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Analysis of Concrete Block by Partial Replacement of Cement with Fly Ash

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***Abstract:** The objective of this research is to enhance the properties of concrete by using Fly Ash as a partial substitution of concrete. Tests carried out on cement are Initial and Final setting time and on aggregates, specific gravity and sieve analysis. The mean target strength with given compressive strength at 28 day and quality control level is calculated. Concrete blend proportions for the first tryout mix is calculated and casting of cube of 15mm size with curing for 28 days, and then test for strength using UTM/CTM machines. C-S-H gel as well as Calcium hydroxide as bi product when reacts with water. C-S-H gel has an ability to keep the ingredients together by making a proper bond whereas lime which is freely available can react with atmospheric moisture and cause efflorescence. In such cases if we use fly ash, it reacts with free lime and produces C-S-H gel again and water as bi product. We have used Fly ash as a partial replacement of cement with variation of fly ash in percentage. In this study fly ash add in increment of 5%, 10%, 15%, 20%, 25%, 30% and 35% replacement of cement which has shown satisfactory results in the strength of the concrete. Fly Ash improved the workability of the concrete, decreases the bleeding, surface finish and increases the cohesiveness. Compressive strength is comparatively increased. The initial strength of concrete with fly ash has lower strength but acquires higher strength after 56 days; which shows that more the nos. of curing days more will be the strength. Thus, it can be used in areas of construction such as dams, pavements etc.*

***Keywords:** Cement Concrete, Fly Ash, Partial Replacement, C-S-H Gel, Compressive Strength, Efflorescence.*

I. INTRODUCTION

Cement is component of concrete which is the high energy consumption in the more expensive concrete. Cost of concrete can be decrease by the substitute of cement with fly ash partially in concrete and partially or totally replace the sand with coal ash from the bottom of the river. The disposal of fly ash and coal ash is one of the main issues for environmentalists because the dumping of coal fly ash and bottom material as waste causes serious environmental problems. The make use of fly ash and bottom of the elimination of coal instead making as waste can be used by hand for economic reasons for the partial replacement of cement and sand in ingredient. Concrete can be defined as a homogenous mixture with cement, coarse aggregate, fine aggregate and water as its basic ingredients in proper proportion. Cement is considered the most important ingredient of concrete which helps in gaining the strength.

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If we look at the composition of cement, it comprises of some compounds like Alite, Belite, Tetra-calcium alumino ferrate etc.

These compounds on reacting with water present in the concrete produces C-S-H gel and Calcium hydroxide (Lime) as a bi-product. This C-S-H gel has an ability to keep the ingredients together by making a proper bond. But lime is freely available which can react with the atmospheric moisture and can cause Efflorescence. It is the case if we use normal cement but on the addition of fly ash in cement the case is different. The fly ash reacts with the free lime produced in the concrete due to the hydration reaction and produces C-S-H gel again and water as a bi-product. So, Fly ash can improve the properties of concrete by producing more C-S-H gel which is a binding compound and moreover it reduces the chances of efflorescence by decreasing the amount of free lime in the mix. It is the work of human beings that determine the value of a material. The materials have potential for beneficial use remains in the waste category including potential conflicts and are subject to proper use. The fly ash and bottom are an example of this, which has-been treated as waste in India, two decades ago, and material resources not only now has become goal also means clustering environment as a savior. In this project, the fly ash used was prepared in essentially the Bhatinda (Guru Nanak Dev Thermal Plant), Punjab plant. This project comprises of replacing of cement (OPC, 43 grade) for different percentages of fly ash and then testing them for their compressive strengths. (1) In a number of activations of the fly ash with lime and ashes mixed with Portland cement, and also follows from what Na2S04 can greatly increase and the energy and cement mixture increase, also increases the activity by the grinding of the fly-ash. (2) Adding of fly ash as a fractional replacement with cement in concrete mix show constructive result like increase in strength, workability up to optimum level which is about 40% of cement. (3) Waste product from a timber industry having pozzolanic properties with a pozzolanic index of 75.9%. They used SDA in as a partial replacement (10%) in cement which shows good strength, workability. (4) Compressive strength and pore size find by using fly ash fineness properties. (5) Class F fly ash as a fractional replacement in cement concrete 28 days compressive strength decreases, splitting tensile, modulus of elasticity, resistance against abrasion and flexural strength as well. (6) The usage of cement and find out fly ash as one of the products. They concluded that Rice Husk Ash, Fly Ash and Egg shell powder mixed cubes had equal strength as that of the conventional concrete cubes. (7) Substitute of cement with fly ash in any proportions decreases the compressive strength of concrete and also delays its hardening. (8)

