# PERFORMANCE OF FERROCHROME ASH (FCA) WITH LIME AS PARTIAL REPLACEMENT OF CEMENT IN SELF COMPACTED CONCRETE

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***Abstract - Waste management is one of the themes basically addressing the current interest now a day. Because of the inadequacy of land filling area, utilization of wastes within the construction sector has become an attractive proposition for disposal.***
***Ferrochrome ash (FCA) is a dirt obtained as a waste product from the gas cleanup plant of Ferro alloy industries. It possesses the chemical necessities of granulated slag material used for the manufacture of Portland cement. The likelihood of using FCA with lime for partial replacement of ordinary Portland cement (OPC) can explore in this analysis. An experimental study is made by preparing specimens by utilizing Ferrochrome ash (FCA) as partial replacement of ordinary portland cement in Self compacted concrete with a percentage replacement from 0% to 40% i.e. (10%, 20%, 30% and 40%) with constant 10% lime. By conducting tests for each the specimens the properties of concrete are investigate. This study ensures that using of Ferrochrome ash (FCA) as partial replacement of ordinary portland cement substitutes in concrete gives a honest approach to reduce cost of materials and can accomplish the higher properties of self-compacted concrete at all ages .***

***Key words: Self-Compacting Concrete (SCC), Ferrochrome ash (FCA), Lime, Fresh properties, Hardened properties.***

## I. INTRODUCTION

"Self-compacted concrete (SCC) is a high flowable concrete which can be placed and compacted without any vibration in complex or dense reinforced formworks. SCC has three essential fresh properties: filling ability, passing ability and segregation resistance. Filling ability is the characteristic of SCC to flow under its own weight and to completely fill the formwork. Passing ability is the characteristic of SCC to flow through and around obstacles such as reinforcement and narrow spaces without blocking. Segregation resistance is the characteristic of SCC to remain homogeneous during and after transporting and placing. It is passing ability that distinguishes SCC from other high consistence concrete.

In general, a newly placed concrete is compacted by vibrating equipment to remove the entrapped air, thus making it dense and homogeneous; this is referred to as normally vibrated concrete (NVC) in this report. Compaction is the key to producing good concrete with optimum strength and durability. However, in Japan in the early 1980"s, because of the increasing reinforcement volumes with smaller bar diameters and a reduction in skilled construction workers, full compaction was difficult to obtain or judge, leading to poor quality concrete. Professor Okamura therefore proposed a concept for a design of concrete independent of the need for compaction. Studies to develop self-compacting concrete, including a fundamental study on the workability of concrete, were carried out by Ozawa and Maekawa at the University of Tokyo. Since that time SCC has gone from a laboratory novelty to practical applications all over the world. The increasing numbers of papers published every year that deal with all aspects of SCC, e.g. mix design, rheological and physical properties and applications in practice indicate research on this technology is thriving".

## II. OBJECTIVE

To evaluate the fresh properties (Passing ability, filling ability and segregation resistance of SCC with use of FCA with10% lime up to 50% Replacement of OPC

To evaluate the harden properties (Compressive strength, tensile strength, flexural strength) by addition of FCA with constant 10% lime in concrete mix.

To Study the durability requirement like acid attack( by HCL), Sorptivity test, RCPT test of SSC

## III. FERROCHROME ASH (FCA)

Ferrochrome ash (FCA) may be a waste material obtained from the gas cleansing plant of a ferrochromium industry. Ferrochrome (FCA) is an alloy of chromium and iron containing 50% to 70% chromium by weight.

"Ferrochrome is produced by electric arc carbothermic reduction of chromite. Most of the world's ferrochrome is made in African nation, Asian country like India and Kazakistan, that have massive domestic mineral resources. Increasing amounts are coming from Russia & China. The production of steel is the largest consumer of ferrochrome(FC), especially the production of stainless steel with chromium content of 15 to 20% is the main application of ferrochrome".

**Figure 1 Ferrochrome ash**

## IV. CHEMICAL COMPOSITION OF OPC, FCA & LIME

**Table 1 Chemical Composition Of Opc, FCA & Lime**

| Chemical composition(%) | OPC | FCA | LIME |
|---|---|---|---|
| CaO | 63.90 | 4.18 | 47.8 |
| SiO2 | 21.40 | 19.80 | 0.80 |
| Al2O3 | 5.50 | 10.90 | 0.55 |
| MgO | 1.90 | 15.70 | 7.10 |
| Fe2O3 | 3.50 | 5.96 | 0.15 |
| SO3 | 1.40 | 1.95 | |
| K2O | 0.50 | 14.20 | |
| Na2O | 0.28 | 1.20 | |
| CL | - | 9.70 | |
| Cr2O3 | - | 12.60 | |

## V. FRESH PROPERTIES TEST RESULTS

There are three fresh property of Self-compacting concrete (SCC) that is filling ability,passing ability and segregation resistance

**Filling ability**

"Flows easily at suitable speed into formwork an completely fills intricate spaces with obstacles."

**Passing ability**

"Passes through reinforcements without blocking and adhere to it without applied other external energy."

**Resistance to segregation**

"The distribution of aggregate particles remains homogeneous in both vertical and horizontal directions."

