# Autoclaved Fly-Ash Pellets as Replacement of Coarse Aggregate in Concrete Mixture

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**Abstract**

**Coal, which is a very promising material for a growing country like India produces fly- ash which is creating a great threat to the environment. Fly-ash is mainly used for dumping or as a fine aggregate. The present study is aimed at developing a technique for producing an aggregate with fly-ash using autoclave and use it in the replacement of normal coarse aggregate. The properties of fly-ash were experimentally checked, whether it is of type-C or of type-F by chemical analysis of the fly-ash. Batches of fly-ash aggregates were manufactured using Autoclaved technique using disc pelletilizer. Based on the cursing value, water absorption, and impact value test results of their properties, fly-ash aggregates were selected. Using the fly-ash aggregates prepared from the Autoclaved technique, their properties were tested. These pellets will be light in weight having specific gravity less than that of gravel (2.67) and will have high impact value than that of gravel (20.12). At the same time, they will also address some of the environmental problems such as disposing the industrial waste which is being generated from thermal waste.**

**Keywords: Autoclaved technique, fly-ash aggregate, fly-ash pellets**

## I. INTRODUCTION

Coal is a very useful material for a developing country like India. In this country for most of the industry (likethermal power plant, iron industry),large quantity of coal is burnt. Thus, a significant amount of fly-ash is produced in our country and it becomes a threat to our society as fly-ash is injurious to our health. To solve this problem, fly- ash is now a days used for dumping in low-land and it is also using for making fly-ash bricks and in a concrete mix with a proper proportion with the fine aggregate. However, another option is to use the fly-ash aggregate is replacement of coarse aggregate. The coarse aggregate which is produced with a mix of cement as a binder has a good pozzolanic property and it also helps us to solve the environmental problem as well. For having green cities, fly-ash aggregate is essential as it is produced by recycling of fly-ash coming from industries [1].

The use of fly-ash by products is very essential now as it is environment friendly and economical [2]. The fly-ash pellets are produced with the help of disc pelletlizer using cement as a binder in making green pellets. After preparing the aggregate, it needs higher energy in curing process. Though the aggregates are formed are round in shape, these have more pozzolanic properties than normal coarse aggregates. Due to higher initial cost, these are not widely used in India. However, there is also a process to make the aggregate using minimum energy for curing than sintering. There are also methods of curing like Autoclaving which do not require energy for making those aggregateas of sintering process [3].

## II. LITERATURE REVIEW

Kockal and Ozturan [4] experimental results revealed that durable high-strength air-entrained lightweight concretes could be produced using sintered or cold-bonded lightweight fly ash aggregates, having comparable performance with the normalweight concretes. The use of lightweight aggregates (LWA) instead of normal weight aggregates in concrete production decreased the strength and stiffness due to the higher porosity and lower strength of the aggregate included in the concrete. However, permeability of sintered fly ash aggregate lightweight concretes was comparable and slightly lower than normal weight concrete, whereas, permeability of cold-bonded fly ash lightweight concrete was greater than the others [4].

Manikandan and Ramamurthy suggested that the durability properties of concrete made with fly ash

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aggregate cured by different methods and found that sintered aggregates have more strength compared to cold bonded aggregates [5].

Priyadarshiny, Ganesh, and Santhi have noticed that the fly ash aggregates produced by normal curing showed comparable studies 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 [6].

In conventional concrete, weight of aggregate is one of the parameters to compare with weight of fly ash aggregate. Normally, density of concrete with coarse aggregate is in the order of 2200 to 2600 kg/m3. This heavy self-weights of the coarse aggregate make an uneconomical structural material as compared to low self-weight of fly ash aggregate. In order to produce concrete mixture of desired density to suit the required application, the self-weight of structural and non-structural members are to be reduced than the original one. Hence, economy will be achieved in the design of supporting structural elements which lead to the development of light weight concrete using fly-ash aggregate. This paper is reviewed on the suitability of using fly ash lightweight aggregate strength properties.

## III. FORMATION OF FLY-ASH PELLETS

The materials used are like cement; fly ash and water are used to produce fly ash pellets. Water is used as the binding material to react and helps the aggregate to gain good strength.

