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# Gainful Utilization of Fly Ash and Hypo Sludge in Concrete

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**Abstract:** *Fly Ash and Hypo Sludge is obtained as waste by-products from the thermal and paper industries. The utilization of thermal industry waste fly ash (Class-F) and paper industry waste hypo sludge can reduce the consumption of natural resources, reduce the quantity of expensive cement and reduce environmental pollution. Investigations were carried out to gainful utilization of fly ash (Class-F) and hypo sludge in concrete mixtures. This research work describes the gainful utilization of the fly ash (Class-F) and hypo sludge in concrete production as partial replacement of cement by weight. The cement has been replaced by fly ash (Class-F) and hypo sludge accordingly in the range of 0% (without fly ash and hypo sludge), 5% + 5%, 10% + 10%, 15% + 15% and 20% + 20% by weight of cement for M-40 mix. Concrete mixtures were produced, tested and compared in terms of compressive strength and flexural strength to the conventional concrete. These tests were carried out to evaluate the mechanical properties for the test results for compressive strength and flexural strength up to 90 days are taken.*

**Keywords:** *Fly Ash, Hypo Sludge, Compressive Strength, flexural strength, Cost*

## 1. Introduction

Fly ash is the most commonly used coal combustion product. Fly ash is also a profitable resource. When fly ash is added to concrete, the amount of cement that is necessary can be reduced. Fly ash is a significant material that gainfully improves the performance of concrete. It is estimated that about 175 million tonnes of fly ash is being produced from different thermal power plants in India. It consumes thousands of hectares of agriculture land for its disposal. It causes serious health and environmental problems. Fly ash helping to leads the fight against global warming.

Paper mill sludge is a foremost economic and environmental problem for the paper and board industry. The material is a by-product of the de-inking and re-pulping of paper. The total quantity of paper mill sludge produced in the world is many million tonnes. The main recycling and disposal routes for paper sludge are land-spreading as agricultural fertilizer, producing paper sludge ash, or disposal to landfill. In efficient terms, paper sludge consists of cellulose fibres, fillers such as calcium carbonate and china clay and residual chemicals bound up with water. The moisture content is typically up to 40%. In the present experimental investigation for gainful utilization of fly ash and hypo sludge in M40 grade of concrete.

## 2. Design Mix Materials

### 2.1 Supplementary Cementitious Material: Fly Ash and Hypo Sludge

Fly ash is composed of the non-combustible mineral portion of coal. The fly ash is procured from Maize Products (A division of Sayaji Industries Ltd) Power plant. This plant is located near kathwada in Ahmedabad District in Gujarat State.

This hypo sludge contains, low calcium and maximum calcium chloride and minimum amount of silica. The hypo sludge is procured from J. K. Papers mill Pvt. Ltd, plant. This plant is located near Songadh in Tappi District in Gujarat State.

The Chemical Properties of Ordinary Portland Cement (OPC), Fly Ash and Hypo sludge as listed in Table 1:

**TABLE 1.** *CHEMICAL PROPERTIES OF ORDINARY PORTLAND CEMENT (OPC), FLY ASH AND HYPO SLUDGE*

| Chemical Properties | Ordinary Portland Cement (OPC) (Percent by mass) | Fly ash (Percent by mass) | Hypo sludge (Percent by mass) |
|---|---|---|---|
| Silicon Dioxide ($SiO_2$) | 21.77 % | 62.22 % | 5.28 % |
| Calcium Oxide (CaO) | 57.02 % | 5.30 % | 47.84 % |
| Magnesium Oxide (MgO) | 2.71 % | 6.09 % | 6.41 % |
| Sulphur Trioxide ($SO_3$) | 2.41 % | 3.00 % | 0.19 % |
| Aluminium Oxide ($Al_2O_3$) | 2.59 % | 7.63 % | 0.09 % |
| Ferric Oxide ($Fe_2O_3$) | 0.65 % | 0.13 % | 0.73 % |
| Loss on Ignition | 2.82 % | 9.98 % | 38.26 % |

*Source: "Geo Test House", Vadodara, Gujarat*

### 2.2 Ordinary Portland Cement

The Ordinary Portland Cement of 53 grades conforming to IS:8112-1989 is used. The physical properties of Ordinary Portland Cement as listed in Table 2:

**TABLE 2.** *PHYSICAL PROPERTIES OF ORDINARY PORTLAND CEMENT 53 GRADES*

| Sr. No. | Physical properties of cement | Result | Requirements as per IS:8112-1989 |
|---|---|---|---|
| 1 | Specific gravity | 3.15 | 3.10-3.15 |
| 2 | Standard consistency (%) | 28% | 30-35 |
| 3 | Initial setting time (hours, min) | 35 min | 30 minimum |
| 4 | Final setting time (hours, min) | 178 min | 600 maximum |
| 5 | Compressive strength- 7 days | 38.49 $N/mm^2$ | 43 $N/mm^2$ |
| 6 | Compressive strength- 28 days | 52.31 $N/mm^2$ | 53 $N/mm^2$ |

### 2.3 Coarse Aggregate

The fractions from 20 mm to 4.75 mm are used as coarse aggregate. The Coarse Aggregates from crushed Basalt rock, conforming to IS: 383 are used.

