THE SIGNIFICANCE OF DESIGN OF M40 CONCRETE MIX

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Abstract— **The scope of present study aims at providing the M40 concrete with an optimum quantity of fly ash content that could be used in structural work/ road construction with acceptable strength values such that the cost of construction may be reduced to a great extent. Moreover, it also helps in reducing the harmful impact of fly ash on environment**

Index Terms— **Cement, Aggregates, Fly ash, M40.**

1. INTRODUCTION

Concrete, typically composed of gravel, sand, water, and portland cement, is an extremely versatile building material that is used extensively worldwide. Reinforced concrete is very strong and can be cast in nearly any desired shape. Unfortunately, significant environmental problems result from the manufacture of Portland cement. Worldwide, the manufacture of Portland cement accounts for 6-7% of the total carbon dioxide (CO_2) produced by humans, adding the greenhouse gas equivalent of 330 million cars driving 12,500 miles per year.

In the HVFAC mechanism, physical and chemical factors combines at all ages to densify and bind the paste. In the early age of concrete, the important factors of strength development are

- Physical effect - fine particles of fly ash act as micro aggregates and densify the mass
- Chemical contribution of the formation of ettringite or related sulpho-aluminate production.

In the later age hydration reaction dominate in the strength development process as additional binders are generated by reaction involving fly ash. Any concrete that uses more fly ash than 25% (weight of cement) would be considered high volume fly ash concrete. With high volume fly ash concrete, you will see less early age strength, but the long term strength is about the same as with normal concrete.

Consequent upon increased generation of electricity through thermal route involving combustion of pulverized coal/ignite, concurrent generation of fly ash in bulk quantities is a matter of serious concern not only because of issues associated with its disposal and utilization but also because of its threat to public health and ecology. At present, large quantity of fly ash is being dumped in slurry form in large areas close to the power plants without being put to gainful use in India. Only a very small percentage (<35%) of fly ash generated in India is being used for gainful applications whereas the corresponding figures of other countries may vary from 60 to 100%[2].

Although fly ash offers environmental advantages, it also improves the performance and quality of concrete. Fly ash affects the plastic properties of concrete by improving workability, reducing water demand, reducing segregation and bleeding, and lowering heat of hydration. Fly ash increases strength, reduces permeability, reduces corrosion of reinforcing steel, increases sulphate resistance, and reduces alkali-aggregate reaction. Fly ash reaches its maximum strength more slowly than concrete made with only portland cement. The techniques for working with this type of concrete are standard for the industry and will not impact the budget of a job. So as a Civil Engineer we should effectively try to use fly ash in construction, as it helps in saving environment with reduced construction cost along with many other advantages, but now question rises to what extent or percentage fly ash could be used in concrete for construction works, and to answer this present study have been made.

World over fly ash has been successfully utilized in cement concrete and as component of Portland Pozzolana Cement/ Blended cement for more than 50 years. Some of the structures wherein fly ash has been utilized are as under[3]:

1. Nearly 20 lakh tones of fly ash from NTPC, Badarpur Thermal Power Station has been utilized in road embankment of Noida- Greater Noida Express Highway.
2. About 1.25 lakh tones of fly ash has been utilized in second Nizamuddin bridge embankment construction by PWD at New Delhi.
3. Fly ash concrete was used in Prudential Building the first tallest building in Chicago after World War II.
4. About 60,000 cum of fly ash concrete with an estimated saving of 3,000 ton of Ordinary Portland Cement was used in Lednock Dam construction in UK during the year 1955.
5. About 60,000 m^3 of fly ash concrete with 80:20 Ordinary Portland Cement: fly ash having average slump of 175 mm was used in the piles and the foundation slab to meet the requirement of sulphate resistance concrete of Ferry bridge C power station in UK during 1964.
6. About 10,000 tonnes of fly ash from Badarpur Thermal Power has been utilized in Sarita-Vihar fly over in Delhi.
7. About 4000 m^3 of pond ash and 800 m^3 of bottom ash has been utilized by CPWD in construction of Okhla fly over bridge constructed at National Highway No. 2
8. Fly ash in concrete was used in construction of Euro Tunnel-second largest rail tunnel in the world during 1987-94. To meet the early stripping requirement, a

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concrete mix containing 30% fly ash with w/c of 0.35 using high efficient water reducing admixture at a total cementitious content of 440 kg/m3 was used in the work. The strength of concrete obtained was more than 80 MPa at 28 days and permeability coefficients were 10^{-13} m/s against requirement of 70 MPa and 10^{-11} m/s.

