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Experimental Study on Concrete with Penta Blended Cement Using Pozzolanic and Micro Sized Materials

Manaswini M pillai[1], Prof. Sarah Anil[2]

[1]MTech Student, Department of Civil Engineering, Kerala, India
[2] Professor, Department of Civil Engineering, Mar Athanasius College of Engineering, Kerala, India

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Abstract – *Concrete is the most consumed material in the world after water. Production of cement results in CO_2 emission into the atmosphere. Hence replacement of cement is one of the best alternative. The present study aims to determine the optimum amount of fly ash , GGBFS , silica fume and micro ferric(iron)oxide powder required for partial replacement of cement to achieve a desired compressive strength of 30MPa for the concrete .Optimum replacement for cement with pozzolanic materials is taken as 20%.Thus 20% cement is replaced with optimum percentages of fly ash (7%),GGBFS (3%) ,and silica fume (10%) .Rest of the 80% cement is partially replaced with optimum amount of ferric oxide (2%) to make penta blended concrete. The work also includes the evaluation of various properties like compressive strength, tensile splitting strength , and flexural strength of the penta blended concrete and compare it with normal concrete of M30 grade. This experimental work proves that these materials can be used effectively as partial replacement materials for cement in the concrete and makes the concrete more eco-friendly*

Key Words: **Fly ash, Silica fume, GGBFS, Ferric Oxide(Fe_2O_3),Binary, Ternary, Quaternary and Penta Blended Concrete**

1. INTRODUCTION

Concrete is the most consumed material in the world after water. In the production of every one tonne of cement, around 0.7 tonne of carbon dioxide is released into the atmosphere which is approximately 7-10 percentage of the world's total carbon dioxide emission. Hence replacement of cement is one of the best alternative.

Fly ash is a kind of ash which is extracted from flue gases through Electrostatic Precipitator in dry form. This ash is fine material & possesses good pozzolanic property. The pozzolanic property of fly ash makes it a resource for making cement and other ash based products.

Ground Granulated Blast furnace Slag (GGBS) is a byproduct from the blast furnaces used to make iron. GGBS is used to make durable concrete structures in combination with ordinary Portland cement and/or other pozzolanic materials.

Silica fume is a byproduct resulting from the reduction of high purity quartz with coal or coke and wood chips in an electric arc furnace during the production of silicon metal or silicon alloys. As for chemical reaction of silica fume, because of high surface area and high content of amorphous silica in silica fume, this highly active pozzolan reacts more quickly than ordinary pozzolans.

The basic purpose of using micro ferric oxide is to improve the compressive and flexural strength compared to early age. It is possible due to the high surface to volume ratio. It also helps to improve the pore structure of concrete. Micro size materials help to reduce porosity as they absorb less water compare to traditional cementitious materials. The presence of Micro materials reduces the amount of cement content in concrete than the conventional concrete.

2. MATERIALS

The materials used for the work are cement, fly ash, silica fume, GGBFS, micro ferric oxide, manufactured sand, coarse aggregate, and water.

2.1 Cement

OPC 53 grade bharathi cement is used in this work.The physical properties are tested and results are given in the Table 1

Table -1: Physical Properties of Cement

Sl No	Properties	Test Results
1	Specific gravity	3.135
2	Standard Consistency	31
3	Initial setting time	89
4	Final setting time	276

2.2 Aggregates

Manufactured sand is used as fine aggregate. The maximum size of coarse aggregate used in the work is 20mm. The physical properties are tested and results are given in the Table 2

Table -2: Physical Properties of aggregates

SI. No	Materials	Properties	Test Results
1	Coarse aggregate	Specific gravity	2.712
		Water absorption (%)	0.35
2	Fine aggregate (M Sand)	Specific gravity	2.67
		Water absorption (%)	1.25

2.3 Fly ash

Class F fly ash of specific gravity 2.7 is used. It is collected from RMC plant, Aluva. Chemical composition given by the manufacturer is given in the Table 3