### 2.4 Fine aggregate

Those fractions from 4.75 mm to 150 microns are termed as fine aggregate. The river sand used in combination as fine aggregate conforming to the requirements of IS: 383. The properties of fine aggregate and coarse aggregate as listed in Table 3:

**TABLE 3.** *PROPERTIES OF AGGREGATES*

| Property | Fine Aggregate | Coarse Aggregate |
|---|---|---|
| Fineness modulus | 3.35 | 7.54 |
| Specific Gravity | 2.38 | 2.76 |
| Water absorption (%) | 1.20 | 1.83 |
| Bulk Density (gm/cc) | 1753 | 1741 |

### 2.5 Water

Water cement ratio used is 0.38 for M40 concrete.

## 3. DESIGN MIX METHODOLOGY

### 3.1 Design Mix

A mix M40 grade was designed as per IS 10262:2009 and the same was used to prepare the test samples. The design mix proportion is shown in Table 4

**TABLE 4.** *CONCRETE DESIGN MIX PROPORTIONS*

| Sr.No | Concrete Mix | % Replacement of Cement By Fly Ash and Hypo Sludge | Concrete Design Mix Proportion (By Weight in kg) | | | Cement Replacement by Fly ash | Cement Replacement by Hypo Sludge |
|---|---|---|---|---|---|---|---|
| | | | C | F. A. | C. A. | | |
| 1 | A2 | 0 % | 473.68 | 341.91 | 1419.30 | - | - |
| 2 | D5 | 5% + 5% | 426.31 | 341.91 | 1419.30 | 23.69 | 23.69 |
| 3 | D6 | 10% + 10% | 378.94 | 341.91 | 1419.30 | 47.37 | 47.37 |
| 4 | D7 | 15% + 15% | 331.58 | 341.91 | 1419.30 | 71.05 | 71.05 |
| 5 | D8 | 20% + 20% | 284.21 | 341.91 | 1419.30 | 94.74 | 94.74 |

C= Cement, F. A. = Fine Aggregate, C. A. = Coarse Aggregate

### 3.2 Compression Test

Standard metallic cube moulds (150*150*150 mm) were casted for compressive strength. A table vibrator was used for compaction of the hand filled concrete cubes. The specimens were demoulded after 24 hours and subsequently immersed in water for different age of testing. For each age three specimens were tested for the determination of average compressive strength. The test was performed on compression testing machine having capacity of 200 MT. Figure 1 shows the setup of compressive strength testing machine.

**Fig.1.** *Setup of Compressive Strength Test*

### 3.3 Flexural Strength Test (IS: 516 - 1959)

Standard metallic beam moulds (100 mm * 100 mm * 500 mm) were casted for the preparation of concrete specimens for flexural strength. A table vibrator was used for compaction of the hand filled concrete beams. The specimens were demoulded after 24 hours and subsequently immersed in water for different age of testing. For each age three specimens were used for the determination of average flexural strength. Test was performed on universal testing machine having capacity of 50 British tonne (BT).

## 4. RESULTS

The compressive strength results are compiled in Table-5. The % replacements of cement v/s compressive strength results are graphically shown in figure 2.

**TABLE 5.** *COMPRESSIVE STRENGTH AT 7, 14, 28, 56 AND 90 DAYS FOR M40*

| Concrete Mix | Average Compressive Strength at | | | | |
|---|---|---|---|---|---|
| | 7 days [N/mm$^2$] | 14 days [N/mm$^2$] | 28 days [N/mm$^2$] | 56 days [N/mm$^2$] | 90 days [N/mm$^2$] |
| A2 | 34.81 | 45.04 | 50.81 | 52.89 | 53.93 |
| D5 | 37.78 | 47.96 | 52.78 | 54.59 | 55.44 |
| D6 | 36.80 | 46.67 | 51.85 | 53.50 | 54.82 |
| D7 | 22.37 | 26.52 | 27.26 | 29.33 | 31.26 |
| D8 | 19.70 | 22.96 | 23.85 | 24.15 | 25.33 |