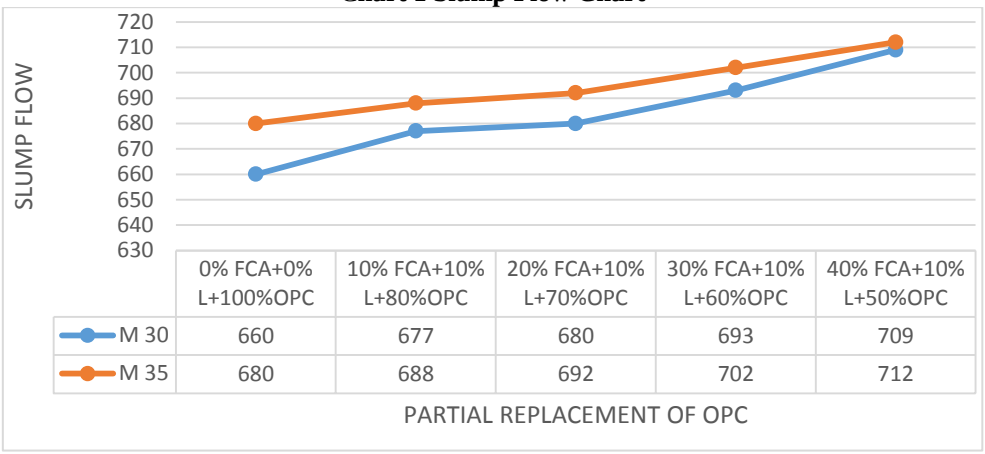
**Table 2 Results of Fresh properties test M-30 grade concrete**

| Sr no. | Type of Mix | Slump (mm) | V-Funnel (sec) | L-Box (h2/h1) |
|---|---|---|---|---|
| | | 650-800 mm | 6-12 sec | 0.8-1 |
| 1 | 0% FCA+0% L+100%OPC | 660 | 11.3 | 0.82 |
| 2 | 10% FCA+10% L+80%OPC | 677 | 10.9 | 0.84 |
| 3 | 20% FCA+10% L+70%OPC | 680 | 10.2 | 0.87 |
| 4 | 30% FCA+10% L+60%OPC | 693 | 9.5 | 0.89 |
| 5 | 40% FCA+10% L+50%OPC | 709 | 8.4 | 0.92 |

**Table 3 Results of Fresh properties test M-35 grade concrete**

| Sr no. | Type of Mix | Slump (mm) | V-Funnel (sec) | L-Box (h2/h1) |
|---|---|---|---|---|
| | | 650-800 mm | 6-12 sec | 0.8-1 |
| 1 | 0% FCA+0% L+100%OPC | 680 | 11 | 0.81 |
| 2 | 10% FCA+10% L+80%OPC | 688 | 10.7 | 0.85 |
| 3 | 20% FCA+10% L+70%OPC | 692 | 9.8 | 0.88 |
| 4 | 30% FCA+10% L+60%OPC | 702 | 8.3 | 0.91 |
| 5 | 40% FCA+10% L+50%OPC | 712 | 7.5 | 0.94 |

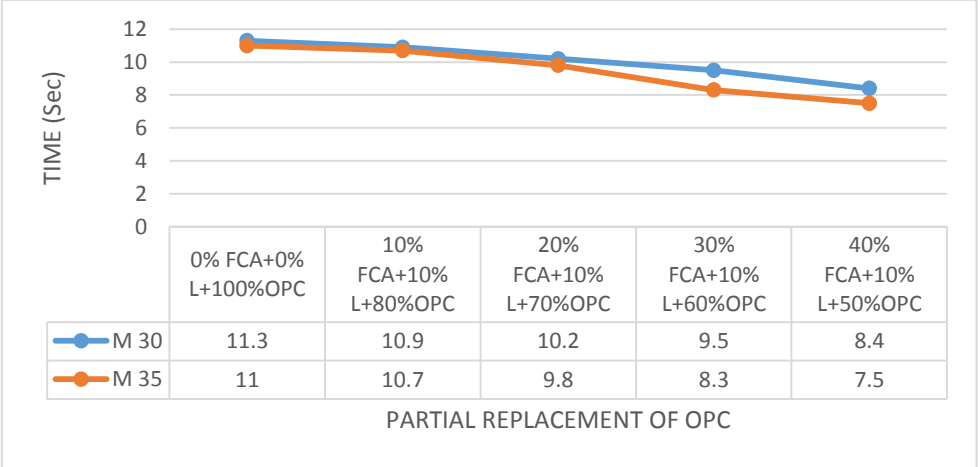
**Chart 1 Slump Flow Chart**




In M-30 grade concrete with the increment of FCA with lime up to total replacement of 50% with increment of 10% with constant 10% lime the value of slump increases in the rate of percentage 2.58, 3.03, 5.00, and 7.42 respectively.

In M-35 grade concrete with the increment of FCA with lime up to total replacement of 50% with increment of 10% with constant 10% lime the value of slump increases in the rate of percentage 1.18, 1.16, 3.24, and 4.71 respectively.

