applications in Structures

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***Abstract--*Two different batches of Lightweight aggregates one with using super plasticizer and another without using super plasticizer were manufactured using cold bonded technique. Based on the test results of their physical and mechanical properties, aggregates with super plasticizer were selected. Using the aggregates prepared from superplasticizer different type of concrete specimens were produced where the proportions of natural aggregates of different sizes differs in each specimen. Concrete specimens prepared from natural aggregates tested and compared with those lightweight aggregate concrete. Based on the test results of the physical and mechanical properties of the concrete cubes, specimens having the compressive strength almost same as that of natural aggregates specimens were chosen. This will ease the burden on depleting natural resources and at the same time it will also address some of environmental problems such as disposing industrial waste which are being used here in construction.**

***Keywords--* Fly ash aggregates, light weight concrete, cold bonded technique, compressive strength, specimens.**

I. INTRODUCTION

In this growing Indian Civilization, 60-70% of power generation is from thermal power plant. This result in environmental pollution air pollution due to the particulate emission from plants, water pollution and shortage of lands due to dumping of fly ash and for fly ash. Also, the major problem is the high content of ash in Indian coals which worsens the problem of pollution [1]. Generally, the state of disposal of Fly Ash is dry and wet both. The elements it contains are Ni, Cd, Sb, As, Cr, Pb, etc. which are injurious to health and can cause respiratory problems, lung cancer, anemia and skin cancer [2]. As, the chemical composition of Fly Ash is almost is same as cement, researchers have been trying to find ways where they can replace cement with fly ash. Now a days, Portland Pozzolanic Cement (PPC) is used in construction industries with fly ash. The major problem of using only fly ash inconcrete is its lower early age strength but on the other hand the advantage of fly ash is the improved compressive strength in concrete and thus improving sulfate resistance and durability [3].

Although the artificial pellet production requires attention in research field, in India it has not been widely implemented. The reason behind this maybe the non-availability of natural resources, relatively higher cost of manufacturing or the requirement of energy curing of artificial aggregates [4]. Fly ash aggregates forms by two process, namely compaction and granulation. Agglomeration technique was developed in 1940s. Granulation technique is the process of sprinkling water on the formed pellets and then rotating it by a pelletizer machine. Whereas, Compaction technique is formation of pellets and then well compacted by briquettes apparatus for hard pressing. Lightweight Aggregate concrete has been successfully produced from past years. Although, from the point of view of mechanical characteristics, LWAC has been fallen apart because of high porosity of aggregates and high permeability however, LWAC of 50 MPa and more have been produced [5, 6].

II. EXPERIMENTAL PROGRAM

2.1 Aggregate and Concrete Material Properties

Cement

Ordinary Portland Cement (OPC) of grade 53 [BSI 12269-1987] was used for the manufacturing process of Lightweight aggregates whose specific gravity was 3.25, consistency was noted as 32% from the lab experiments and was also used for the concrete mix.

Fly Ash

Class C Fly ash was used confirming to ASTM C 618 as both binder and mineral admixture. Fly ash was taken from Neyveli thermal power plant, Tamil Nadu, India had specific gravity 2.46. Table 1 shows the chemical composition of Fly ash.

Natural Aggregates

Coarse aggregates of size 20 mm and 12.5 mm were used and natural sand was collected from Local River

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having the fineness modulus as 2.55 and specific gravity 2.4 from lab experiments.

Table 1:
Chemical Composition of Fly Ash

Characteristics	From test in %	From IS 3812 Part I requirement in %
Silica (as $Si0_2$)	57.65	Min 25.0
Calcium oxide (Lime content) as CaO	11.64	-
Alumina (as Al_20_3)	15.29	-
Iron oxide (as Fe_2O_3)	6.10	-
Magnesia (as MgO)	0.37	Max 5.0
Sulphuric anhydride (as $S0_3$)	1.82	Max 3.0
Total loss on ignition	2.86	Max 5.0
Total chlorides (as Cl)	0.02	Max 0.05
Sodium oxide (as Na_2O)	0.44	Max 1.5
Potassium oxide (as K_2O)	0.04	-
Total alkalies (as Na_2O)	0.47	-
Silicon dioxide ($Si0_2$) + Aluminum oxide (Al_20_3) + Iron oxide (Fe_2O_3) in % by mass	79.04	Min 50.0

