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# Experimental Investigation on High Performance Concrete with Partial Replacement of fine aggregate by Foundry Sand with cement by Mineral Admixtures

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**Abstract:** High performance concrete appears to be a better choice for a strong and durable structure. In this project, investigations were carried out on strength properties such as compressive strength, split tensile strength and flexural strength of M75 grade of HPC mixes with different replacement levels such as 10%, 20%, and 30% of foundry sand with fine aggregate and 10%, 20%, 30% and replacing cement by mineral admixtures such as fly ash and ground granulated blast furnace slag by adopting water-binder ratio of 0.3. Conplast SP430 is based on Sulphonated Napthalene Polymers can be used as a super plasticiser for better workability for high performance concrete. The HPC mix, grade M75 concrete is designed as per ACI 211.4R-08 "Guide for selecting proportions for high strength concrete with Pozzolana Portland cement and other cementitious materials". Mechanical characteristics like Compressive strength, Split-tensile strength, Flexural strength were examined. The result of these investigations demonstrates the strength characteristics of foundry sand based concrete mixes. Based on the results obtained, the replacement of 30% foundry sand with 3% of super plasticiser which superior strength characteristics was arrived. The details of the investigations along with the results are presented in this report.

***Keywords:*** *High Performance Concrete, High Strength, Foundry Sand, Fly Ash, Ground Granulated Blast Furnace Slag*

## Introduction:

High performance concrete (HPC) is a concrete that meets special combinations of performance and uniformity requirements which cannot always be achieved routinely using conventional constituents and normal mixing and placing and curing practices. To produce high performance concrete it is generally essential to use chemical and mineral admixtures in addition to the same ingredients, which are generally used for normal concrete. In recent times, many researches are going on for improving the properties of concrete with respect to strength, durability, and performance as a structural material. There are many materials like fly ash, furnace slag, foundry sand and silica fume etc. One among these special concrete is the foundry sand which is new emerging as one of new generation construction material in producing high strength and performance concrete for special structures. The interest in fly ash and ground granulated blast furnace slag started in enforcement of air pollution control in many countries. This implies that the industry had to stop releasing fly ash and foundry sand into the atmosphere. To find solution to this problem studies were initiated and after some investigations, it was found that the foundry sand could be used as a very useful material in concrete. Foundry sand in concrete for quite some time in countries like Norway and U.S very high strength concrete is being produced using this fine highly reactive industrial by product. In India, improved Foundry sand and fly ash is finding its use now a day.

## Materials Used:

*A. Cement*

Portland-Pozzolana cement of grade 53 was used for casting all the specimens should be confirming to IS 1489 (Part 1 ) : 1991. Portland-pozzolana cement can be produced either by grinding together Portland cement clinker and pozzolana with addition of gypsum or calcium sulphate, or by intimately and uniformly blending Portland cement and fine pozzolana. Portland-pozzolana cement produces less heat of hydration and offers greater resistance to the attack of aggressive waters than normal Portland cement. Moreover, it reduces the leaching of calcium hydroxide liberated during the setting and hydration of cement. Specific gravity and fineness modulus of cement is 3.15 and 7.5 respectively.

*B. Fine aggregate*

Clean and dry river sand available locally was used. Sand passing through IS 4.75 mm sieve was used for casting all the specimens. Specific gravity and fineness modulus is 2.64 and 2.79 respectively.

*C. Coarse aggregate*

Coarse aggregate passing through 12.5 mm sieve as given in IS 383 – 1970 was used for all the specimens. In addition to cement paste- aggregate ratio, aggregate type has a great influence on concrete dimensional stability. Specific gravity and fineness modulus is 2.77 and 5.90 respectively.

*D. Foundry sand*

Foundry sand is high-quality uniform silica sand that is used to make moulds and cores for ferrous and nonferrous metal castings. Foundry sand is a by-product of the castings industry typically comprising uniformly sized sands with various additives and metals associated with the specific casting process. Foundry sand is the most essential raw material and its importance is sometimes forgotten amongst Foundry personnel. Foundry sand is as used by Foundries is desired for its thermal resistance and availability. Most metal casting sand (FS) is high quality silica sand with uniform physical characteristics. Specific gravity of foundry sand is 2.75 and fineness modulus is 2.74

*E. Fly Ash (FA)*

Fly ash is finely divided residue resulting from the combustion of ground or powered coal. The hardened fly ash concrete shows increased strength together with a lower permeability, where the latter leads to a higher resistance towards aggressive admixtures in addition, partial replacement of cement with fly ash reduces the production cost of concrete due to the lower price of fly ash compared to cement . Class F Fly ash(contains less than 20% lime) is collected from Mettur Thermal Power Plant (MTTP), Mettur. Specific gravity of fly ash 2.30 is and fineness modulus is 7.86.