The fly ash cements concrete for road construction and accomplished that 30% of fly ash along with 70% of cement has higher performance.

Fly ash when used in concrete makes it flexible with the selection of mixture proportions. Also because of its lower unit weight, compressive strength is increased and it achieves maximum strength faster. (9) High strength and light weight are possible to produce and the mechanical properties of the concrete could be enhanced by using 10% fly ash. Also, 450kg/m^3 mixture was having the highest strength values. (10) Fly ash is related to its particle size, surface role to specific surface area and shape of particle determines the water affinity and lubricating role. (14) High volume fly ash concrete (HFC) is having higher resistance against acid, alkali and chloride as compared to normal concrete. (15) Use of waste material like fly ash as partial replacement in concrete can also help to reduce the impact of global warming gases.The objective of this study is to do some preliminary laboratory tests for fine aggregates, coarse aggregates for mix design and to check proper proportioning of ingredients for mix design for adequate and sufficient workability. The water to binder ratio was kept 0.50 throughout for M20 grade concrete. The cubes were casted as per 15*15*15cm size and cured in water tank for different mix proportions. The replacement of cement by fly ash was done by 5%, 10%, 15%, 20%, 25%, and 30%. The workability test was conducted for every mix to determine the type of slump. Each and every test including the mixing of cement and fly ash was done in the lab itself under proper and aesthetic lab conditions. The compressive strength test and analysis to calculate the mechanical properties of concrete at 7, 14, 28, and 56 days from the date of casting of specimen was done under proper guidance. It is found that the resistance of control concrete to all the three chemical attack is better only up to 28 days of water curing. At 56 days of water curing LFC shows better resistance against the control and HFC (16).

II. MATERIAL

A. Fly Ash

Fly Ash is a mineral admixture that is obtained by burning wood. The particle size of fly ash is not as much of as the particle size of cement. It can be of Class C and Class F. The main composition of fly ash is Silicon dioxide (SiO2) in both crystalline and amorphous form along with Aluminum oxide (Al2O3) and Calcium oxide (Cao). Class C fly ash is formed by the burning of harder, older anthracite and bituminous coal while Class F fly ash is formed by the burning of younger lignite or sub-bituminous coal. Class F fly ash requires any cementing agent such as ordinary Portland cement or quicklime that also mixed with water to react and produce cementations compounds. But unlike Class F fly ash, Class C fly ash does not require an activator to produce cementations compounds. In this we have used Class C fly ash in which the chemical compound of fly ash i.e. SiO2 reacts with the free lime formed during the hydration reaction of cement to produce more C-S-H gel which can enhance the strength of concrete. We have got this fly ash from ACC Plant near Phagwara Jalandhar Highway. Fly ash obtained from thermal power plant can be used as a reinforced material to fabricate aluminum matrix composites (AMCs) using liquid stir casting technique.[13]

We have taken Ordinary Portland cement having Specific gravity of 3.15 with Grade 43. The cement has Initial and final setting time was 30 and 600 min respectively as per IS code. Accurate results are found and written in the paper. Coarse aggregate Passing through 20 mm and retains 10mm sieve size with specific gravity of 2.7. Fine aggregate Sand was used as fine aggregate.(7) Ingredients suitable concrete selection process and determine their relative equivalent of the water required to produce concrete strength has having, durability and maneuverability as possible saving is called the design of the concrete mix.

Design Mix

There are few basics which form the root of selection as well as mix ingredients. From Structural point of view, minimum compressive strength is required. For full compaction there must be availability of adequate workability along with the compacting equipments. To give requisite stability for the particular site situation there must be highest water-cement ratio and/or highest cement content. Those mixes in which the Aggregate cement ratios are pre-defined. It can be up to M25.