2.2 Production of Fly Ash aggregates

There are many different process for the formation of artificial aggregates like autoclaving, cold bonding or sintering (Bijen, 1986; Baykal and Doven, 2000; Mangialardi, 2001). Research studies are the proofs that usage of waste products will give better results as artificial aggregates like bottom ash, copper slag, Fly ash. So, in this research study the artificial pellets have been formed by cold bonding technique which is also known as normal water curing technique. The formation of pellets was done by using pelletizer machine which was 0.55 m in diameter and 0.250 m depth and with a rotating speed of 40 rpm. The angle kept for the rotation was maintained at 55° as per the previous studies as they give better results and better grade pellets (Manikandan and Ramamurthy, 2007). The effects of various binders in the formation of sintered Flyash aggregates were critically studied by (Ramamurthy and Harikrishnan, 2006).

Although Class C Fly Ash have CaO content for better binding property, addition of CaO ameliorates the efficiency, dampens the duration and dose of binders in pelletization process (Geetha and Ramamurthy, 2010). Due to this formation of C-S-H bond with silica in fly ash and thus it enhances its strength. Therefore, there should be an addition of 2% of $Ca(OH)_2$ for better agglomeration. OPC Cement is used as 8% as the binder material. First of all Fly Ash is mixed thoroughly with Binder Cement in pelletizer machine. And then water is sprayed with $Ca(OH)_2$ into it. It should be carefully observe that water shouldn't be sprayed continuously at one place only as it can make slurry mud balls. The formed balls then kept at room temperature for one day so that it can attain initial strength and then it is cured or 28 days. It was seen that calcium hydroxide gave better initial strength which also helps in easy handling of pellets.

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Fig. 1: Formation of Fly Ash Pellets

2.3 Properties of Fly Ash Aggregates

Aggregates passing through 20 mm and retaining on 12.5 mm sieve as well as aggregates retaining on 12.5 mm sieve were used for the Mechanical tests (IS 2386 (Part 4): 1963).

The crushing value, impact value, abrasion resistance of aggregates were found using IS 2386 (Part 4): 1963. Similarly Specific Gravity test, bulk density, water absorption and void ratio were calculated as per IS 2386 (Part 3): 1963.

Table 2:
Materials used for manufacturing of aggregates

MIX ID 1	MIX ID 2	MIX ID 3
Cement – OPC 53 Grade (200 gms)	Cement – OPC 53 Grade (200 gms)	Cement – OPC 53 Grade (200 gms)
Flyash – Class C (1800 gms)	Flyash – Class C (1600 gms)	Flyash – Class C (1600 gms)
Water (1 lit)	Water (1 lit)	Water (1 lit)
Superplasticizer (8 gms)	Superplasticizer(8 gms)	Superplasticizer(8 gms)
Lime (40 gms)	Lime (40 gms)	Lime (40 gms)
	Bottam Ash (100 gms)	Bottam Ash (200 gms)
	Copper Slag (100 gms)	

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2.4 Study on Fly Ash Aggregate Concrete

2.4.1 Mix Proportions

The designing of mix was done for 28 days as per IS 10262:2009.

The table given below gives the proportioning of natural gravel concrete and fly ash aggregate concrete results. Cubes were tested for 7 days and 28 days curing period.

Table 3
Mix Design for M20 Concrete

Materials Required	Quantity
Cement (Kg/m^3)	311
Fine Aggregates (Kg/m^3)	743.1
Coarse Aggregates (Natural Aggregates) (Kg/m^3)	1327.57
Water to cement ratio	0.45
Water (Kg/m^3)	140 liters/m^3
Superplasticizer (Kg/m^3)	0.20% of cement

The above table shows the ratio employed for the M20 design mix. In this mix ratio natural aggregates were replaced by fly ash aggregates. Therefore, four replacements were taken as 25%, 50%, 75% and 100% of natural aggregates by volume.