*F. Ground Granulated Blast Slag(GGBS)*

Ground Granulated blast furnace slag is a glassy granular material formed when molten blast furnace slag is rapidly chilled, as by immersion in water. The cementations action of a granulated blast furnace slag is dependent to large extent on the glass content. GGBS hydrates are generally found to be more gel like than the products of hydration of Portland cement, so it denses the cement paste.

*G. Super Plasticizer*

Super plasticizer CONPLAST SP 430, based on Sulfhanated naphthalene polymers, complies with IS 9103-1999\and ASTM C-494 [6] was used.

*H. Water*

In this project, casting and curing of specimens were done using potable water which shall be free from deleterious materials. Water plays an important role in concrete production (mix) in that it starts the reaction between the cement and the aggregates. It helps in the hydration of the mix.

**Mix Design:**

In this investigations concrete mix design (M75) was designed based on ACI 211.4R-1993[7].This code presents a generally applicable method for selecting mixture proportion for high strength concrete and optimizing this mixture proportion on basis of trial batches. The method is limited to high strength concrete production using conventional materials and production techniques. Mix proportioning details are given below in table 2.

Table I Mix Design

| Cement | Fine aggregate | Coarse aggregate | Water |
|---|---|---|---|
| 1 | 1.03 | 1.973 | 0.45 |

Table II Details of Mix Proportions

| Mix | Cement Kg/m³ | Foundry sand Kg/m³ | Fly ash Kg/m³ | GGBS Kg/m³ | Fa Kg/m³ | Ca Kg/m³ |
|---|---|---|---|---|---|---|
| M1 | 583 | 0 | 0 | 0 | 601 | 1151 |
| M2 | 524.6 | 60.135 | 58.34 | 0 | 541 | 1151 |
| M3 | 466.318 | 120.27 | 116.6 | 0 | 481 | 1151 |
| M4 | 407.977 | 180.405 | 175.0 | 0 | 420.7 | 1151 |
| M5 | 524.6 | 60.135 | 0 | 58.34 | 541 | 1151 |
| M6 | 466.318 | 120.27 | 0 | 116.6 | 481 | 1151 |
| M7 | 407.977 | 180.405 | 0 | 175.0 | 420.7 | 1151 |

**Method of Experiment:**

It is important that the constituent material of concrete remain uniformly distributed within the concrete mass during the various stages of handling and that full compaction is achieved, and making sure that the characteristics of concrete which affect full compaction like consistency, mobility and compatibility are in conformity with relevant codes of practice.

The tests were carried out in accordance with relevant IS Standards. The aggregates were tested for physical properties such as: specific gravity and particle distribution test. The fresh concrete was subjected to the slump test followed by casting of concrete in moulds for further investigations. All the mixes were prepared by mixing the concrete in laboratory mixer along with water and super plasticizer. For compressive strength studies 72 cube specimens of size 150 mm x 150 mm x 150 mm, for flexural strength studies, 72 prism specimens of size 100 mm x 100 mm x 500 mm and 72 cylinder specimens of size 300 mm height and 150 mm diameter for split tensile strength studies were prepared. All the specimens were cast and cured for 28 days as per standard curing methods.

**Results and Discussion:**

*I. Properties of foundry sand and natural sand*

Foundry sands consist of green sand and resin sand. Green sands typically comprise of high-quality silica sand, 5-10 % bentonite clay, 2 to 5 % water and less than 5 % sea coal. The green sand process constitutes upwards of 90 % of the moulding materials used.