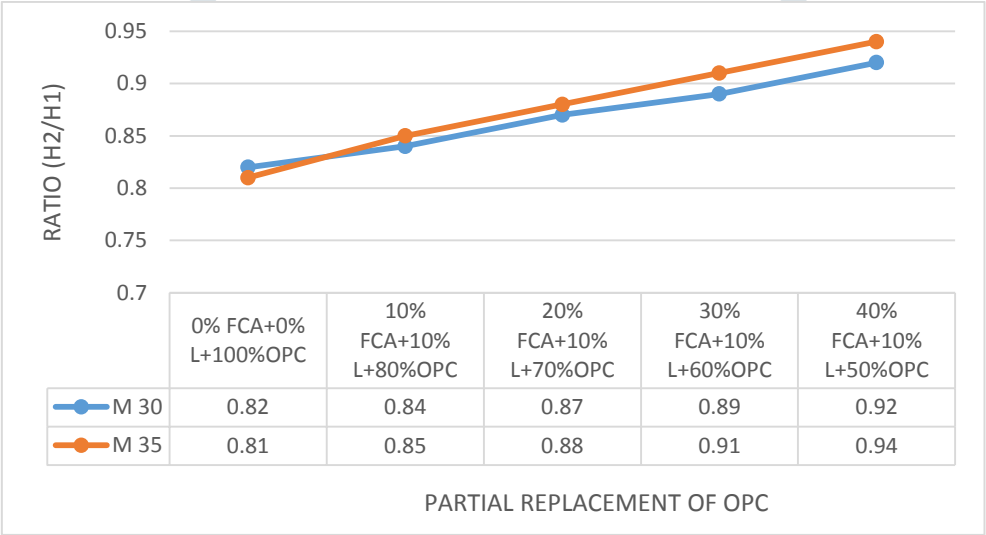
**Chart 2 V-Funnel Charts**




In M-30 grade concrete with the increment of FCA with lime up to total replacement of 50% with increment of 10% with constant 10% lime the value of slump decreases in the rate of percentage 3.54, 9.73, 15.93 and 25.66 respectively.

In M-35 grade concrete with the increment of FCA with lime up to total replacement of 50% with increment of 10% with constant 10% lime the value of slump decreases in the rate of percentage 2.73, 10.91, 24.55 and 31.52 respectively.

**Chart 3 L-Box Chart**




In M-30 grade concrete with the increment of FCA with lime up to total replacement of 50% with increment of 10% with constant 10% lime the value of L-Box increases in the rate of percentage 2.44, 6.10, 8.54, and 12.20 respectively.

In M-35 grade concrete with the increment of FCA with lime up to total replacement of 50% with increment of 10% with constant 10% lime the value of L- Box increases in the rate of percentage 4.94, 8.64, 12.35, and 16.05 respectively.

## VI. HARDEN PROPERTIES TEST RESULTS

### Compressive strength result

The compressive strength of SSC is increases with increase the percentage of FCA with LIME. The result of compressive strength of SCC as shown in below:.

**Table 4 Compressive Strength of Cubes for M-30**

| **Compressive Strength for M-30 Grade in Mpa** | | | | | |
|---|---|---|---|---|---|
| **Target mean strength-38.75** | | | | | |
| **Sr. No.** | **Type of Mix** | **7 days** | **14 days** | **28 days** | **56 days** |
| 1 | 0% FCA+0% L+100%OPC | 27.73 | 33.27 | 41.25 | 44.12 |
| 2 | 10% FCA+10% L+80%OPC | 28.12 | 33.78 | 41.55 | 44.6 |
| 3 | 20% FCA+10% L+70%OPC | 28.25 | 34.88 | 42.33 | 45.25 |
| 4 | 30% FCA+10% L+60%OPC | 29.36 | 36.52 | 43.92 | 46.84 |
| 5 | 40% FCA+10% L+50%OPC | 27.67 | 33.41 | 42.15 | 45.2 |