**Fig. 1.Green Pellets**

## IV. MATERIALS USED FOR MAKING FLY-ASH PELLETS

### *A. Cement*

Cement used in this project was Portland Pozzolana Cement (P.P.C.) according to IS: 12269-1987, 1987 [7].

Table I gives the chemical components of cement and fly-ash.

**TABLE I.**
**CHEMICAL COMPONENTS OF CEMENT AND FLY-ASH**

| | CaO | $SiO_2$ | $Al_2O_3$ | $Fe_2O_3$ | $Na_2O$ | $K_2O$ | MgO | Density (g/cc) |
|---|---|---|---|---|---|---|---|---|
| Cement | 63.45 | 19.4 | 2.52 | 2.02 | 0.63 | 0.4 | 1.32 | 2.93 |
| Fly-ash | 1.45 | 54.75 | 31.05 | 8.78 | 1.18 | 2.32 | 1.84 | 2.78 |

### *B. Fly-ash Class C*

Fly ash produced from the burning of younger lignite or sub-bituminous coal, in addition to having pozzolanic properties, also has some self-cementing properties. In the presence of water, Class C fly ash hardens and gets stronger over time. Class C fly ash generally contains more than 20% lime (CaO). Unlike Class F, self-cementing Class C fly ash does not require an activator. Alkali and sulphate ($SO_4$) contents are generally higher in Class C fly ashes.

### *C. Water*

Portable water was used for making fly-ash pellets.

## V. METHODS OF PREPARATION OF FLY-ASH AGGREGATES

### *A. Pelletizing Process*

The desired grain size distribution of an artificial fly-ash aggregate is either crushed or by means of agglomeration process as per IS: 383-1970, 1970[8]. The pelletization process is used to manufacture lightweight coarse aggregate; some of the important 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. Different types of pelletizer machine were used to make the pellet such as disc type or pan type, drum type, cone type, and mixer type. With disc type pelletizer, the pellet size distribution is easier to control [9]. Smaller grains are produced initially and are subsequently increased in particle size by disc type