9. Fly ash from NTPC's Dadri Thermal power stations is being utilized in prestigious Delhi Metro Rail Corporation (DMRC) works at New Delhi. : More than 60,000 tonne of fly ash has been utilized in the work so far. In this project, the requirement of cement concrete was high strength, high durability (less shrinkage and & thermal crakes), low heat of hydration, easy placement, cohesiveness and good surface finish. Use of fly ash in concrete has fulfilled the entire above requirements. In this work the concrete of M-35 and above were used in structural works.
10. Self-Compacting concrete using fly ash from Kota thermal power station has been utilized for structural members of Rajasthan Atomic Power Project. Self-compacting concrete was used due to difficulties in placing concrete in structures having heavily congested reinforced bars and openings.
11. Recently, about 38,000 m^3 fly ash concrete has been used in main plant civil work of Rajasthan Atomic Power Project (RAPP) unit 5 &6.
12. DLF have utilized fly ash from NTPC Dadri in concrete for residential buildings at Gurgaon, Haryana.
13. Ready Mixed Concrete (RMC) plants located in Mumbai, Delhi and adjoining areas are using fly ash in concrete. These RMC plants are taking fly ash from Nasik and Dahanu thermal power stations located near Mumbai and Dadri near Delhi and supplying fly ash based concrete for various housing and infrastructure projects.

2. FLY ASH

Fly ash is one of the residues generated in combustion as shown in Figure 3.1, and comprises the fine particles that rise with the flue gases. Ash which does not rise is termed bottom ash. In an industrial context, fly ash usually refers to ash produced during combustion of coal. Fly ash is generally captured by electrostatic precipitators or other particle filtration equipment before the flue gases reach the chimneys of coal-fired power plants, and together with bottom ash removed from the bottom of the furnace is in this case jointly known as coal ash. Depending upon the source and makeup of the coal being burned, the components of fly ash vary considerably, but all fly ash includes substantial amounts of silicon dioxide (SiO_2) (both amorphous and crystalline) and calcium oxide (CaO), both being endemic ingredients in many coal-bearing rock strata.

Toxic constituents depend upon the specific coal bed makeup, but may include one or more of the following elements or substances in quantities from trace amounts to several percent: arsenic, beryllium, boron, cadmium, chromium, chromium VI, cobalt, lead, manganese, mercury, molybdenum, selenium, strontium, thallium, and vanadium, along with dioxins and PAH compounds.[22]

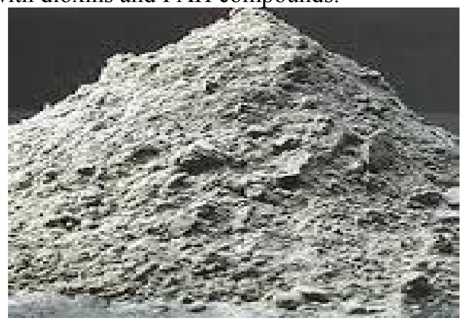

Figure 3.1: Fly Ash

In the past, fly ash was generally released into the atmosphere, but pollution control equipment mandated in recent decades now require that it be captured prior to release. In the US, fly ash is generally stored at coal power plants or placed in landfills. About 43 percent is recycled, often used to supplement Portland cement in concrete production. Some have expressed health concerns about this.

In some cases, such as the burning of solid waste to create electricity, the fly ash may contain higher levels of contaminants than the bottom ash. So, mixing the fly and bottom ash together brings the proportional levels of contaminants within the range to qualify as nonhazardous waste in a given state, whereas, unmixed fly ash would be within the range to qualify as hazardous waste.

2.1 HOW FLY ASH WORKS WITH CEMENT IN CONCRETE?

Ordinary Portland Cement (OPC) is a product of four principal mineralogical phases. These phases are Tricalcium Silicate- C_3S ($3CaO.SiO_2$), Dicalcium Silicate - C_2S ($2CaO.SiO_2$), Tricalcium Aluminate- C_3A ($3CaO.Al_2O_3$) and Tetracalcium alumino-ferrite - C_4AF($4CaO.\ Al_2O_3.\ Fe_2O_3$). The setting and hardening of the OPC takes place as a result of reaction between these principal compounds and water. The reaction between these compounds and water are shown as under:

$$2C_3S + 6H \rightarrow C_3S_2H_3 + 3CH$$

(Tricalcium Silicate) (Water) (C-S-H gel) (Calcium Hydroxide)

$$2C_2S + 4H \rightarrow C_3S_2H_3 + CH$$

(Dicalcium Silicate) (Water) (C-S-H gel) (Calcium Hydroxide)

The hydration prod ucts from C_3S and C_2S are similar but quantity of calcium hydroxide (lime) released is higher in C_3S as compared to C_2S .