**Chart 4 Compressive Strength of M-30**

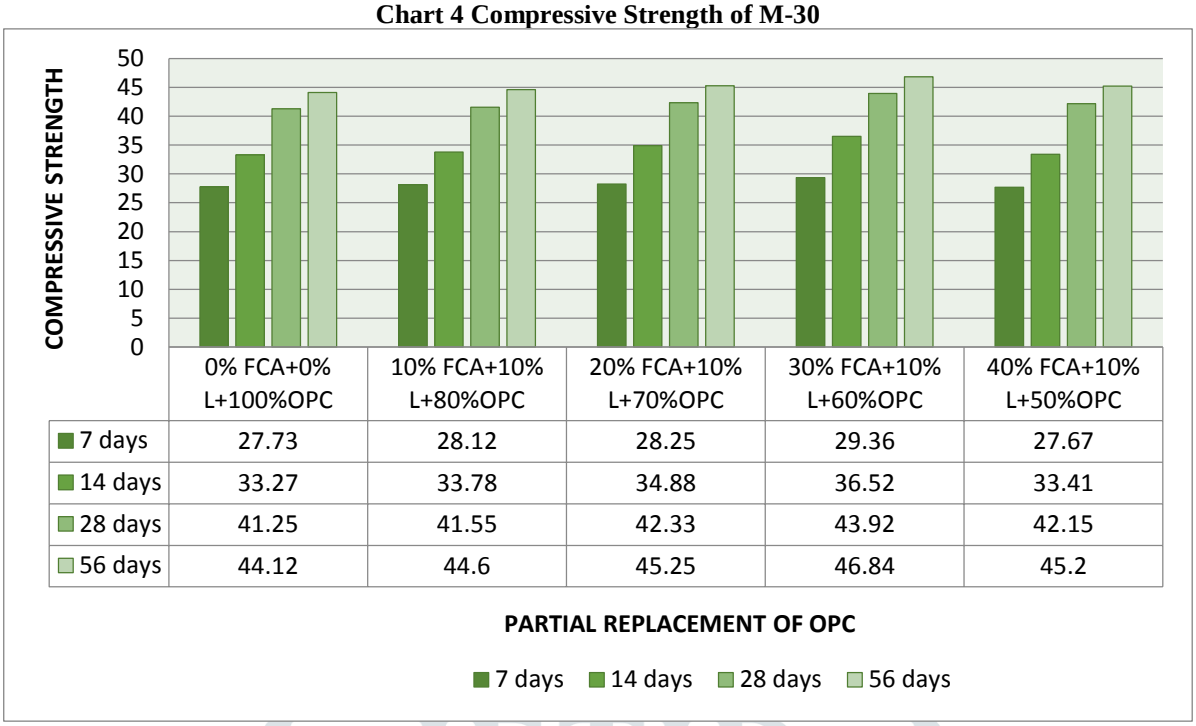
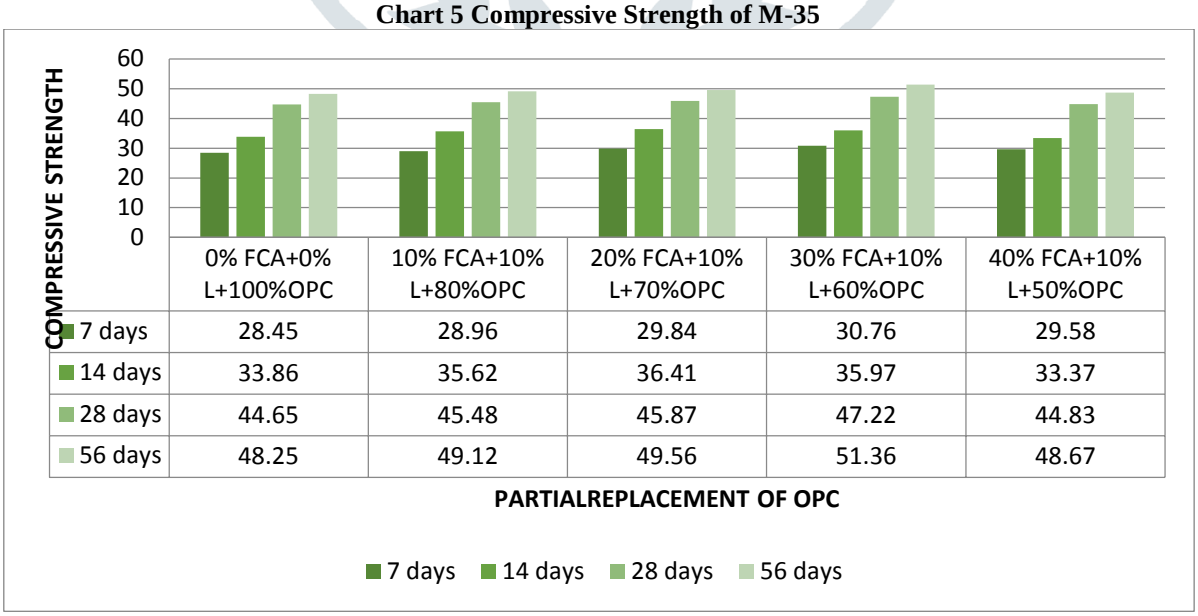



**Table 5 Compressive Strength of Cubes for M-35**

| **Compressive Strength for M-35 Grade in Mpa** | | | | | |
|---|---|---|---|---|---|
| **Target mean strength-43.25** | | | | | |
| **Sr. No.** | **Type of Mix** | **7 days** | **14 days** | **28 days** | **56 days** |
| 1 | 0% FCA+0% L+100%OPC | 28.45 | 33.86 | 44.65 | 48.25 |
| 2 | 10% FCA+10% L+80%OPC | 28.96 | 35.62 | 45.48 | 49.12 |
| 3 | 20% FCA+10% L+70%OPC | 29.84 | 36.41 | 45.87 | 49.56 |
| 4 | 30% FCA+10% L+60%OPC | 30.76 | 35.97 | 47.22 | 51.36 |
| 5 | 40% FCA+10% L+50%OPC | 29.58 | 33.37 | 44.83 | 48.67 |

**Chart 5 Compressive Strength of M-35**




In M-30 grade concrete the value of 30% FCA replacement with constant 10% lime gives maximum 43.92MPA comprerssive strength.

In M-35 grade concrete the value of 30% FCA replacement with constant 10% lime gives maximum 47.22MPA comprerssive strength.

**Flexural strength Results**

The flexural strength of Self compacted concrete is increases with increase the percentage of FCA with LIME. The result of compressive strength of SCC as shown in below:.

**Table 6 Flexural Strength of Grade M-30**

| Flexural Strength for M-30 Grade in Mpa | | | | |
|---|---|---|---|---|
| **Sr. No.** | **Type of Mix** | **7 days** | **14 days** | **28 days** |
| 1 | 0% FCA+0% L+100%OPC | 2.65 | 3.14 | 3.95 |
| 2 | 10% FCA+10% L+80%OPC | 2.71 | 3.24 | 4.26 |
| 3 | 20% FCA+10% L+70%OPC | 2.78 | 3.36 | 4.36 |
| 4 | 30% FCA+10% L+60%OPC | 2.85 | 3.45 | 4.41 |
| 5 | 40% FCA+10% L+50%OPC | 2.72 | 3.31 | 3.11 |