2.4.2 Preparations of Test Samples

The dimensions of cubes used for moulding were 100X100X100 mm. Before casting Moulds were maintained properly by cleaning and oiling it. Compacting rod and vibration table used for better compaction and were filled in three layers.

III. Result And Discussions

3.1 Properties of Fly Ash Aggregates

After performing the various mechanical tests on aggregates, following results were obtained which showed that Mix 2 shows better crushing value than Mix 1 and Mix 3 which is includes the gradual application of loads.

Although it shows lower value than Mix 3 in Impact Strength which involves application of shock loads but showed better results than Mix 1. Similarly, Mix 2 is less dense than Mix 3 but more dense than Mix 1. Whereas in Abrasion Test by Los Angeles Method among it showed Mix 2 was best among all mixes. After 28 days curing of these aggregates, different tests were performed on them and following results were obtained as shown in table.

So, it was decided that Concrete Cubes will be cast using Mix ratio 2 and Mix 3 as it gave an overall better results than the mix ratio 1 and mix ratio 3. Mix 1 was rejected as it didn't give any satisfactory result. Finally Mix 2 and Mix 3 was casting of Concrete Cubes.

Cubes were tested for 7 days and 28 days curing period. Table 7 shows the results obtained when they were tested for compressive strength.

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Table 3:
Properties of aggregates

TEST PERFORMED	MIX ID 1	MIX ID 2	MIX ID 3	MAXIMUM LIMITS OF AGGREGATES	Reference
CRUSHING STRENGTH	28.80	25.82	29.86	LESS THAN 45% FOR NS	IS – 2386 Part 4
				LESS THAN 30% FOR WS	IS – 2386 Part 4
ABRASION STRENGTH	60.00	43.64	51.48	LESS THAN 50% FOR NS	IS – 2386 Part 4
				LESS THAN 30% FOR WS	IS – 2386 Part 4
IMPACT STRENGTH	53.50	24.18	23.64	LESS THAN 45% FOR NS	IS – 2386 Part 4
				LESS THAN 30% FOR WS	IS – 2386 Part 4
SPECIFIC GRAVITY	1.95	1.92	1.85	2.72	IS – 2386 Part 4