The reaction of C_3A with water takes place in presence of sulphate ions supplied by dissolution of gypsum present in OPC. This reaction is very fast and is shown as under:

C_3A + $3(CSH_2)$ + $26H$ $\rightarrow$ $C_3A(CS)_3H_{32}$

(Tricalcium Alluminate) (Gypsum) (Water) (Ettringite)

$C_3A + CS$ + $10H$ $\rightarrow$ C_3ACSH_{12}

(Water) (Monosulpho-aluminate hydrate)

2.2 HOW FLY ASH HELPS IN CONCRETE?

Fly ash can play a vital role in the improvement of various properties of concrete. The various ways in which fly ash helps concrete are discussed below:

3. Reduced Heat of Hydration

In concrete mix, when water and cement come in contact, a chemical reaction initiates that produces binding material and consolidates the concrete mass. The process is exothermic and heat is released which increases the temperature of the mass. When fly ash is present in the concrete mass, it plays dual role for the strength development. Fly ash reacts with released lime and produces binder as explained above and render additional strength to the concrete mass. The un-reactive portion of fly ash act as micro aggregates and fills up the matrix to render packing effect and results in increased strength.

The large temperature rise of concrete mass exerts temperature stresses and can lead micro crackes. When fly ash is used as part of cementitious material, quantum of heat liberated is low and staggers through pozzolanic reactions and thus reduces micro-cracking and improves soundness of concrete mass.

4. Effect of fly ash on Carbonation of Concrete

Carbonation phenomenon in concrete occurs when calcium hydroxides (lime) of the hydrated Portland Cement react with carbon dioxide from atmospheres in the presence of moisture and form calcium carbonate. To a small extent, calcium carbonate is also formed when calcium silicate and aluminates of the hydrated Portland cement react with carbon dioxide from atmosphere. Carbonation process in concrete results in two deleterious effects:

shrinkage may occur.

concrete immediately adjacent to steel reinforcement may reduce its resistance to corrosion.

5. Corrosion of steel

Corrosion of steel takes place mainly because of two types of attack. One is due to carbonation attack and other is due to chloride attack. In the carbonation attack, due to carbonation of free lime, alkaline environment in the concrete comes down which disturbs the passive iron oxide film on the reinforcement. When the concrete is permeable, the ingress of moisture and oxygen infuse to the surface of steel initiates the electrochemical process and as a result-rust is formed. The transformation of steel to rust increases its volume thus resulting in the concrete expansion, cracking and distress to the structure.

In the chloride attack, Chloride ion becomes available in the concrete either through the dissociation of chlorides-associated mineralogical hydration or infusion of chloride ion. The sulphate attack in the concrete decomposes the chloride mineralogy thereby releasing chloride ion. In the presence of large amount of chloride, the concrete exhibits the tendency to hold moisture. In the presence of moisture and oxygen, the resistivity of the concrete weakens and becomes more permeable thereby inducing further distress. The use of fly ash reduces availability of free limes and permeability thus result in corrosion prevention.

6. EFFECT OF QUALITY OF FLY ASH ON CONCRETE

The characteristics of fly ash depends upon the characteristics of coal burnt in the furnace of boiler, degree of pulverization of coal, rate and temperature of combustion, fuel air ratio etc. The important characteristics, which affect the performance of fly ash in concrete, are:

1. Loss on Ignition (LOI)
2. Fineness
3. Calcium (CaO) content

1) Loss on Ignition

When fly ash is burnt at about 1000^0C, it suffers a loss of weight through the presence of carbonates, combined water in residual clay mineral and combustion of free carbon. The combined effect is termed the LOI. The carbon contained in fly ash has high porosity and a very large specific area and is able to absorb significant quantity of water as well as admixture. Thus increase water and admixture requirement and affect properties of concrete. It may be stated that lower the LOI, the better will be the fly ash.

2) Fineness

Fineness of fly ash, which is also represented in terms of specific surface area, is determined by Blaine method. This method is based on the resistance offered by material to airflow. More the surface area greater will be fineness. Fineness is also determined by wet sieve analysis and represented in terms of amount retained when wet-sieved on 45 micron (No. 325) sieve. Finer fly ash will have more reactive surface area available to react with lime and thus more will be the pozzolanic activity of fly ash. In short, it can be concluded that finer the fly ash and lower the carbon content, the greater will be the pozzolanic activity and greater the contribution to the strength in concrete of the same workability.