**Chart 6 Flexural Strength of M-30**

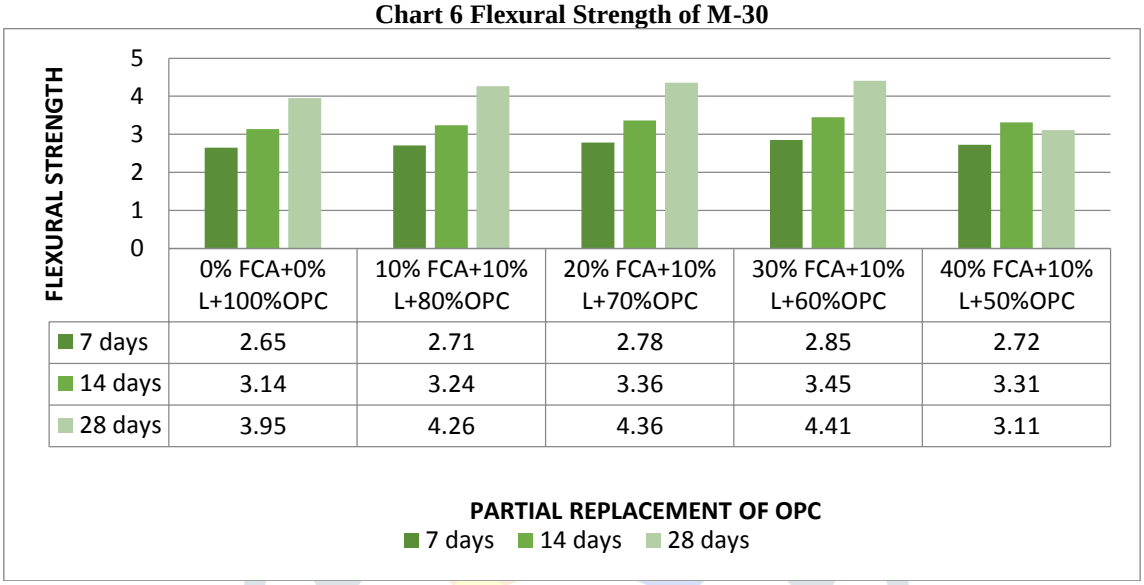
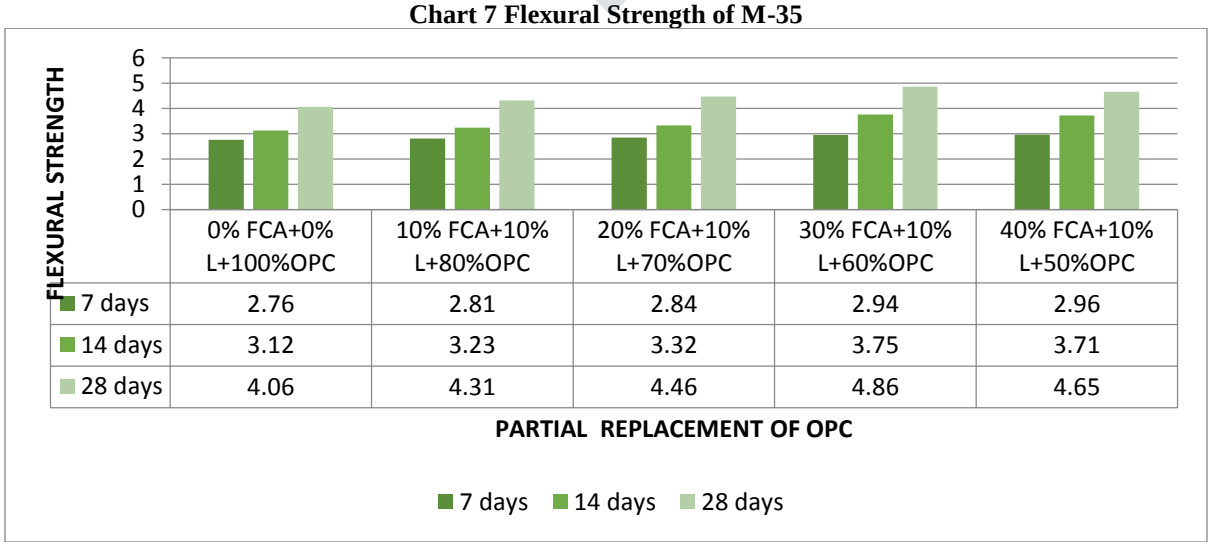



**Table 7 Flexural Strength of Grade M-35**

| Flexural Strength for M-35 Grade in Mpa | | | | |
|---|---|---|---|---|
| **Sr. No.** | **Type of Mix** | **7 days** | **14 days** | **28 days** |
| 1 | 0% FCA+0% L+100%OPC | 2.76 | 3.12 | 4.06 |
| 2 | 10% FCA+10% L+80%OPC | 2.81 | 3.23 | 4.31 |
| 3 | 20% FCA+10% L+70%OPC | 2.84 | 3.32 | 4.46 |
| 4 | 30% FCA+10% L+60%OPC | 2.94 | 3.75 | 4.86 |
| 5 | 40% FCA+10% L+50%OPC | 2.96 | 3.71 | 4.65 |

**Chart 7 Flexural Strength of M-35**




In M-30 grade concrete the value of 30% FCA replacement with constant 10% lime gives maximum 4.41MPA Flexural strength
In M-35 grade concrete the value of 30% FCA replacement with constant 10% lime gives maximum 4.86MPA Flexural strength.

**Split Tensile Strength Results**

The Split tensile strength of Self compacted concrete is increases with increase the percentage of FCA with LIME. The result of compressive strength of SCC as shown in below:.