Graphical Representation –

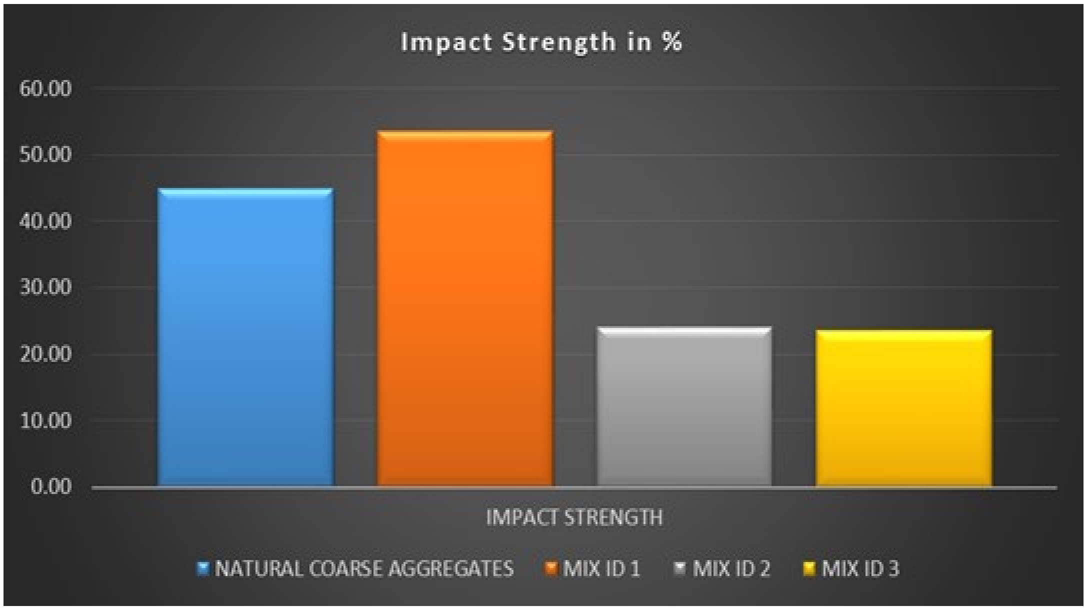

Fig. 2: Impact value in %

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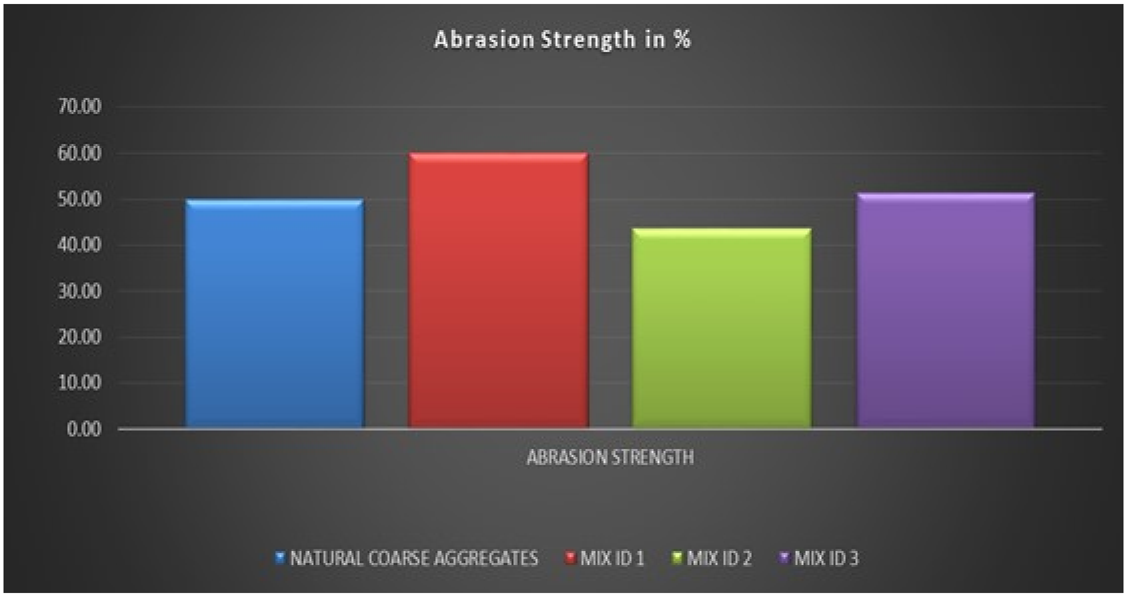