Table 1 showing predefined aggregate cement ratios of mix

Mix	Aggregate cement ratios
M10	1:3:6
M15	1:1.5:3
M20	1:2:4
M25	1:1:2

B. Types of Mixtures

Nominal mix: Those mixes in which the Aggregate cement ratios are pre-defined. It can be up to M25. In our Project we have used Standard mix of M20 with the replace of cement by Fly ash in different quantity. Designed Mix: Those mixes are design mix in which the aggregate cement ratios are not pre-defined.

C. Mix proportion designs

In general, the proportion of the concrete mix of ingredients is expressed in provisions of ratios cement, fine and coarse aggregates. E.g. A 1: 2: 6 mixtures of concrete means that the cement, fine aggregates and course in same ratio. It is also unstated that the mixture contains cement to two parts of fine aggregate and aggregate coarse six parties. General proportions are by weight or volume. Water-cement weight ratio is usually expressed. Numerous factors are taken into account for the mix design feature: for example, providing quality requirements of concrete strength of designations, the frequency of the development of the compressive strength of concrete influenced by the type of cement. At most nominal aggregate size should be used in concrete can be as large as possible within the range of what has been, within the limits prescribed by IS 456: 2000. The cement content must be prevented us Syndrome withdrawal, cracking and creep. Dimensions (size and shape), the quantity techniques and methods used for transportation, placement and compaction are related to the workability of concrete to place acceptable.

III. TEST AND PROCEDURE

Tests carried out on cement are Initial and Final setting time and on aggregate are specific gravity and grain size distribution test results are showing in table 2:

Table 2: Various tests conducted along with their results

S.No.	Tests	Results
1.	Initial Setting tine of cement	35 min.
2.	Final setting time of cement	9.30 hr
3.	Specific gravity of fine aggregate	2.60
4.	Fineness modulus of sand	2.73
5.	Slump test	True slump

Aggregate is medium sand as the fineness modulus is 2.73 and the figure 1 is also showing that it is uniform sand. Percentage passing (IS Sieve 600 micron) are showing in table 3.

Table 3: Percentage passing (IS Sieve 600 micron)

Percentage Passing			
Zone-I	Zone-II	Zone-III	Zone-IV
15-34	35-59	60-79	80-100

The zone of fine aggregates is coming out to In Zone II, because our cumulative percentage that passing from IS sieve 600 microns. The values lie in range 35-59 (Zone II) according to IS Code 383 specifications. [14].

A. Mix Design

The procedure for mix design requires a no. of steps to follow. Initially the mean target strength with given compressive strength at 28 day and quality control level is calculated using the relation.

$$ft = fck + 1.65S \qquad \text{Equation no. 1}$$

Where

f_t = target strength.

f_{ck} =compressive strength.

S-σ = (standard deviation from table).

The water-cement ratio target average is obtained by the relationship between the ratio of cement and water resistance to compression and compared with the ratio of water and cement to limit these two values. Air trapped for a nominal maximum aggregate width is estimated from the table is selected and a working capacity water content and desirable that the maximum aggregate size. The percentage of fines in the aggregate totals is calculated using the absolute volume of the table for concrete. The water content and the percentage of sand is maintained as mentioned in the table for any difference in handling, sorting, roundness added. After that, the calculation of water content of cement content and the ratio of final water content blocks cement verification regarding minimum cement content for durability and maximum of the two values is selected.The amount of water, per unit volume of cement concrete and the percentage of sand, the amount of coarse aggregate and ending per unit volume is calculated using

$$V = \left[w + \frac{c}{s_c} + \frac{1}{p}\frac{f_a}{s_{f_a}}\right] \times \frac{1}{1000} \qquad \text{Equation no. 2}$$

$$V = \left[w + \frac{c}{s_c} + \frac{1}{1-p}\frac{c_a}{s_{ca}}\right] \times \frac{1}{1000} \qquad \text{Equation no. 3}$$

Where

V = Overall volume of concrete

(1m3 gross volume less the trapped air volume)

S_c = Specific gravity of cement.

