# Experimental and sustainable development of high-performance concrete using industrial by products

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***ABSTRACT -*** Although the capability of metakaolin as pozzolanic material to improve mechanical and durability properties of concrete if used as partial replacement of Portland cement is well noted in concrete science, its utilization in building industry was limited to date, mainly due to its high price dictated by the low production amounts. However, with the current shortage of silica fume and high-quality slag in some countries the attitude of concrete producers to metakaolin may change in the near future. This change of mind can be facilitated by providing a more comprehensive view of the properties of composite materials with metakaolin, thus contributing to wider realization of the benefits of metakaolin in concrete. In this study, to replace the constituent materials by mineral admixtures, chemical admixtures and additives also, it is proposed to use high performance concrete. Also, High Performance concrete specimens with fibre and without fibre in size 150mmx150mmx150mm, cylinder of 150mmx300mm and prism of 100mmx100mmx500mm were cast and the strength tests were observed. Finally mechanical properties of concrete were carried out by ANN modelling.

***KEYWORDS: HPC, Admixtures, Fibres, Strength properties, ANN, Prediction.***

## I. INTRODUCTION

Concrete is most widely used construction material. Because of its specialty of being cast in any desirable shape, it has replaced stone and brick masonry. In spite of all this, it has some serious deficiencies which, but for its remarkable qualities of resilience, flexibility and ability to redistribute stress, world have prevented its use as a building material. A high-performance concrete is something which demands much higher performance from concrete as compared to performance expected from routine concrete [1]. Use of chemical admixtures reduces the water content, thereby reducing the porosity within the hydrated cement paste. Mineral admixtures, also called as cement replacement materials (CRM), act as pozzolanic materials as well as fine fillers, thereby the microstructure of hardened cement matrix becomes denser and stronger. Materials selection will play a large part in the improved concrete of the new century. The choice of w/cm will be eliminated from concrete specification. The judicious selection and use of chemical admixtures will continue to enhance the durability of concrete [2]. These benefits will in turn protect the concrete from aggressive chemical elements, reduce the rate of carbonation, improve corrosion resistance and extend the life of transportation infrastructure. Chemical admixtures that inhibit corrosion, reduce the formation of ASR products inhibit water penetration and reduce shrinkage will provide important benefits as well [3].

## II. EXPERIMENTAL INVESTIGATION

In the experimental study, generally a good quality of cement like 43 grade cement is preferred but it may vary according to the grade of HPC needed. Natural sands crushed and rounded sands and manufactured sands are suitable for HPC. River sand of specific gravity 2.65 and conforming to zone II of IS 363 was used for the present study. The shape and particle size distribution of the aggregate is very important as it affects the packing and voids content [4]. The moisture content, water absorption, grading and variations in fines content of all aggregate should be closely and continuously monitored and must be taken into account in order to produce HPC of constant quality. Coarse aggregate used in this study had a maximum size of 10mm. Specific gravity of coarse aggregate used was 2.75 as per IS 363. Ordinary potable water was used [5]. The pH value is not less than 8.0. Super plasticizers are high range water reducing admixtures an essential component of HPC. Conplast SP 430 was used as super plasticizer. Silica fume imparts very good improvement to rheological, mechanical and chemical properties. It improves the durability of the concrete by reinforcing the microstructure through filler effect and thus reduces segregation and bleeding. It is also helps in achieving high early strength. Fly ash produced from the burning of younger lignite or sub bituminous coal, in assertion to having pozzolanic properties, also has some self-cementing properties [6]. Class C fly ash generally contains more than 20% lime (CaO). Glass fiber also called fiberglass. It is material made from extremely fine fibers of glass. Fiber glass is a lightweight, extremely strong and robust material. Glass is the oldest, and most familiar, performance fiber. Generally glass consists of quartz sand, soda, sodium sulphate, potash feldspar and a number of refining and dying additives. Steel fiber products are available in a variety of types and sizes from various manufacturers [7]. A plasticizer or super plasticizer is often used to enhance mix workability. About two decades back, steel fiber reinforced concrete (SFRC) was considered a new technology for the construction industry [8]. However today this technology has found wider acceptance among the construction industry. The objective of the study is to evaluate the effectiveness of various percentages of mineral and chemical admixtures in producing high performance concrete. The experimental programme was planned to study the following properties: Cement: Ordinary Portland cement of 43 grades conforming to IS-12269 having specific gravity of 3.08. Fine aggregate: Natural river sand conforming to IS-383, Zone-II has specific gravity 2.65. Coarse aggregate: Crushed granite angular aggregate of size 20mm passing confirming to IS-383 having specific gravity 2.75. Mineral admixtures: fly ash and silica fume. Additives: Steel fiber and Glass fiber Chemical admixture: Conplast Sp-430 Water: Ordinary portable water conforming to IS 456. Material replacement [9]:

- Fly ash - 20% replacement of cement.
- Silica fume – 10 % replacement of cement
- Steel fibre – 1% in volume of concrete
- Glass fibre – 1% in volume of concrete Super plasticizer Conplast SP430 is high range water reducing admixtures. The details of the specimens were shown in Table 1.

Table 1 Detail of Specimens

| Sl.n o | Name of testing | No of specimens | | |
|---|---|---|---|---|
| | | Cube | Cylinder | Pris m |
| 1 | Compressive strength | 27 | 27 | - |
| 2 | Split tensile strength | 27 | 27 | - |
| 3 | E for concrete | - | 27 | - |
| 4 | Flexural strength | - | - | 27 |

The specimens of having dimensions Cube

150mmx150mm, Cylinder 150mmx300mm, Prism 100mmx100mmx500mm could be used to determine all the above-mentioned properties [10].

## III. MIX DESIGN AND CASTING

Materials confining to IS standards are selected and casting is done with proper mix proportioning as per the mix design. Mineral admixtures are added to the concrete by replacing the cement to achieve the high strength concrete.

Table 2. Mixed Design and Casting

| | |
|---|---|
| Water | 140 kg/m$^3$ |
| PPC 43 Grade | 504.21 Kg/m$^3$ |
| Sand | 683.24 Kg/m $^3$ |
| 12.5 mm crushed aggregate | 1108.13 Kg/m$^3$ |
| 28-day cube strength N/mm$^2$ | 60 X 10$^3$ N/mm$^2$ |
| Mix Ratio Cement: FA: CA | 1: 1.35 :2.19 |

**Preparation of Concrete Specimen**

Concrete mix is prepared as per the mix design. Cement is replaced by Silica Fume in the ratio of 0%, 2.5%, 5% and 7.5%. Materials are mixed as per the mix design and casted in the cube and cylindrical specimen and proper curing were done.

Table -3. Mix Proportion for the Specimen

| mix | Cement (Kg/m$^3$) | Silica Fume | | Aggregates (Kg/m$^3$) | |
|---|---|---|---|---|---|
| | | % | Kg/m$^3$ | Coarse | Fine |
| HPC0 | 504.21 | 0 | 0 | 1108.13 | 683.24 |
| HPC1 | 491.61 | 2.5 | 12.60 | 1108.13 | 683.24 |
| HPC2 | 478.99 | 5 | 25.21 | 1108.13 | 683.24 |
| HPC3 | 466.39 | 7.5 | 37.81 | 1108.13 | 683.24 |

## IV. RESULTS AND DISCUSSION

### Slump Flow Test

To determine the reference slump value for concrete and to calibrate it against an equivalent measure using a flow table. Mould is the shape of a truncated cone with the internal dimensions 200 mm diameter at the base, 100mm diameter at the top and a height of 300 mm. Concrete is poured in three layers. Each layer is tampered about 25 times.

Immediately the cone is lifted in an upward direction.

Figure 1: Slump Cone Test

### Compressive Strength Test

Compressive strength test is used to determine the hardness of a specimen. Strength of a concrete specimen is tested for various time periods. Mineral admixtures added to the concrete do a great role in controlling the strength of concrete. After curing the concrete cube specimen was surface dried for 24 hours. Then the compression tests were taken using the Compression Testing Machine (CTM). Using the below formula, the compressive strengths were calculated. Compressive strength = Load/Area.

Table -3: Compressive Strength Test Results

| Sl. N0 | Mix Proportion | Compressive Strength | | |
|---|---|---|---|---|
| | | 7 days (N/mm$^2$) | 14 days (N/mm$^2$) | 28 days (N/mm$^2$) |
| 1 | HPC0 | 14.20 | 29.56 | 38.14 |
| 2 | HPC1 | 31.33 | 48.43 | 55..24 |
| 3 | HPC2 | 28.56 | 44.53 | 58.54 |
| 4 | HPC3 | 33.52 | 52.53 | 62.12 |

The cube Compressive Strength results of High-Performance Concrete mixes at the ages of 7, 14, 28 days are presented in Table 7. The development of Compressive Strength of M60 grade of HPC mixes containing 2.5, 5, 7.5, percent of Silica Fume at the various stages are plotted in the form of graphs are shown in F Chart 1.