Fig. 3: Abrasion Value

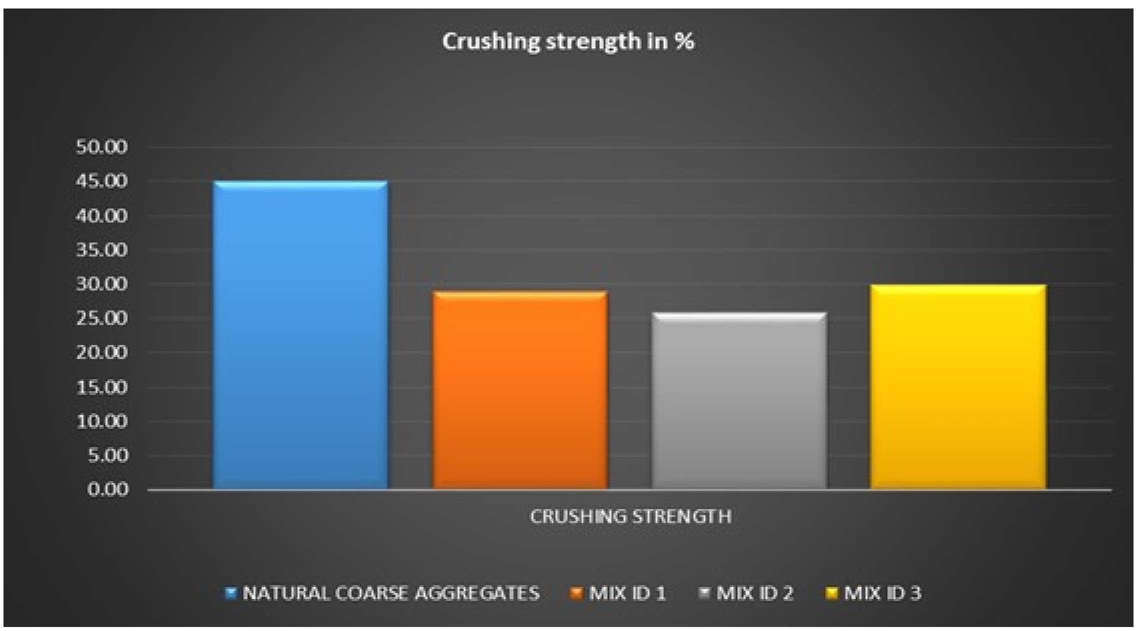

Fig. 4: Crushing Strength in %

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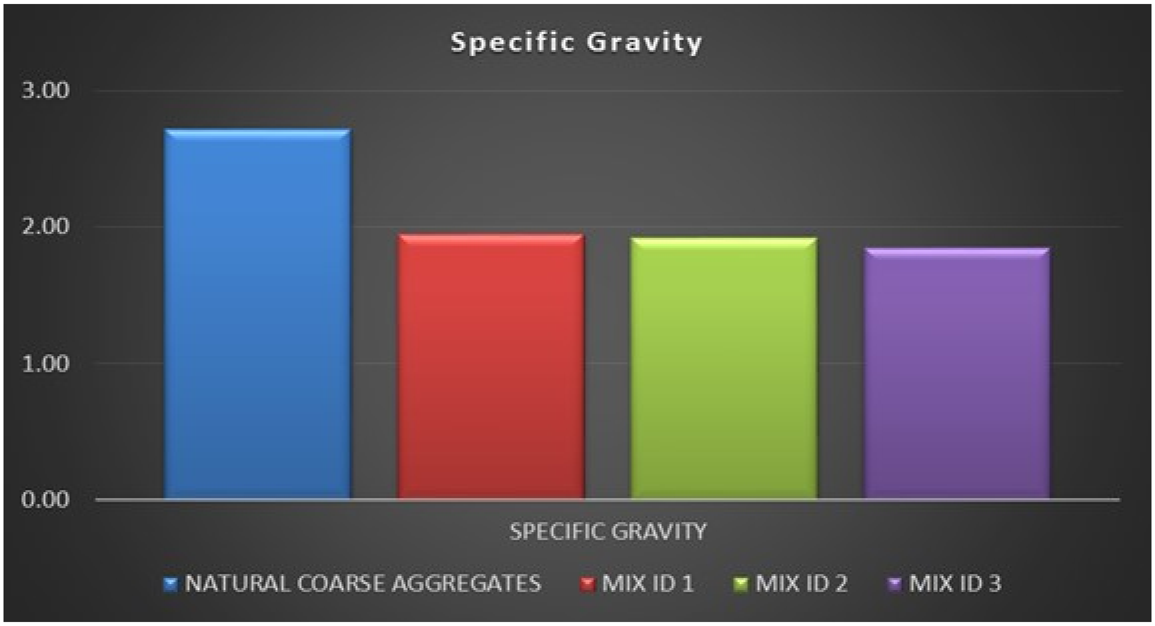

Fig. 5: Specific Gravity

3.2 Concrete Properties

The aggregates chosen for the concrete formation were replaced in the ratio of 25%, 50%, 75% and 100% with the natural aggregates.

Therefore, in total 8 Mix IDs were formed tested for compressive strength. Following were the densities of the Cubes that were used for testing their compressive strength.