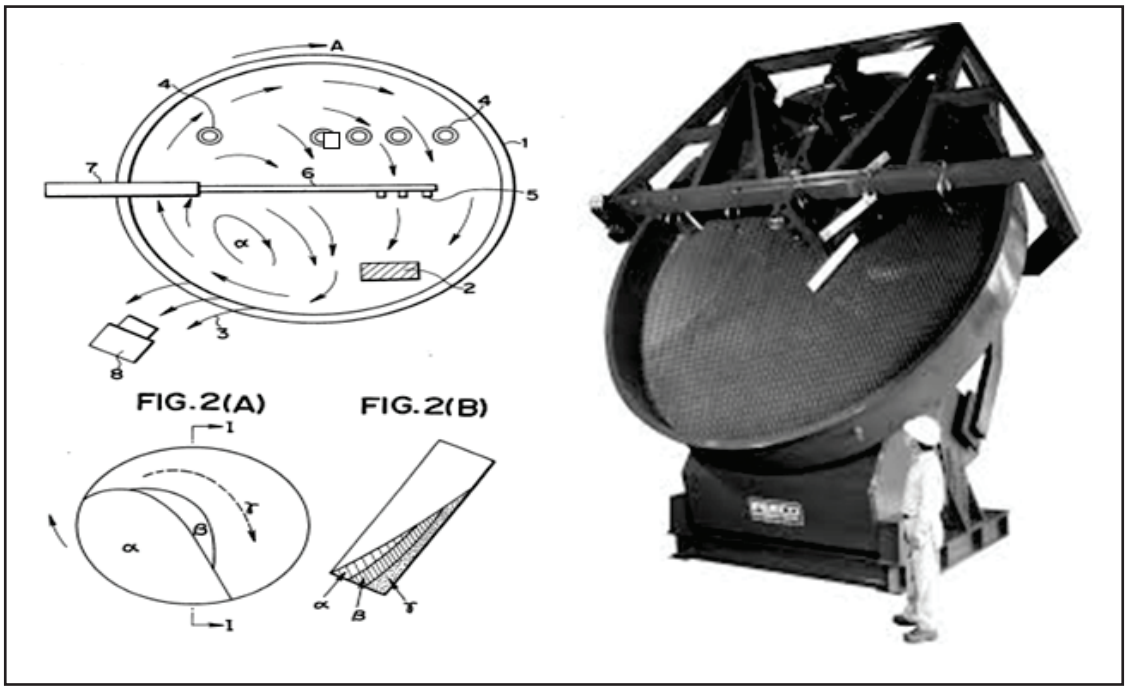


**Fig. 2. Pelletization Process and Disc Pelletizer**

pelletizer. The disc pelletizer size is 0.57m in diameter and side depth of the disc is 0.250 m. It is fixed in a flexible frame by adjusting the angle of the disc from 35° to 55°. To control the rotate disc in vertical manner, speed is 35 to 55 rpm [10]. Using this method, we can have the green pellets.

### *B. Hardening of Pellets*

Green pellets are passed through AUTO-CLAVE having 120°-150° and 15-20 psi pressure for two to three

**Fig. 3. Autoclave Machine and Autoclaved Fly-ash Pellet**

hours. The final product coming from auto-clave can be used in the field as it is stronger than green pellets.

## VI. COMPARISON OF PHYSICAL PROPERTIES OF AGGREGATE

The fly-ash aggregates are porous materials, so for hardening the pellets we have to use cement as binder material. The hardening of the pellets can be done by following the process: cold bonding, sintering, and autoclaving. Green pellets can be hardened by normal water curing, steam curing, and autoclaving. Among all these three processes, Autoclaving is the most effective process to increase the strength of the pellets in a short time span. So, to increase the strength of the pellets after removing them from the pelletilizer, we have to pour it into Auto-clave machine with120-150$^{o}$ and 15-20 psi pressure for 2-3 hours.

Study on properties of fly-ash aggregate shiws that aggregates passing through 12.5 mm sieve and retained in 10 mm sieve are used for fly-ash aggregates and coarse aggregate to find the strength of the material. Crushing value, Impact value, Abrasion value tests were performed as per IS 2386 Part-4; and water absorption,

**Table II.**
**TEST PERFORMED ON COARSE AGGREGATE AND FLY-ASH AGGREGATE**

| | UNITS | 12.5 mm gravel 5000g | 500g cement+ 5000g Fly-ash | 1000g cement+ 5000g Fly-ash | 2000g cement+ 5000g Fly-ash | 3000g cement+ 5000g Fly-ash | 4000gm cement+ 5000g Fly-ash | 5000g cement+ 5000g Fly-ash | ALLOWABLE LIMIT | REFERENCE |
|---|---|---|---|---|---|---|---|---|---|---|
| Water Absorption | % | 1.38 | 9.54 | 8.89 | 8.55 | 8.21 | 7.87 | 7.53 | | IS 2386 Part-3 |
| Crushing value | % | 35.65 | 28.68 | 30.79 | 33.06 | 35.33 | 38.7 | 38.78 | <45% | IS 2386 Part-4 |
| Impact Value | % | 21.720 | 31.330 | 29.640 | 27.870 | 26.530 | 24.760 | 22.810 | <45% | IS 2386 Part-4 |
| Abrasion Value | % | 3.65 | 5.12 | 4.45 | 4.23 | 4.18 | 3.95 | 3.87 | <50% | IS 2386 Part-4 |
| Bulk Density | kg/lts | 2.50 | 1.38 | 1.15 | 1.13 | 0.95 | 0.84 | 0.69 | | IS 2386 Part-3 |
| Specific Gravity | | 3.1 | 1.78 | 1.8 | 1.86 | 1.9 | 2.01 | 2.2 | | IS 2386 Part-3 |
| Size | mm | 4.75-20 | 4.75-20 | 4.75-20 | 4.75-20 | 4.75-20 | 4.75-20 | 4.75-20 | | |
| Shape | | Angular | Circular | Circular | Circular | Circular | Circular | Circular | | |