**Table 8 Split Tensile Strength of Grade M-30**

| Split Tensile Strength for M-30 Grade in Mpa | | | | |
|---|---|---|---|---|
| **Sr. No.** | **Type of Mix** | **7 days** | **14 days** | **28 days** |
| 1 | 0% FCA+0% L+100%OPC | 2.32 | 2.75 | 3.24 |
| 3 | 10% FCA+10% L+80%OPC | 2.36 | 2.85 | 3.36 |
| 5 | 20% FCA+10% L+70%OPC | 2.45 | 3.04 | 3.58 |
| 7 | 30% FCA+10% L+60%OPC | 2.58 | 3.34 | 4.18 |
| 9 | 40% FCA+10% L+50%OPC | 2.54 | 3.26 | 3.96 |

**Chart 8 Split Tensile Strength of M-30**

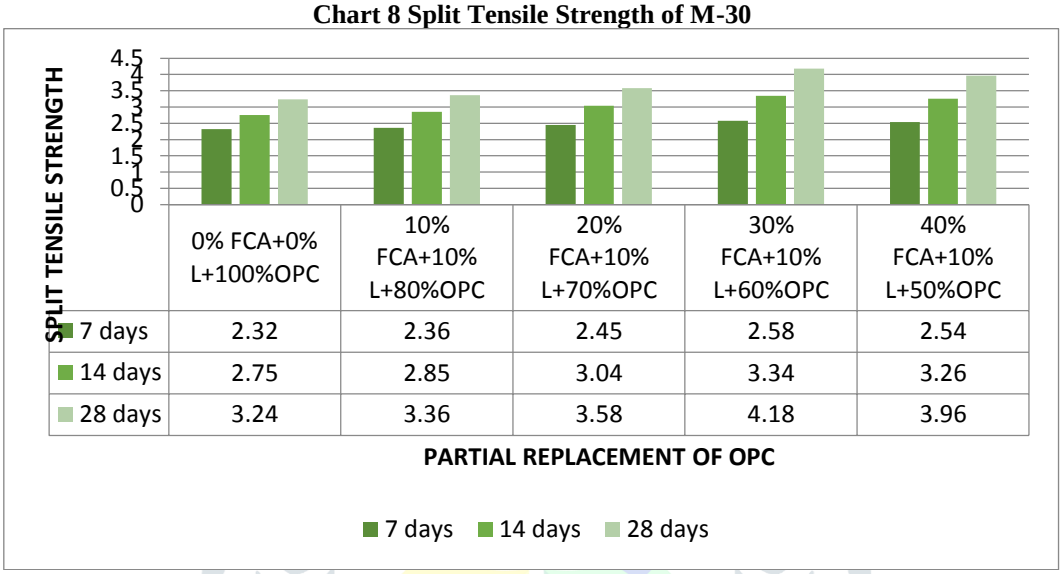
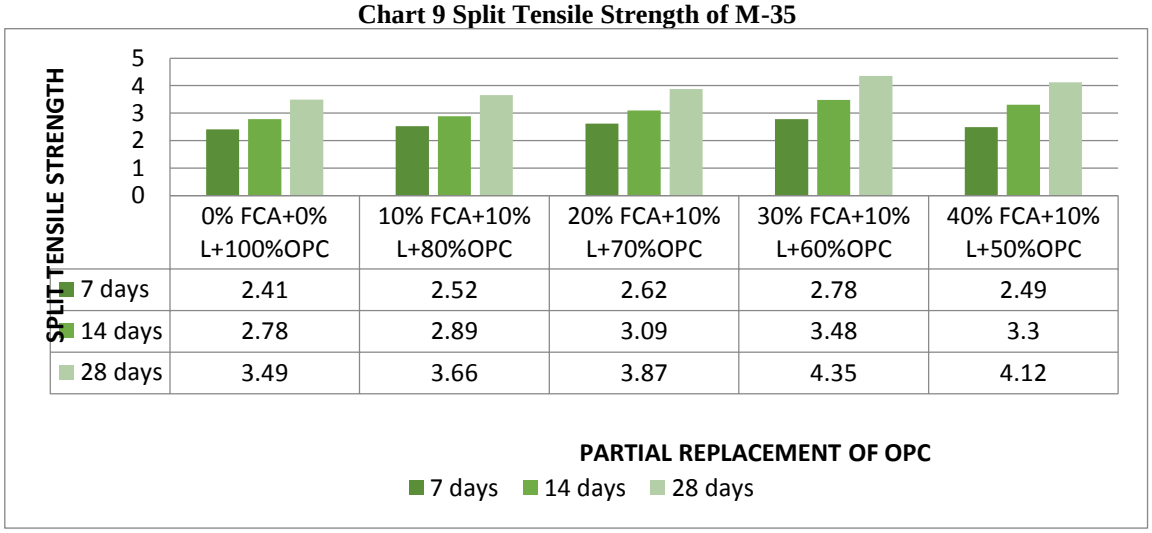



**Table 9 Split Tensile Strength of Grade M-35**

| Split Tensile Strength for M-35 Grade in Mpa | | | | |
|---|---|---|---|---|
| **Sr. No.** | **Type of Mix** | **7 days** | **14 days** | **28 days** |
| 1 | 0% FCA+0% L+100%OPC | 2.41 | 2.78 | 3.49 |
| 3 | 10% FCA+10% L+80%OPC | 2.52 | 2.89 | 3.66 |
| 5 | 20% FCA+10% L+70%OPC | 2.62 | 3.09 | 3.87 |
| 7 | 30% FCA+10% L+60%OPC | 2.78 | 3.48 | 4.35 |
| 9 | 40% FCA+10% L+50%OPC | 2.49 | 3.3 | 4.12 |

**Chart 9 Split Tensile Strength of M-35**




In M-30 grade concrete the value of 30% FCA replacement with constant 10% lime gives maximum 4.18MPA Split tensile strength.
In M-35 grade concrete the value of 30% FCA replacement with constant 10% lime gives maximum 4.35MPA Split tensile strength.