Table 4:
Density of Specimens

MIX ID	Density (in Kg/m^3)	
	7 days	28 days
MB1	2.42	2.43
MB2	2.23	2.21
MB3	2.17	2.20
MB4	2.11	2.14
MC1	2.38	2.36
MC2	2.28	2.29
MC3	2.15	2.19
MC4	2.07	2.06

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Graphical Representation:-

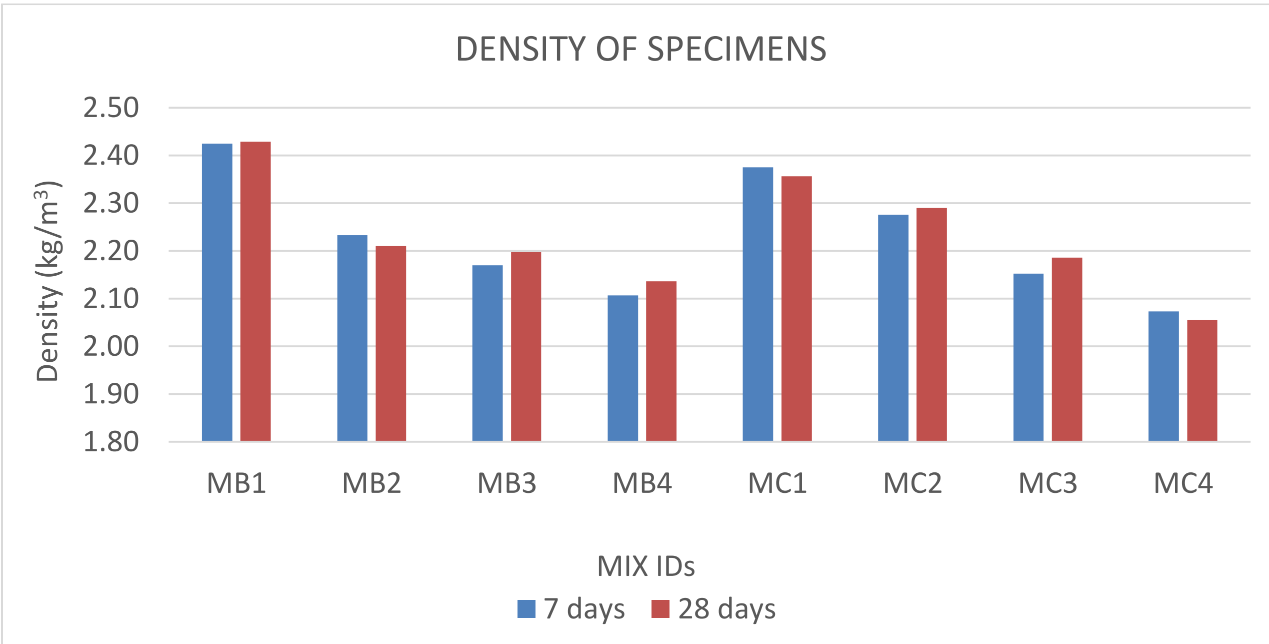

Fig: 6 Density of Specimens

Notation B and C denotes Mix 2 and Mix 3 aggregates were used respectively for the casting for cubes as light weight aggregates.

Notation 1, 2, 3 and 4 implies 25%, 50%, 75% and 100% replacement of natural aggregates respectively.

When it comes to the compressive strength, Mix ID MC1 showed best results among all the Mix IDs and Mix ID MB4 wasn't upto mark when compared with all the Mix IDs. Following were the compressive strength test results of the speciemns both figuratively and graphically.