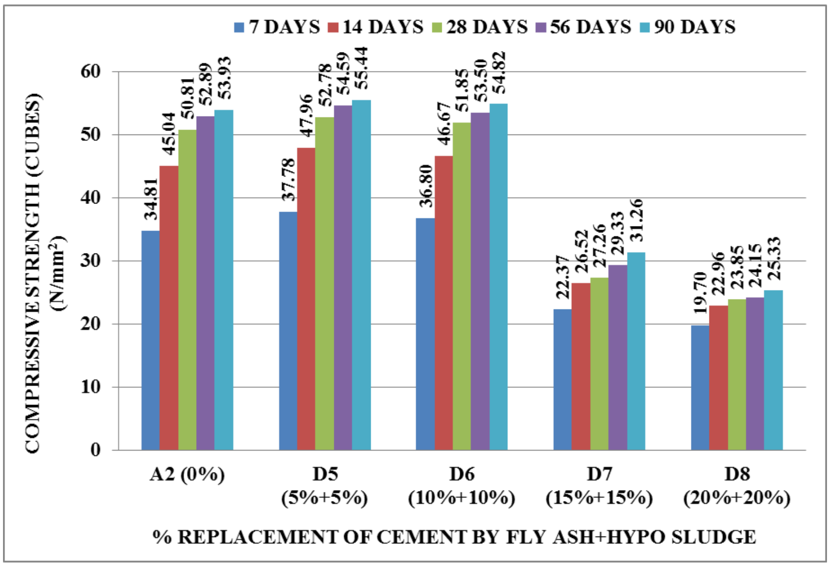


**Fig.2.** *% Replacement of Cement V/S Compressive Strength of Concrete (N/mm$^2$) Specimen at 7, 14, 28, 56 and 90 Days for M40*

The flexural strength results are compiled in Table-6. The % replacements of cement v/s flexural strength results are graphically shown in figure 3.

**TABLE 6.** *FLEXURAL STRENGTH AT 7, 14, 28, 56 AND 90 DAYS FOR M40*

| Concrete Mix | Average Flexural Strength at | | | | |
|---|---|---|---|---|---|
| | 7 days [N/mm$^2$] | 14 days [N/mm$^2$] | 28 days [N/mm$^2$] | 56 days [N/mm$^2$] | 90 days [N/mm$^2$] |
| A2 | 3.62 | 4.27 | 6.10 | 6.95 | 7.46 |
| D5 | 3.90 | 4.80 | 6.35 | 7.15 | 7.86 |
| D6 | 3.71 | 4.62 | 5.29 | 5.57 | 6.04 |
| D7 | 1.87 | 2.19 | 3.13 | 3.47 | 3.82 |
| D8 | 1.69 | 1.97 | 2.80 | 3.07 | 3.52 |

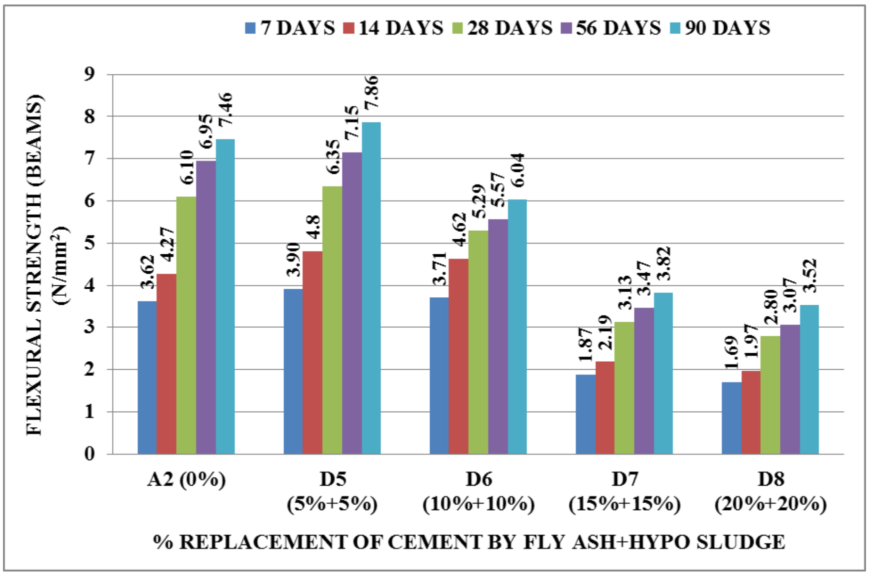


**Fig.3.** *% Replacement of Cement V/S Flexural Strength of Concrete (N/mm$^2$) Specimen at 7, 14, 28, 56 and 90 Days for M40*

## 5. Cost Impact on Concrete

The basic market rates of materials are given in table 7. The change in cost due to % replacement of cement by fly ash and hypo sludge is worked out in table 8 and graphically shown in figure 4. Cost decrease due to reduction in cement.