## VI. DURABILITY TEST RESULTS

### Rapid Chloride Permeability Test

The results of RCPT of SCC are shown below:

**Table 10 Rapid Chloride Permeability Test For M-30**

| RCPT TEST FOR M-30 Grade | | | | | |
|---|---|---|---|---|---|
| Sr. No. | Type of Mix | 7 days ChloridePermeability | | 28 days ChloridePermeability | |
| | | Coulombs | Remarks | Coulombs | Remarks |
| 1 | 0% FCA+0% L+100%OPC | 6748 | H | 5360 | H |
| 2 | 10% FCA+10% L+80%OPC | 5980 | H | 4152 | H |
| 3 | 20% FCA+10% L+70%OPC | 5224 | H | 3957 | M |
| 4 | 30% FCA+10% L+60%OPC | 3960 | M | 3756 | M |
| 5 | 40% FCA+10% L+50%OPC | 3546 | M | 3220 | M |

**H= HIGH, M=MODERATE**

**Chart10 Rapid Chloride Permeability Test For M-30**

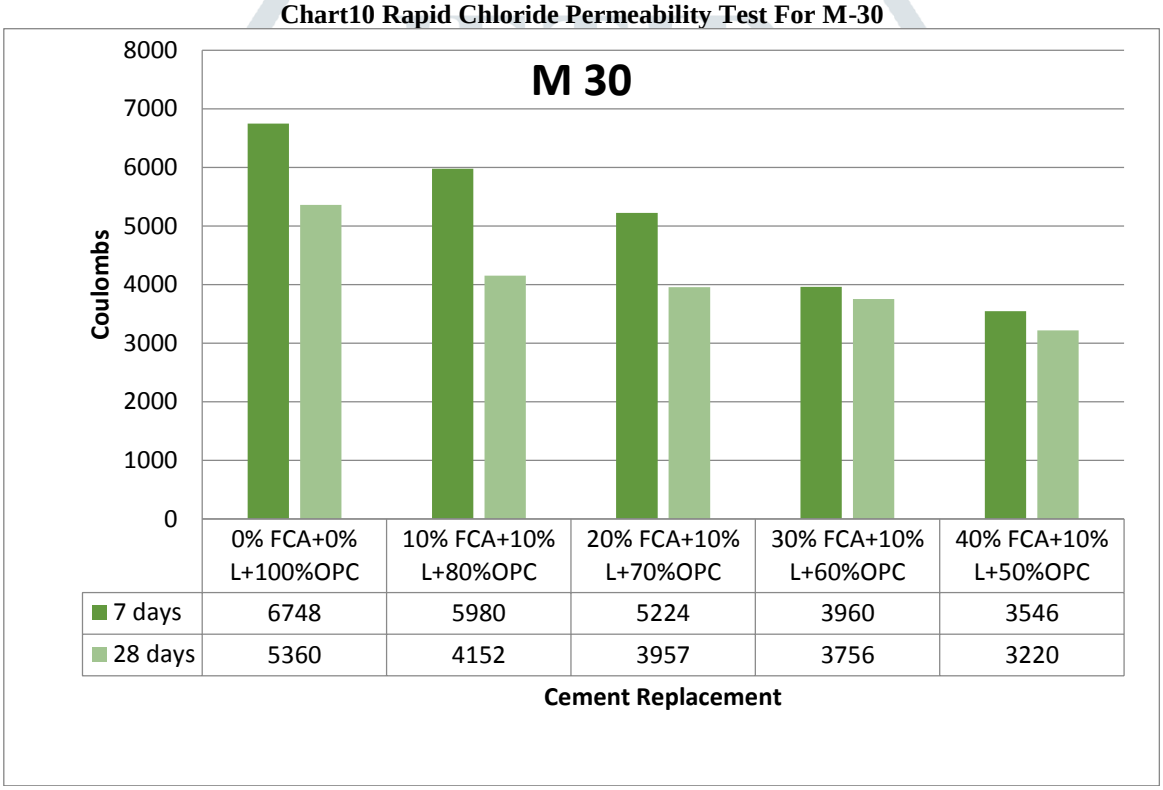
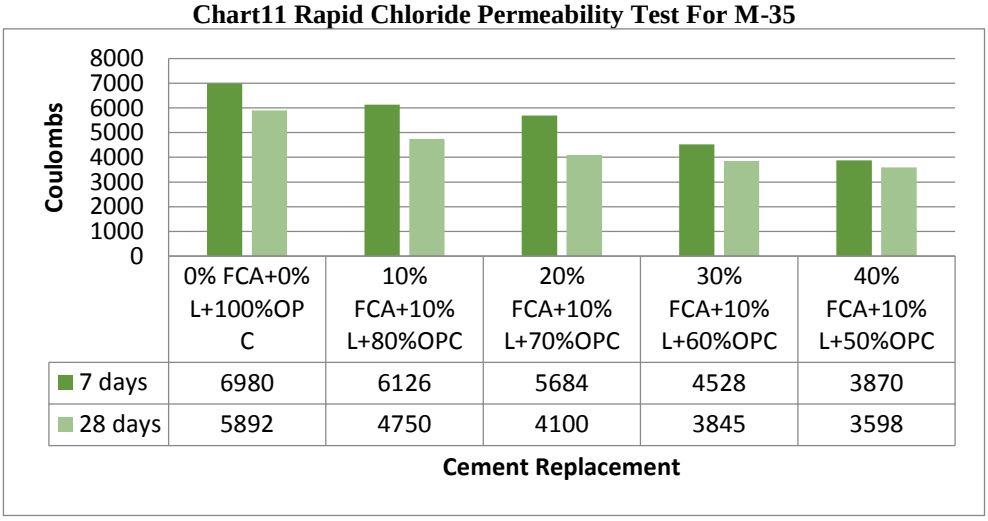