Table III Chemical Properties of Foundry Sand

| Compound | | Percent by weight |
|---|---|---|
| Calcium Oxide | (CaO) | 0.14 |
| Silicon di Oxide | ($SiO_2$) | 87.91 |
| Aluminum Oxide | ($Al_2O_3$) | 4.7 |
| Magnesium Oxide | (MgO) | 0.30 |
| Phosphorus | ($P_2O_5$) | 0.01 |
| Ferric Oxide | ($Fe_2O_3$) | 0.94 |
| Potassium Oxide | ($K_2O$) | 0.25 |
| Sodium Oxide | ($Na_2O$) | 0.19 |
| Loss on ignition | (LOI ) | 5.15 |

Table IV Physical Properties of Foundry Sand and Natural Sand

| Property | Natural sand | Foundry sand | Test method |
|---|---|---|---|
| Specific gravity | 2.64 | 2.75 | IS 2386 (Part III) – 1963 |
| Fineness modulus | 2.79 | 2.74 | IS 2386 (Part I) – 1963 |
| Sieve analysis for grading | II | Nearly II | IS 2386 (Part I) – 1963 & IS 383 – 1970 |

*J. Properties of fly ash*

Table V Chemical Properties of Fly Ash

| Compound | | Percent by weight |
|---|---|---|
| Calcium Oxide | (CaO) | 18.67 |
| Silicon di Oxide | ($SiO_2$) | 45.98 |
| Aluminum Oxide | ($Al_2O_3$) | 23.55 |
| Magnesium Oxide | (MgO) | 1.54 |
| Potassium Oxide | ($K_2O$) | 1.80 |
| Sodium Oxide | ($Na_2O$) | 0.24 |

Table VI Physical Properties of Fly Ash

| Compound | | Percent by weight |
|---|---|---|
| Calcium Oxide | (CaO) | 18.67 |
| Silicon di Oxide | ($SiO_2$) | 45.98 |
| Aluminum Oxide | ($Al_2O_3$) | 23.55 |
| Magnesium Oxide | (MgO) | 1.54 |
| Potassium Oxide | ($K_2O$) | 1.80 |
| Sodium Oxide | ($Na_2O$) | 0.24 |

*K. Properties of Ground Granulated Blast Slag*

Table VII Chemical Properties of Ground Granulated Blast Slag

| Compound | | Percent by weight |
|---|---|---|
| Calcium Oxide | (CaO) | 40 |
| Silicon di Oxide | ($SiO_2$) | 35 |
| Aluminum Oxide | ($Al_2O_3$) | 16 |
| Magnesium Oxide | (MgO) | 6 |
| Ferric Oxide | ($Fe_2O_3$) | 3 |

*L. Slump test*

The slump flow test is used to assess the horizontal free flow of HPC in the absence of obstructions. The test method is based on the conventional slump test. The diameter of the concrete circle is a measure for the filling ability of the concrete. It is the most commonly used test, and gives a good assessment of filling ability. It gives no indication of the ability of the concrete to pass between reinforcement without blocking, but may give some indication of resistance to segregation. The higher the slump flow value, the greater is its ability to fill formwork under its own weight. Acceptable range for HPC is from 50 to 80 mm.

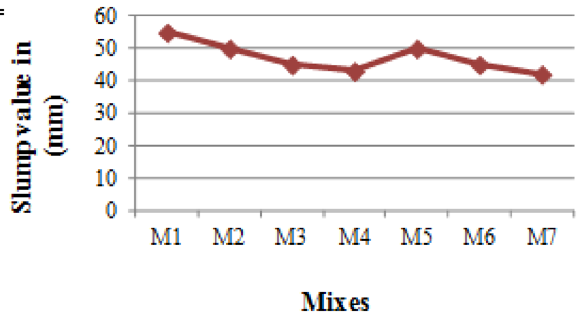


*Fig. 1 Slump value for different % of mixes*

*M. Compressive strength test*

The compressive strength for concrete with replacement of natural sand with foundary sand of 10%, 15%, 20%, and cement by mineral admixtures at the age of 7,14 and 28 days was found as shown in Table VIII and Fig.2.