Table -3: Chemical Composition of Fly ash

Sl No	Properties	Test Results
1	Silicon dioxide(SiO_2) + Aluminum oxide(Al_2O_3) + Iron oxide(Fe_2O_3)	88
2	Silicon dioxide(SiO_2)	58
3	Reactive Silica	26

2.4 GGBFS

GGBFS of specific gravity 2.85 is used. It is collected from Astrra Chemicals, Chennai. Chemical composition given by the manufacturer is given in the Table 4

Table -4: Chemical Composition of GGBFS

Sl No	Properties	Test Results
1	Glass	91
2	CaO + MgO + SiO_2	76.03
3	Magnesia	7.73

2.5 Silica fume

Silica fume of specific gravity 2.24 is used. It is collected from Bison Shelter Pvt. Limited, Ernakulam. Chemical composition given by the manufacturer is given in the Table 5

Table -5: Chemical Composition of Silica fume

Sl No	Properties	Test Results
1	SiO_2	Above 97
2	CaO	0.6

2.6 Ferric Oxide

Ferric oxide powder of specific gravity 4.2 is used.It is collected from Medilise Chemicals, Kothamangalam.

3. MIX DESIGN

Mix design of M30 grade concrete is done according to IS 456:2000 and IS 12062:2000 and is given in the Table 6

Table -6: Mix Design

Contents	Quantity(kg/m³)
Cement	370.00
Fine aggregate	933.53
Coarse aggregate	1015.84
Water	157.60
Water cement ratio	0.43

4. MIX DESIGNATION

The various mix designations that have used in the project is given in Table 7

Table -7: Mix Designation

Mix ID	Description
NC	Normal Concrete
F_{16}	84% Cement + 16% Fly ash powder
F_{18}	82% Cement + 18% Fly ash powder
F_{20}	80% Cement + 20% Fly ash powder
F_{22}	78% Cement + 22% Fly ash powder
$F_{14}S_6$	80%Cement + 14%Fly ash +6% Silica fume
$F_{12}S_8$	80%Cement + 12%Fly ash +8% Silica fume
$F_{10}S_{10}$	80%Cement + 10%Fly ash +10% Silica fume
F_8S_{12}	80%Cement + 8%Fly ash +12% Silica fume
$F_5G_5S_{10}$	80%Cement + 5%Flyash +5%GGBFS + 10%Silica fume
Mix ID	Description
$F_6G_4S_{10}$	80%Cement + 6%Flyash +4%GGBFS + 10%Silica fume
$F_7G_3S_{10}$	80%Cement + 7%Flyash +3%GGBFS + 10%Silica fume
$F_8G_2S_{10}$	80%Cement + 8%Flyash +2%GGBFS + 10%Silica fume
$F_7G_3S_{10}I_1$	79%Cement + 7%Flyash +3%GGBFS + 10%Silica fume + 1% Iron Oxide
$F_7G_3S_{10}I_{1.5}$	78.5%Cement + 7%Flyash +3%GGBFS + 10%Silica fume + 1.5% Iron Oxide
$F_7G_3S_{10}I_2$	78%Cement + 7%Flyash +3%GGBFS + 10%Silica fume + 2% Iron Oxide
$F_7G_3S_{10}I_{2.5}$	77.5%Cement + 7%Flyash +3%GGBFS + 10%Silica fume + 2.5% Iron Oxide

4. RESULTS AND DISCUSSIONS

In this chapter the results of various tests conducted on concrete are tabulated and discussed. Unless otherwise specified, all the test results reported here are average of three tests, by using specified methods as per IS recommendation after 28 days of curing.