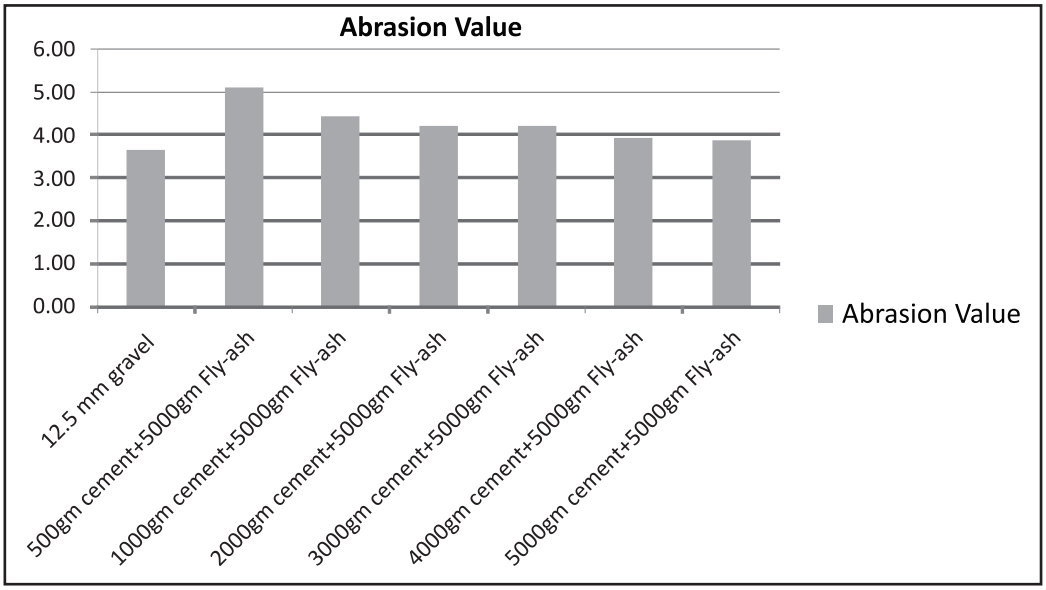


**Fig. 4. Abrasion Value test of different Autoclaved Fly-ash Pellets**

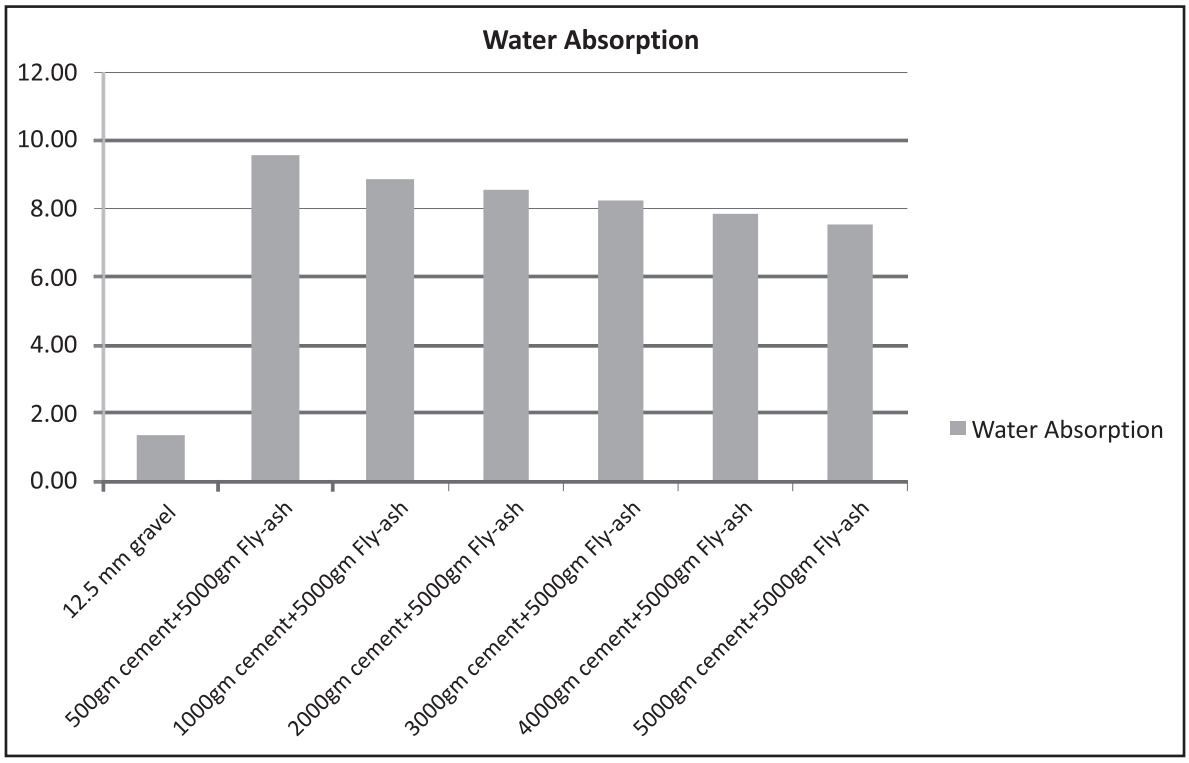


**Fig. 5. Water absorption test of different Autoclaved Fly-ash Pellets**

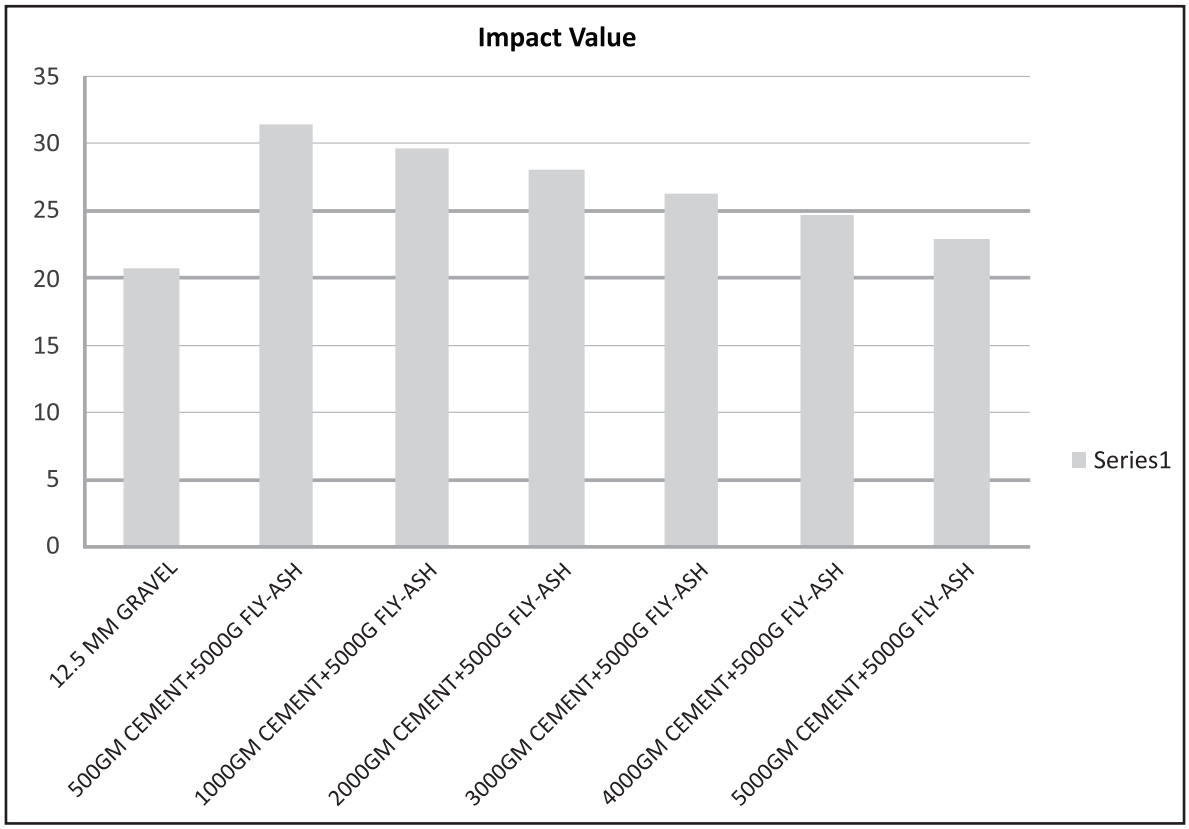


**Fig. 6. Impact test of different Autoclaved Fly-ash Pellets**

bulk density, specific gravity tests were performed as per IS 2386 Part-3 [11]. Table II gives the result of tests performed on fly-ash aggregate and coarse aggregate.