3) Calcium (CaO) content

Fly ash consist of large amount of noncrystalline particles or glass and small amount of one or more of the four major crystalline phases; quartz, mullite, magnetite and hematite.

The reactivity of fly ash is related to the noncrystalline phases or glass. Pozzolanic reactivity of fly ash is more in high calcium fly ash than low calcium fly ash. The reason for high reactivity in high calcium fly ash partially may be because of different chemical composition of glass than the glass of low calcium fly ash.

Design of M40 Concrete Mix

The concrete mix was designed as per code IS 10262-1982[39] and SP:23-1983 and the various design stipulations are enlisted below:

i) Characteristic strength of concrete at 28 days (f_{ck})	40N/mm^2
ii) Maximum size of crushed aggregate	20 mm
iii) Degree of workability	Low
iv) Value of statistical coefficient (K)	1.65
v) Value of standard deviation (S)	5.00
vi) Type of exposure	Moderate

1) Test Data For Materials:

i) Cement used	PPC
ii) Specific gravity of cement	2.75
iii) Specific gravity of coarse aggregates	2.60
iv) Specific gravity of fine aggregates	2.70
v) Water absorption of coarse aggregates	1.00%
vi) Water absorption of fine aggregates	1.10%
vii) Free surface moisture of coarse aggregates	0.00
viii) Free surface moisture of fine aggregates	1.50%

2) Target Mean Strength of Concrete:

Target mean strength is given by $f_t = f_{ck} + KS$

Where, f_t= Target mean strength at 28 days.

f_{ck}= Characteristic compressive strength at 28 days

S = Standard coefficient

K = Statistical coefficient

Target mean strength of concrete = 40 + 1.65×5.00 = 48.25 N/mm^2.

3) Selection of Water Cement Ratio:

Water cement ratio for Target Mean Strength	0.40
Maximum water cement ratio from durability consideration	0.50
Therefore, W/C ratio	0.40

4) Selection of Aggregate Cement Ratio:

1) MAS = 20 mm
2) Fine Aggregates Percentage = 29.25%
3) Coarse Aggregates CA-I (10 mm) Percentage = 20.30%
4) Coarse Aggregates CA-II (20 mm) Percentage = 50.45%
5) Zone of Aggregates = 3
6) Degree of Workability = Low
7) Water Cement Ratio = 0.4
8) Aggregate Cement Ratio Fine Aggregates = 4.7
9) Aggregate Cement Ratio CA-I = 3.7
10) Aggregate Cement Ratio CA-II = 3.7

Final Aggregate Cement Ratio = (4.7+3.7+3.7)/3 = 3.99

5) Cement Content Per Meter Cube of Concrete

Cement content is calculated by the formula = Density/(1+A/C+W/C)

= 2400/(1+3.99+0.4) = 445 Kg

Here, A/C = Aggregate Cement Ratio

W/c = Water Cement Ratio

6) Actual Quantities Required For The M40 Per Cubic Metre of Concrete:

1) Cement = 445 kg
2) Total Aggregates = Cement Content x A/C Ratio = 445x3.99 = 1777 Kg
3) Fine Aggregates are 29.25% of Total Aggregates as per design made, so value of Fine Aggregates = 29.25% x 1777 = 520 Kg
4) Similarly CA-I = 20.30% x 1777 = 361 Kg

   CA-II = 50.45% x 1777 = 896 Kg
5) Water
   a) For water cement ratio of 0.40, water required= 178 Lt.
   b) Extra quantity of water to be added for absorption in case of coarse aggregates@ 0.75% by mass= 9.72 litre (+).
   c) Quantity of water to be deducted for the free moisture present in sand@ 1.5%= 7.8 litre (-).

   Actual quantity of water to be added = 178+9.42-7.8 = 180 Lt (Approximately).
6) Admixture are added 1% by the weight of cementitious material.
7) The estimated actual mix proportion for one cubic metre of M40 concrete at 28%, 50% and 70%

CONCLUSION

In conclusion, the high -volume concrete offers a holistic solution to the problem of meeting the increasing demands for concrete in the future in a sustainable manner and at a reduced or no additional cost, and at the same time reducing the environmental impact of two industries that are vital to economic development namely the cement industry and the coal-fired power industry.

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