4.1 Optimum Dosage of Fly Ash

Cement is replaced with fly ash, silica fume, and GGBFS individually to find their optimum replacement. Although optimum replacement of silica fume give more strength, optimum of fly ash is taken to continue the work due to economic point of view. The compressive strength tests were conducted on concrete cubes with various levels of

replacement of cement by fly ash powder from 16% to 22% at an increment of 2% in normal concrete to form binary blended concrete.Chart -1 shows the residual compressive strength at various levels of fly ash powder replacement in normal concrete

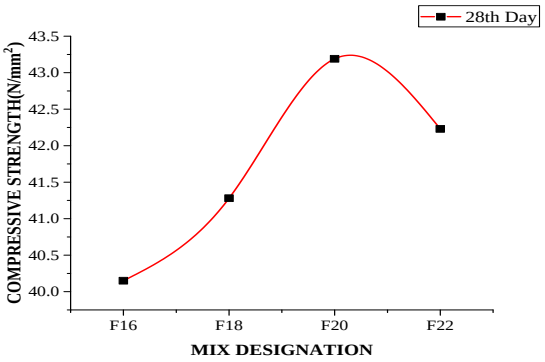

Chart -1: 28th Day Compressive Strength at Various Levels of Fly Ash

The optimum percentage of cement replacement with fly ash powder is 20. The 28th day compressive strength at 20% addition is 7% higher than NC. In all other percentages the strengths are less than optimum but satisfies the target strength. So the addition of fly ash improves the compressive strength of concrete due to the pozzolanic property of fly ash. With the increase in percentage of fly ash beyond its optimum value (which is 20% in present case) compressive strength decreases, this is due to insufficient $Ca(OH)_2$ in the matrix.

4.2 Optimum Dosage of Fly Ash and Silica Fume

Optimum replacement of cement with pozzolanic materials like fly ash and silica fume (combindly) is taken as 20%.Therefore 20% cement is replaced with silica fume from 6% to 8% at an increment of 2% and fly ash from 14% to 8% at a decrement of 2% in normal concrete to form ternary blended concrete. Chart 2 shows the residual compressive strength at various levels of Fly ash and Silica Fume replacement in the concrete.

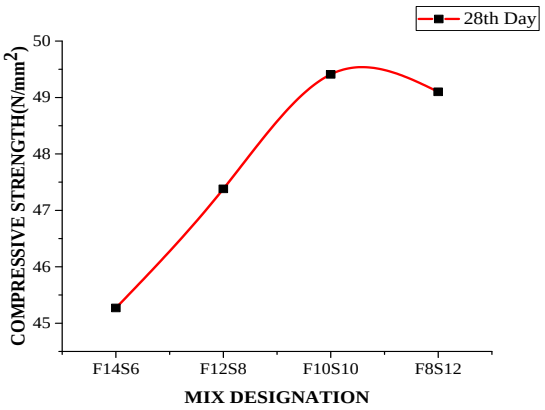

Chart -2: 28th Day Compressive Strength at Various Levels of Fly Ash and Silica Fume

4.3 Optimum Dosage of Fly Ash,Silica Fume and GGBFS

Optimum replacement of cement with pozzolanic materials is taken as 20%.Percentage replacement of silica fume is kept constant throughout the mix. From the literature review its concluded that fly ash and GGBFS shows similar contribution to the compressive strength of concrete. Therefore 20% cement is replaced with fly ash from 5% to 8% at an increment of 1% along with GGBFS from 5% to 2% at a decrement of 1% and 10% silica fume in normal concrete to form quaternary blended concrete.Chart 4.3 shows the residual compressive strength at various levels of Fly ash, GGBFS and Silica fume replacement in the concrete.