## VII. MIX DESIGN

The preparation of concrete with fly ash pellets is done as that of conventional concrete, but the changes in the mix design must be done to corresponding changes in the densities of the coarse aggregates. Here is the list of materials used along with their quantity and the final mix design for M-10, M-15, M-20, M-25, M-30, M-35, and M-40 concrete.

(i) Admixture= 2.4 kg/$m^3$
(ii) Water cement ratio = 0.5

Cement, sand, fly-ash aggregate were used as per the Design Mix.

Extra quantity of water was added for the absorption of coarse aggregate for 1%.

## VIII. WORKABILITY OF CONCRETE SPECIMEN

The shape and texture of aggregate affects the fresh property of the concrete. Fly ash aggregate is rounded in shape. Rounded aggregates promote workability of

**TABLE III.**
**WORKABILITY OF DIFFERENT CONCRETE MIXTURES**

| TRIAL MIX | WORKABILITY (SLUMP HEIGHT IN MM) | | | | |
|---|---|---|---|---|---|
| | M-10 | M-15 | M-20 | M-25 | M-40 |
| Conventional Concrete | 45 | 47.07667 | 70 | 81.23 | 110 |
| Fly-ash Pellets Concrete(10:1) | 46.98 | 50.66 | 75 | 81.98 | 115 |
| Fly-ash Pellets Concrete(5:1) | 47.23 | 54.24333 | 75.6 | 82.58 | 120 |
| Fly-ash Pellets Concrete(5:2) | 47.05 | 57.82667 | 78 | 83.28 | 128 |
| Fly-ash Pellets Concrete(5:3) | 47.98 | 61.41 | 79.23 | 83.955 | 135 |
| Fly-ash Pellets Concrete(5:4) | 48.01 | 64.99333 | 80.32 | 84.63 | 145 |
| Fly-ash Pellets Concrete(5:1) | 48.23 | 68.57667 | 80.52 | 85.305 | 150 |