W = Weight of water per cubic meter of concrete (kg).

C = Mass of cement per meter cube of SCAF,

S_{ca} = specific gravities saturated area aggregates fine and coarse.

p = Aggregate Ratio end the total absolute volume.

F_a, Ca = Total mass of fine and coarse aggregates, for cubic meter of concrete.

Finally calculate the concrete mix proportions for the first examination mix and cast the cube of 15mm size. Cure it for 28 days and then test for strength using UTM/CTM machines. [1, 4]

B. Concrete mix proportioning as per IS 10262:2009

The target average compressive strength (f'ck) at 28 days was determined by using the following equation:

$$f'ck = fck + t * s$$

Where,

f'ck = After 28 days target strength

fck = Characteristics strength of concrete after 28 days

t = A statistics, depending upon the accepted proportion of low results and the number of tests; the value of t was taken from table 2 of IS 10262- 1982 Page no.6, t=1.65

s = standard deviation, for M20 standard deviation,

s= 4.6 for good control, taken from table no.1 IS 10262-1982. which comes out to be 20+1.65*4.6=27.6 N/mm2

Selection of mix proportions:

W/C ratio for the required strength of 26.6 N/mm2 is 0.50. This is obtained from IS 10262-1982 for target strength 26.6. From table 3 of IS 10262-1982, for 20 mm Zone 3 found for nominal maximum size aggregate and sand, water content per cubic meter of concrete= 186 kg and sand content as percentage of total aggregate by absolute volume= 35 percent. Adjustment required= 3 % (given in IS 10262-1982) Therefore require water= 186 + ((186*3)*100) = 191.61 kg. Accordingly the required cement content = 191.6/0.50=383 kg/m3

Table 4: Determining the coarse aggregate

Air entrapped	2 %
Design volume	0.98 mm^3
Quantity of fine aggregate	546kg/mm^3
Quantity of Coarse aggregate	1187kg/mm^3

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Table 5: Mix Proportion

Cement	Fine aggregate	Coarse aggregate	Water
383kg	546kg	1187kg	191.6kg or 0.50
1	1.42	3.09	

Table 6: Actual quantities required for 3 cubes mold of dimension 150x150x150mm each.

uantities required	Quantity
Volume of each mould	0.00375m^3
Design Volume	0.00513 m^3
Quantity of Coarse Aggregates	4.487kg
Quantity of Fine Aggregates	2.35kg
Quantity of Cement	1.40kg
Quantity of water	0.70kg

IV. COMPRESSIVE TEST ON CUBES

Firstly the cubes were made as per the design mix and then placed in water for curing. The compressive test was performed on the cubes and results were verified after7, 14, 28, 56 days of curing. Specimen of the test was 54 cubes of 15 cm size with M20 design mix. The 7 days testing done in water and the maintained temperature is 27+-2oC. According to the curing period, testing on cubes was done using CTM and test results were checked for every cube with different curing period. Compressive test results:
live picture from laboratory are shown below,

Figure 1: Failure of concrete block

Figure showing the values obtained on graph plotted between compressive strength and the partial replacement of cement with fly ash in different combinations