Table VIII Compressive Strength

| Mix | FS by % of FA | FA by % of cement | GGBS by % of cement | Average compressive strength MPa | | |
|---|---|---|---|---|---|---|
| | | | | 7 days | 14 days | 28days |
| M1 | 0 | 0 | 0 | 35 | 43 | 75 |
| M2 | 10 | 10 | 0 | 37 | 45 | 75 |
| M3 | 15 | 15 | 0 | 37 | 50 | 77 |
| M4 | 20 | 20 | 0 | 42 | 54 | 79 |
| M5 | 10 | 0 | 10 | 45 | 51 | 86 |
| M6 | 15 | 0 | 15 | 43 | 55 | 83 |
| M7 | 20 | 0 | 20 | 41 | 53 | 82 |

M = mega, Pa = pascal,FS = Foundry sand, FA =Fly ash, FA =fine aggregate, GGBS = Ground Granulated Blast Slag

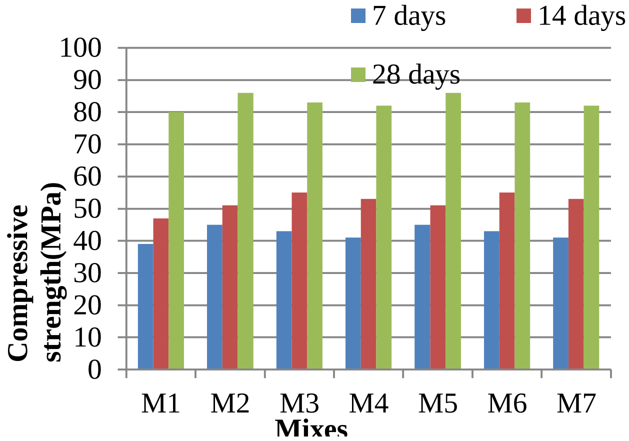


*Fig. 2 Comparison of compressive strength for different mixes*

The compressive strength continued to increase as the curing period increased. The control mix had a compressive strength of 75MPa at 28 days. Addition of increasing amounts of foundary sand generally increased. The greatest compressive strength was achieved when the mixture contained 30% of fine aggregate replacement of foundary and 10 % addition of Ground Granulated Blast Slag(GGBS**)** with the water cement ratio 0.3. Improvement stemmed from the void-filling ability of the smaller particles and was more pronounced at lower w/c ratios.

*A. Split tensile strength*

The split tension test result is shown in Table IX and Fig 3.

Table IX Split Tensile Strength

| Mix | FS by % of FA | FA by % of cement | GGBS by % of cement | Average split tensile strength MPa | | |
|---|---|---|---|---|---|---|
| | | | | 7 days | 14 days | 28 days |
| M1 | 0 | 0 | 0 | 3.345 | 4.512 | 6.015 |
| M2 | 10 | 10 | 0 | 3.445 | 4.834 | 6.04 |
| M3 | 15 | 15 | 0 | 3.344 3 | 4.545 | 6.0222 |
| M4 | 20 | 20 | 0 | 3.433 | 4.656 | 6.055 |
| M5 | 10 | 0 | 10 | 3.545 | 51 | 6.14 |
| M6 | 15 | 0 | 15 | 3.533 | 55 | 6.1222 |
| M7 | 20 | 0 | 20 | 3.533 | 53 | 6.155 |

M = mega, Pa = pascal,FS = Foundry sand, FA =Fly ash, FA =fine aggregate, GGBS = Ground Granulated Blast Slag

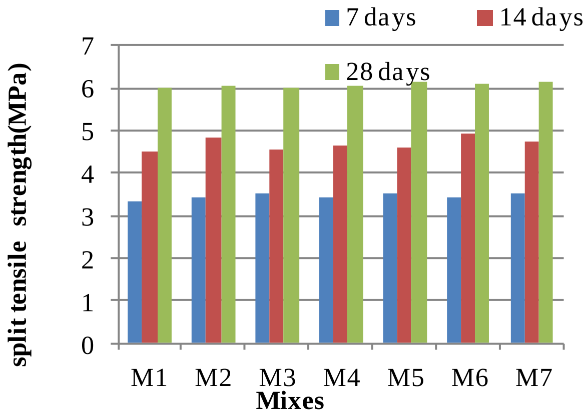


*Fig. 3 Comparison of split tensile strength for different mixes*

It is a method of determining the tensile strength of concrete using a cylinder which splits across the vertical diameter. It is expressed as the minimum tensile stress (force per unit area) needed to split the material apart.We observed that the development of tensile strength of mixes increases as the replacement of natural sand by 10 % of GGBS gives higher strength compared to the control mix.