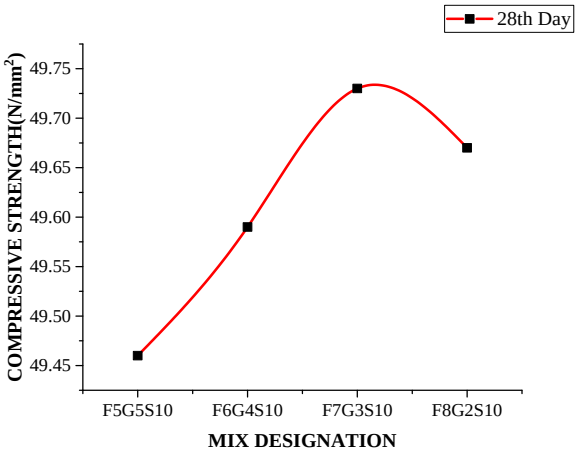

Chart -3: 28th Day Compressive Strength at Various Levels of Fly Ash, Silica Fume and GGBFS

The optimum percentage of fly ash, GGBFS and silica fume in quaternary blended concrete is 7%, 3% and 10% respectively. The 28th day compressive strength at optimum addition is 19.32% higher than NC. In all other percentages the strengths are less than optimum mix but satisfies the target strength. Improvement in the compressive strength of concrete is due to the pozzolanic property of the materials. After optimum, strength decreases due to insufficient $Ca(OH)_2$ in the matrix.

4.4 Optimum Dosage of Fly Ash, Silica fume, GGBFS and Ferric Oxide

Ferric Oxide powder doesn't have pozzolanic property. It is used as a filler material in concrete to improve the strength.20% cement is replaced with fly ash, silica fume and GGBFS at 7%, 10% and 3% respectively. Rest of the 80% cement is partially replaced with ferric oxide powder from 1% to 2.5% at an increment of 0.5% in normal concrete to form penta blended concrete. Chart 4 shows the residual compressive strength at various levels of Fly ash, GGBFS, silica fume and ferric oxide replacement in the concrete.

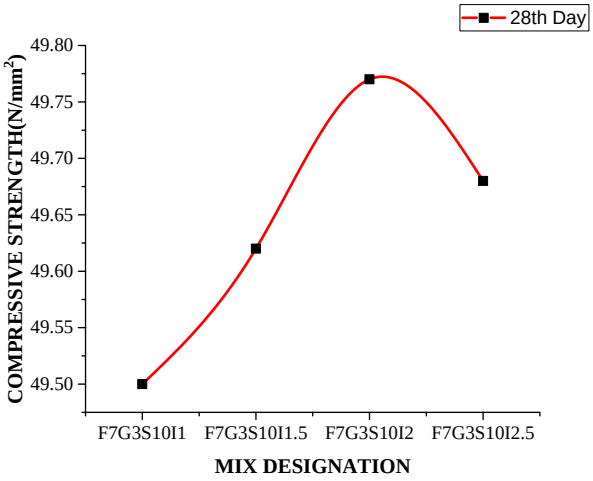

Chart -4: 28th Day Compressive Strength at Various Levels of Fly Ash, Silica Fume, GGBFS and Ferric Oxide

The optimum percentage of fly ash, GGBFS, silica fume and ferric oxide in penta blended concrete is 7%, 3%,10% and 2% respectively. The 28th day compressive strength at optimum addition is 19.38% higher than NC. In all other percentages the strengths are less than optimum but satisfies the target strength. Ferric oxide powder act as a filler material and they fill the voids in concrete which increase its strength and durability. After optimum, strength decreases due to insufficient voids in the matrix.

4.3 Comparison Between Normal Concrete and Normal Concrete

The cement is replaced with fly ash, GGBFS, silica fume and micro iron oxide powder at 7%,3%,10% and 2.5% respectively to make penta blended concrete of M30 grade. Normal Concrete of M30 grade was also made .Both concrete was tested for its 28 day compressive, flexural and split tensile strength and results are shown in chart 5,6 and 7