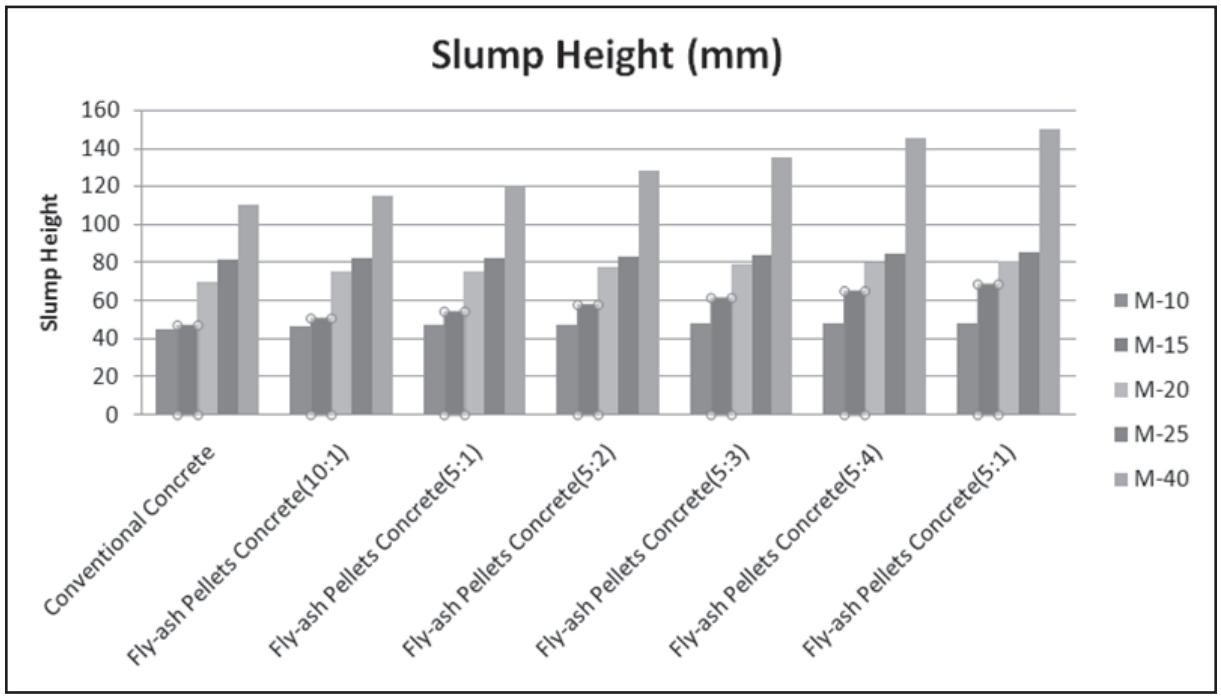


**Fig. 7. Slump Height Test of Different Autoclaved Fly-ash Pellets Using Different Concrete Mix**

concrete, while the angular nature of natural gravel gives a better bonding property but requires more cement mortar for better workability. Table III shows the workability of different concrete mixtures.

**TABLE IV.**
**THE TABLE SHOWS THE COMPRESSIVE STRENGTH OF CUBE AND CYLINDER**

| Sl.No. | SPECIMEN | DAYS | GRADE | CONVENTIONAL | FLY ASH PELLETS CONCRETE | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | CONCRETE | 10:01 | 05:01 | 05:02 | 05:03 | 05:04 | 05:05 |
| 1 | Cube | 28 | M-10 | 16.23 mpa | 17.45 mpa | 17.98 mpa | 18.23 mpa | 18.75 mpa | 19.01 mpa | 19.78 mpa |
| | | | M-15 | 21.08 mpa | 22.45 mpa | 22.96 mpa | 23.18 mpa | 23.78 mpa | 24.76 mpa | 25.12 mpa |
| | | | M-20 | 27.26 mpa | 28.13 mpa | 28.54 mpa | 29.65 mpa | 29.75 mpa | 29.98 mpa | 30.23 mpa |
| | | | M-25 | 31.76 mpa | 32.25 mpa | 32.98 mpa | 33.13 mpa | 33.53 mpa | 33.98 mpa | 34.43 mpa |
| | | | M-40 | 62.96 mpa | 62.98 mpa | 63.45mpa | 63.66 mpa | 63.78 mpa | 63.96 mpa | 64.08mpa |
| 2 | Cylinder | 28 | M-10 | 15.78 mpa | 16.13 mpa | 16.53 mpa | 17.02 mpa | 17.15 mpa | 17.52 mpa | 18.56 mpa |
| | | | M-15 | 20.78 mpa | 21.34 mpa | 22.27 mpa | 22.78 mpa | 23.01 mpa | 23.57 mpa | 24.78 mpa |
| | | | M-20 | 26.6 mpa | 27.01 mpa | 27.46 mpa | 27.75 mpa | 28.31 mpa | 28.76 mpa | 29.21 mpa |
| | | | M-25 | 31.45 mpa | 32.05 mpa | 32.68 mpa | 33.08 mpa | 33.23 mpa | 33.78 mpa | 34.03 mpa |
| | | | M-40 | 61.52Mpa | 62.24 mpa | 62.53mpa | 62.89 mpa | 62.97 mpa | 63.02 mpa | 63.15mpa |

## IX. CHARACTERISTIC COMPRESSIVE STRENGTH OF FLY ASH PELLETS CONCRETE - COMPARISON OF COMPRESSIVE STRENGTH

**TABLE V.**
**THE TABLE SHOWS COSTING DIFFERENCE OF CONVENTIONAL AGGREGATE AND FLY-ASH PELLETS**

| | | CONVENTIONAL CONCRETE | | FLY ASH PELLETS CONCRETE | | | | |
|---|---|---|---|---|---|---|---|---|
| | | 12 mm Gravel | 10:1 | 5:1 | 5:2 | 5:3 | 5:4 | 1:1 |
| S.No. | MATERIAL | RATE (₹ per kg) | RATE (₹ per kg) | RATE (₹ per kg) | RATE (₹ per kg) | RATE (₹ per kg) | RATE (₹ per kg) | RATE (₹ per kg) |
| 1 | Cement | 17 | 17 | 17 | 17 | 17 | 17 | 17 |
| 2 | Fine aggregate | 5 | 6 | 6 | 6 | 6 | 6 | 6 |
| 3 | Coarse aggregate | 32 | 15 | 18 | 20 | 22 | 24 | 25 |