**TABLE- 7.** *COST OF MATERIALS*

| Sr. No. | Materials | Rate (Rs/Kg) |
|---|---|---|
| 1 | Cement (OPC 53 grade) | 6.40 |
| 2 | Fly Ash | 0.50 |
| 3 | Hypo sludge | 0.50 |
| 4 | Fine aggregate | 0.60 |
| 5 | Coarse aggregate | 0.65 |

**TABLE-8.** *MATERIALS FOR DESIGNED M40 CONCRETE*

| Concrete Mix | % Replacement of Cement By Fly Ash and Hypo Sludge | Designed Materials for Concrete | | | | | Total Cost [$m^3$] |
|---|---|---|---|---|---|---|---|
| | | Cement [$kg/m^3$] | Fine aggregate [$kg/m^3$] | Coarse aggregate [$kg/m^3$] | Fly ash [$kg/m^3$] | Hypo sludge [$kg/m^3$] | |
| A2 | 0 % | 473.68 | 341.91 | 1419.30 | - | - | 4159.24 |
| D5 | 5% + 5% | 426.31 | 341.91 | 1419.30 | 23.69 | 23.69 | 3881.19 |
| D6 | 10% + 10% | 378.94 | 341.91 | 1419.30 | 47.37 | 47.37 | 3603.12 |
| D7 | 15% + 15% | 331.58 | 341.91 | 1419.30 | 71.05 | 71.05 | 3325.12 |
| D8 | 20% + 20% | 284.21 | 341.91 | 1419.30 | 94.74 | 94.74 | 3047.06 |

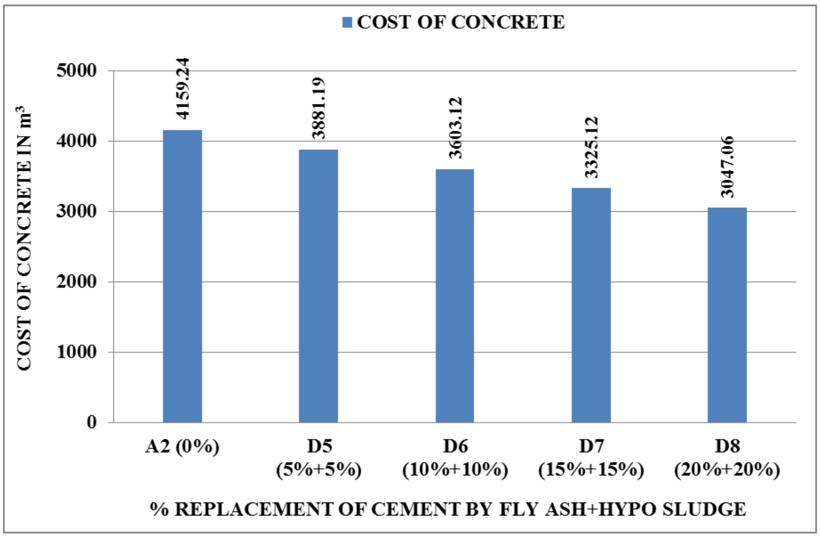


**Fig.4.** *Comparison of Cost of Concrete in $m^3$ of Various Mix of Fly Ash + Hypo Sludge in M40 Grade Concrete*

## 6. Conclusions

Based on limited experimental investigations concerning the compressive of concrete, the following conclusions are drawn:

(a) For grade of concrete M40 10% hybrid mix (fly ash and hypo sludge) replacement with cement gives the design strength at 28 days. (D5)

(b) For design mix M40 grade concrete up to 10% replacements gains early strength at 7 days and required strength of 66% at 14 days age. Average increase in strength from 28 to 90 days for grade M40 with an optimum replacement of cement with a hybrid mix (fly ash and hypo sludge) (10%) founds to be 5.03%.

(c) Hybrid mix (fly ash and hypo sludge) samples up to 10% replacement gains required flexural strength at 28 days and beyond 10% replacement there is less in strength.

(d) All the mixes reflect progressive gain in strength linearly from the age of 7 days to 90 days.

(e) The cost analysis indicates that percentage cement reduction decreases cost of concrete, but at the same time strength also decreases.

(f) Use of fly ash (thermal industry waste) and hypo sludge (paper industry waste) in concrete can save the disposal costs and produce a 'greener' concrete for construction.

(g) This research concludes that fly ash and hypo sludge can be innovative supplementary cementitious Construction Material but judicious decisions are to be taken by engineers.

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