Table 5:
Compressive Strength of Specimens

MIX ID	COMPRESSIVE STRENGTH (IN MPa)	
	7 days	28 days
MB1	24.5	32.2
MB2	21.4	25.5
MB3	15.4	19.7
MB4	15.0	18.3
MC1	26.9	35.3
MC2	24.0	25.6
MC3	16.4	22.2
MC4	15.2	17.8

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Graphical Representation:-

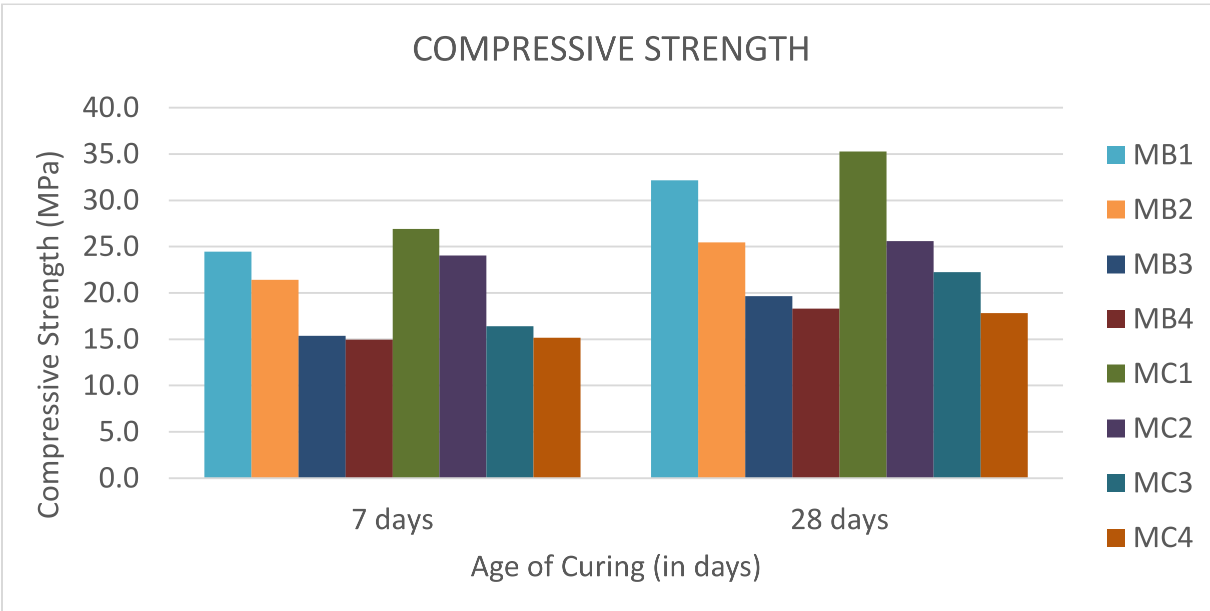

Fig 7: Compressive Strength of Speciemens

IV. CONCLUSIONS

As a pilot study, it has been proved that by cold bonding techniques and pelletizing fly ash aggregates can be formed and the obtained aggregates properties has been compared with those of natural and found comparable. Even though the cost of light weight aggregates used is slightly more than that of natural aggregates, it has many indirect benefits related to environment.

- ✓ First of all, the shape of aggregates, which is rounded shape gave better workability than the angular shape of natural aggregates.
- ✓ It will reduce the quantity of cement by 50% which will reduce the emission of carbon dioxide (CO_2) in environment.
- ✓ This will reduce the quantity of natural aggregates by 50% which will be reducing the load on natural resources.
- ✓ Usage of light-weight aggregates will reduce the dead load of structure thus reducing the requirement of other construction materials.
- ✓ Due to decrease in dead load, it is possible to construct longer halls with less number of columns.
- ✓ The properties of these fly ash aggregates have been tested and compared with natural gravel and the study shows that cold bonded fly ash aggregates can be used as an aggregate replacement material in concrete.
- ✓ The strength property and density of concrete made with artificial fly ash aggregates and natural gravel were also studied which confirms that introduction of fly ash aggregates in concrete reduces the compressive strength but meets the required strength to be used as a structural material.
- ✓ The compressive strength and density of concrete, made by using different mix of fly ash aggregates and natural aggregates, were studied and it was observed that larger amount of fly ash aggregates yields lower compressive strength but they all were above desirable strength.

Further studies can be done to reduce the cost of light weight aggregates by either reducing the use of lime and super-plasticizer or by replacing them with some other materials.

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