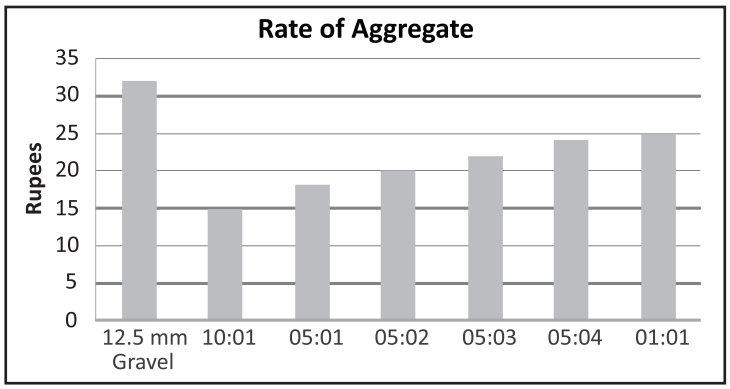


**Fig. 8. Cost of different Autoclaved Fly-ash Pellets**

## X. COMPARISON OF COST FOR ONE CUBE (0.15M X0.15M X0.15M)

Here, the cost of both conventional concrete and fly ash pellets concrete for one cube (0.15m x 0.15m x 0.15m)in lab scale are discussed.

Table V compares the costing variation of conventional concrete and fly ash pellets concrete for a cube. From the comparison it is found the concrete from 5:1 ratio pellets is more cost efficient i.e. nearly 35% of cost saving as compared to conventional along with having proper strength. The cost efficiency is directly proportional to the efficiency in the manufacturing of pellets. If the production is fully efficient, the cost efficiency will increase to a greater extent on a large scale.

## XI. CONCLUSION

The following conclusions can be drawn from the test and analysis result:

❖ The physical properties of fly-ash pellets have attained the required value as per IS 2386-part3 and IS 2386-part4 are concerned.

❖ As the pellets produced by ratio of fly-ash and cement i.e.10:1, 5:1, 5:2, 5:3, 5:4, 1:1 is giving the values of Abrasion test(for fly-ash aggregate: 4.89, 4.35, 4.23, 4.11, 3.89, 3.87; for gravel: 3.85) Crushing test(for fly-ash aggregate: 28.52, 30.79, 33.06, 35.33, 37.6, 39.87; for gravel: 34.21) is nearly the same as that of coarse aggregate. So, the coarse aggregate can be replaced by pellets and can give the same strength as that of coarse aggregate in the concrete mix.

❖ Though the specific gravity of the fly-ash aggregate is less than gravel and the impact value of the gravel is lesser than fly-ash aggregate.

❖ The compressive strength of class F fly ash pellets concrete has surpassed the minimum strength that a M40 concrete has i.e. 48.25Mpa.

❖ The cost analysis also proved that Class F fly ash pellets are more cost effective than conventional aggregate.

❖ We prefer 1:1 ratio than other ratios, though they have mostly the same cost as having more strength than that of regular M40 concrete cube.

❖ The coarse aggregates are very useful in concrete. The use of regular coarse aggregate causes destruction of hills as it may cause geological and environmental imbalance. The environmental impacts on crushing of stone to supply coarse aggregate may cause natural calamities as well. Pollution hazards, noise, dust, blasting vibration, loss of forests, and destruction of nature is a great threat to our nature as well as to our society. Landslides of weak and steep hill slopes are induced due to destruction of hills for getting coarse aggregate. On the other hand,fly-ash coming out from industries may also cause a great problem of rehabilitation, so it will be a great environment friendly step to make fly-ash pellets a replacement of coarse aggregate.

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