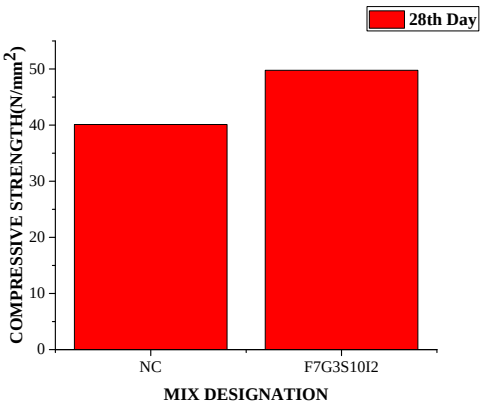

Chart -5: Comparison Between 28th Day Compressive Strength of Normal and Penta Blended Concrete

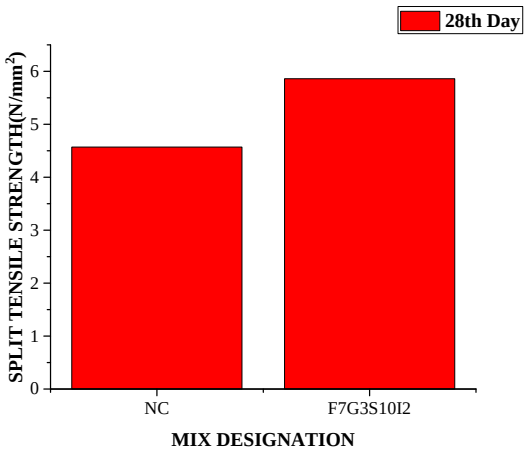

Chart -6: Comparison Between 28th Day Split Tensile Strength of Normal and Penta Blended Concrete

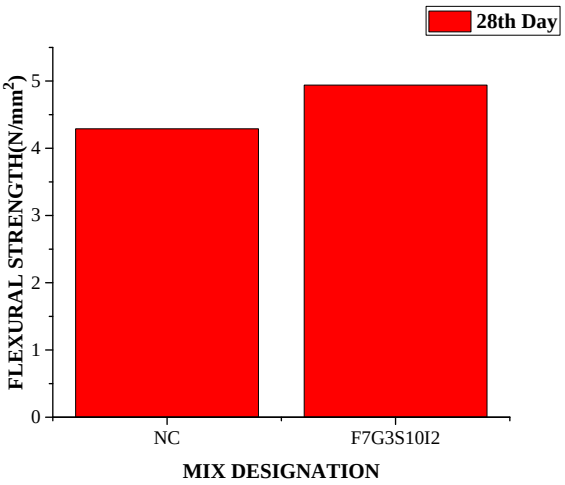

Chart -7: Comparison Between 28th Day Flexural Strength of Normal and Penta Blended Concrete

4. CONCLUSIONS

From this study of penta blended concrete, following conclusions were obtained:

- Replacement of cement with other materials reduces the CO_2 production thereby reduces environment hazards.
- When the percentage of fly ash, silica fume, GGBFS and iron oxide powder increases, the workability decreases.
- The adoptable percentage of replacement of cement with pozzolanic materials is 20.
- The optimum amount of fly ash and silica fume to form ternary blended concrete is 10%, and 10% respectively.

- The 28th day compressive strength at optimum addition of fly ash and silica fume is 19% higher than NC due to the high pozzolanic reaction of silica fume.
- The optimum amount of fly ash, GGBFS and silica fume to form quaternary blended concrete is 7%, 3% and 10% respectively.
- The 28th day compressive strength at optimum addition of fly ash, GGBFS and silica fume is 19.32% higher than NC due to the pozzolanic reaction of fly ash, GGBFS and silica fume.
- The optimum amount of fly ash, GGBFS, silica fume and Fe_2O_3 to form penta blended concrete is 7%, 3%, 10% and 2% respectively.
- The 28th day compressive strength at optimum addition of fly ash, GGBFS, silica fume and Fe_2O_3 is 19.32% higher than NC. Only small increase in strength can be noticed because Fe_2O_3 act as filler material and less contributes to strength.
- Replacement of cement with pozzolanic and micro sized materials resulted in improvement on all the properties of normal concrete.

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