*B. Flexural strength test*

A beam specimen is casted to test the flexural strength of the concrete. After casting the test specimen it is cured for 7 days and 28 days and tested for maximum load. The result is given the Table X. Fig. 4 shows the variation in flexural strength for different replacement with respect to controlled concrete for 7 days, 14 days and 28 days respectively.

Table X Flexural Strength Test Results

| Mix | FS by % of FA | FA by % of cement | GGBS by % of cement | Average compressive strength MPa | | |
|---|---|---|---|---|---|---|
| | | | | 7 days | 14 days | 28 days |
| M1 | 0 | 0 | 0 | 3.2 | 4.5 | 6.012 |
| M2 | 10 | 10 | 0 | 3.4 | 4.5 | 5.99 |
| M3 | 15 | 15 | 0 | 3.2 | 4.6 | 6.022 |
| M4 | 20 | 20 | 0 | 3.5 | 4.7 | 6.03 |
| M5 | 10 | 0 | 10 | 3.6 | 4.8 | 6.455 |
| M6 | 15 | 0 | 15 | 3.4 | 4.9 | 6.522 |
| M7 | 20 | 0 | 20 | 3.7 | 4.6 | 6.23 |

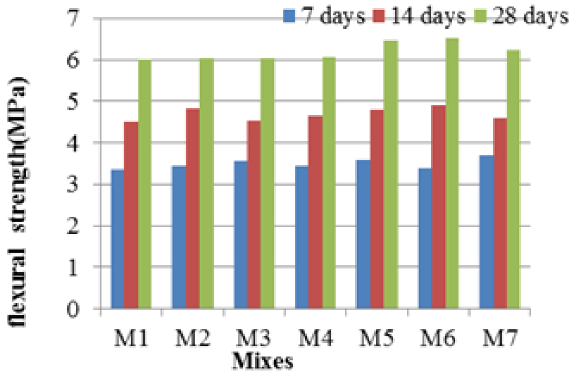


Fig. 4 Comparison of flexural strength for different mixes

The flexural strength continued to increase as the curing period increased. The control mix had a flexural strength of 75MPa at 28 days. Addition of increasing amounts of foundary sand generally increased 20% replacement. The greatest flexural strength was achieved when the mixture contained 30% of fine aggregate replacement of foundary and 20 % addition of Ground Granulated Blast Slag (GGBS) with the water cement ratio 0.3.

*C. Discussion*

The compressive strength continued to increase as the curing period increased. The control mix had a compressive strength of 75MPa at 28 days. Addition of increasing amounts of foundary sand generally increased. The greatest compressive strength was achieved when the mixture contained 30% of fine aggregate replacement of foundary and 10 % addition of Ground Granulated Blast Slag (GGBS) with the water cement ratio 0.3. Improvement stemmed from the void-filling ability of the smaller particles and was more pronounced at lower w/c ratios. We observed that the development of tensile strength of mixes increases as the replacement of natural sand by foundry sand and 10 % of GGBS gives higher strength compared to the control mix. The flexural strength continued to increase as the curing period increased. The control mix had a flexural strength of 75MPa at 28 days. Addition of increasing amounts of foundary sand generally increased 20% replacement. The greatest flexural strength was achieved when the mixture contained 30% of fine aggregate replacement of foundary and 20 % addition of Ground Granulated Blast Slag(GGBS)

**Conclusion:**

In this study it has been found that adding optimum superplasticizer dosage the workability is reached. So that the required slump value can be obtained for HPC. The slump value for M75 grade using foundry sand and fly ash is reduced.For 30% fly ash and 30% GGBS replacement, the fresh properties observed were good as compared to 10%, 20% replacement. Hence fly ash replacement is effective for HPC in order to attain high strength. Compare to ordinary concrete M75 grade concrete attain good strength by using lower water/binder ratio. Hence segregation and bleeding occurs in the concrete can be reduced. Foundry sand substitution generally results in favourable outcomes and is highly recommended for all HPC mixes. The strength of concrete structures using foundry sand is always similar to conventional concrete. The presence of foundry sand and mineral admixtures increasing the compressive strength and also withstanding the maximum load.Compare to fly ash GGBS attains good strength as cement replacement.

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