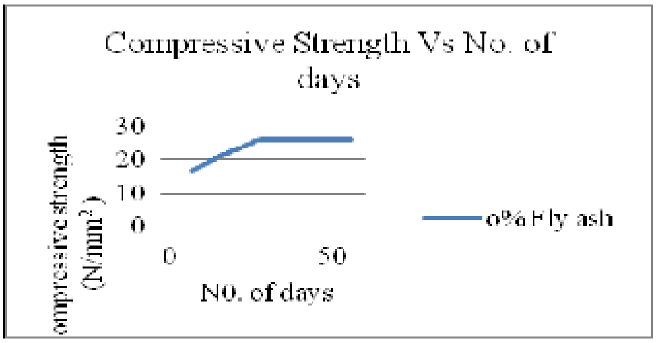

Figure 2: Compressive strength in parent combination

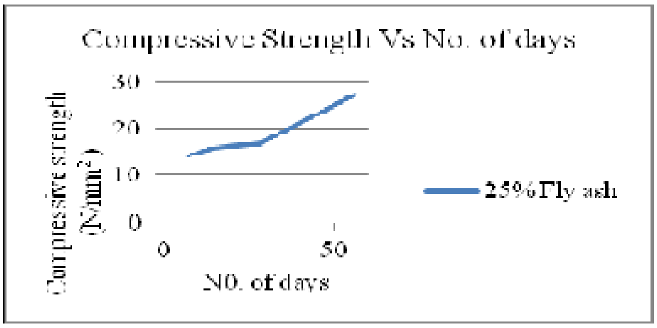

Figure 3: Compressive strength in 25% replacement

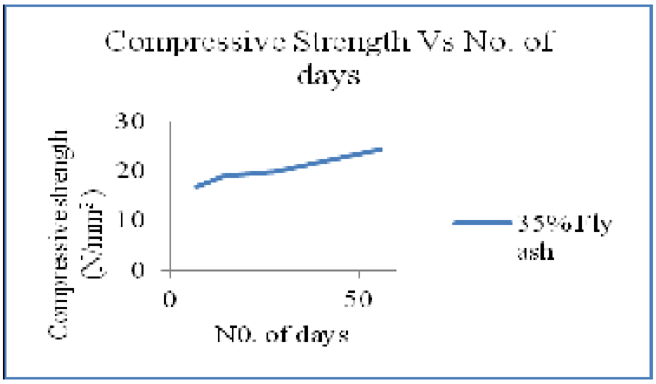

Figure 4: Compressive strength in 35% replacement

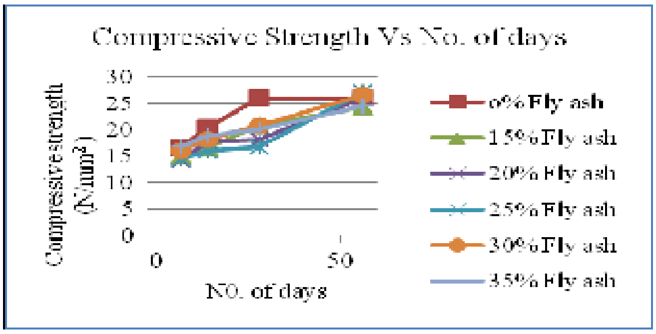

Figure 5: Compressive strength in all combination

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V. CONCLUSION

Concrete mainly produces C-S-H gel and Calcium hydroxide as bi product when reacts with water. C-S-H gel has an ability to keep the ingredients together by making a proper bond whereas lime which is freely available can react with atmospheric moisture and cause efflorescence. In such cases if we use fly ash, it reacts with free lime and produces C-S-H gel again and water as bi product. From the test performed the results are following and conclusion appear to be convincing with respect to the use of Fly Ash.

- The workability of concrete improved by use of Fly Ash.
- Bleeding in fly ash concrete is notably reduced and additional properties like cohesiveness and surface finish are improved.
- Compressive strength of the concrete made with 25% showed a greater value of strength as compared to that other partial replacement.
- The replacement of cement is satisfactory only when the initial strength of the structure is not of much importance.
- It can be easily and satisfactorily used for concrete used in Dams and other heavy structure where the heat of hydration is required to be kept to a smaller value. This can be easily proved from the strength that the 25%, 30% and 35% replacement of cement with Fly Ash showed after 56 days.
- The initial strength of concrete with fly ash has lower strength but acquires higher strength after 56 days. This strength will be even more after 90 days. Though initial strength seems to be low it can be satisfactorily used for even in areas where initial strength keeps importance by adding admixtures. Adding admixtures accelerates the setting time hence grater initial strength.
- As the replacement of cement with fly ash showed satisfactory results, we would highly recommend the replacement of Fly Ash in areas of construction such as Dams, pavements, in bricks manufacturing, in Canal Construction.
- Use of Fly Ash should be encouraged as it not only makes the concrete economical but also saves the environment from the pollution of Fly Ash. Furthermore, use of fly ash will save valuable land where fly ash is dumped currently

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