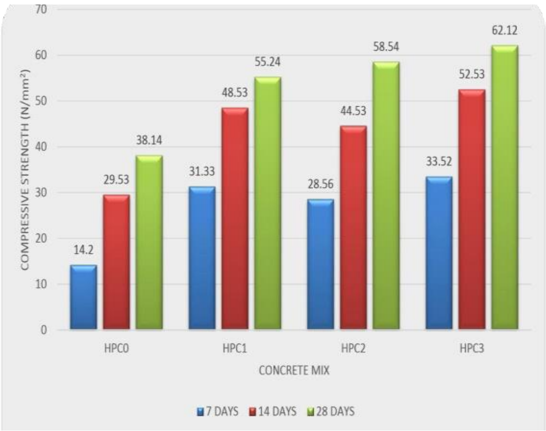


**Chart -1**: Compressive Strength Test Results

Results shows that of Silica Fume mixed with cement gives higher compressive strength than normal HPC0 (HPC with 0% replacement of cement). It is interesting to see that the compressive strength of HPC with 7.5% Silica Fume was higher than that of the Controlled mix. This result shows the benefit of using Silica Fume to produce HPC with higher replacement of cement about 7.5%. When compared with the conventional concrete, HPC3 showed 19.3%, 23.3% and 23.98% increase in Compressive Strength for 7 days, 14 days and 28 days curing.

### Split Tensile Strength Test

The tensile strength will affect the cracking behavior, stiffness, damping action, durability of concrete, based on the split strength the behavior of concrete under shear loads are determined. The tensile strength is determined either by direct tensile tests or by indirect tensile tests such as split cylinder tests. In split tensile test cylinders after 28 days were removed from the curing tank and was left to dry for 24 hours after that cylinder is placed in CTM for testing. The load is applied until the cracks were in the cylinder specimen. The split tensile strength result of concrete was presented in Table 8.

The split tensile strength results of High-Performance Concrete mixes at the ages of 7, 14, 28 days are presented in table 8. The split tensile strength of M60 grade of HPC mixes containing 2.5, 5, 7.5, percent of Silica Fume at the various stages are plotted in the form of graphs are shown in Chart 2

**Figure 3**: Split Tensile Strength Testing Machine

Table -4. Split Tensile Strength Test Results

| Sl. N0 | Mix Proportion | Split Tensile Strength | | |
|---|---|---|---|---|
| | | 7 days (N/mm$^2$) | 14 days (N/mm$^2$) | 28 days (N/mm$^2$) |
| 1 | HPC0 | 1.37 | 2.56 | 3.21 |
| 2 | HPC1 | 1.24 | 2.88 | 3.44 |
| 3 | HPC2 | 2.26 | 3.52 | 4.27 |
| 4 | HPC3 | 2.71 | 3.91 | 4.33 |

According to result the combination of concrete mix with Silica Fume gives a high tensile strength than the normal High-Performance Concrete (HPC with 0% replacement of cement). It is interesting to see that the tensile strength of HPC with 7.5% Silica Fume was higher than that of the Controlled mix. When compared with the conventional concrete, HPC3 showed 1.34%, 1.35% and 1.12% increase in Tensile Strength for 7 days, 14 days and 28 days curing.


**Chart -2**: Split Tensile Strength Test Result

## V. CONCLUSION

This project work is primarily focused on the properties of materials used, mix proportion of High-Performance Concrete, making of concrete specimen, curing and testing of harden concrete. On performing the various tests, the physical properties of the specimens are studied and the following conclusions are arrived. On comparing the result high performance concrete having 7.5% Silica Fume gives a maximum compressive strength value. Maximum splitting tensile strength value is achieved when cement is replaced with 7.5% of Silica Fume.

Hence it is concluded 7.5% of Silica Fume gives the maximum compressive and tensile strength to the concrete we can say that concrete mix is high strength concrete. Performance properties of the concrete need to be studied.

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