**Table 11 Rapid Chloride Permeability Test For M-35**

| RCPT TEST FOR M-35 Grade | | | | | |
|---|---|---|---|---|---|
| Sr. No. | Type of Mix | 7 days ChloridePermeability | | 28 days ChloridePermeability | |
| | | Coulombs | Remarks | Coulombs | Remarks |
| 1 | 0% FCA+0% L+100%OPC | 6980 | H | 5892 | H |
| 2 | 10% FCA+10% L+80%OPC | 6126 | H | 4750 | H |
| 3 | 20% FCA+10% L+70%OPC | 5684 | H | 4100 | H |
| 4 | 30% FCA+10% L+60%OPC | 4528 | H | 3845 | M |
| 5 | 40% FCA+10% L+50%OPC | 3870 | M | 3598 | M |

**Chart11 Rapid Chloride Permeability Test For M-35**




**Sorptivity test results:**

The results of Sorptivity test of SCC are shown below:

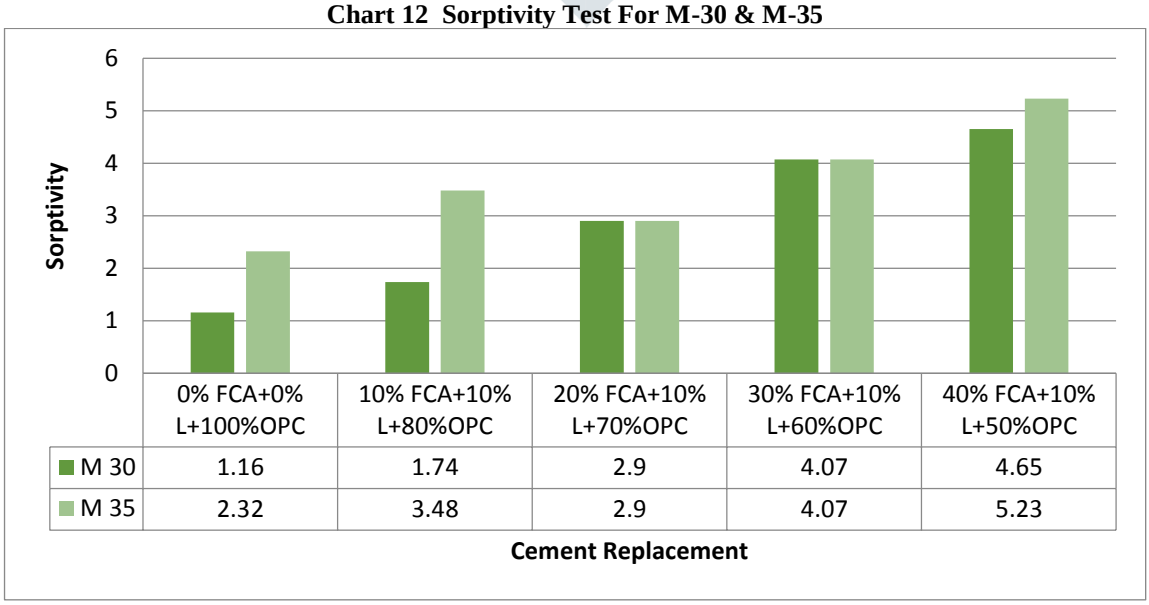
**Table 12 Sorptivity Test For M-30**

| Sr. no. | Concrete type | Cement Replace ment (%) | Dry wt. in gram | Wet wt. in gram | Sorptivity value in 10^(-5)mm/ mm^(0.5) |
|---|---|---|---|---|---|
| 1 | 0% FCA+0% L+100%OPC | 0% | 992.5 | 993.5 | 1.16 |
| 2 | 10% FCA+10% L+80%OPC | 20% | 980.3 | 981.05 | 1.74 |
| 3 | 20% FCA+10% L+70%OPC | 30% | 943 | 944.25 | 2.9 |
| 4 | 30% FCA+10% L+60%OPC | 40% | 931.25 | 933 | 4.07 |
| 5 | 40% FCA+10% L+50%OPC | 50% | 948 | 950 | 4.65 |

**Table 13 Sorptivity Test For M-35**

| Sorptivity Results for M35 | | | | | |
|---|---|---|---|---|---|
| **Sr. no.** | **Concrete type** | **Cement Replace ment (%)** | **Dry wt. in gram** | **Wet wt. in gram** | **Sorptivity value in 10^(-5)mm/ mm^(0.5)** |
| 1 | 0% FCA+0% L+100%OPC | 0% | 997.25 | 998.25 | 2.32 |
| 2 | 10% FCA+10% L+80%OPC | 20% | 968.5 | 970 | 3.48 |
| 3 | 20% FCA+10% L+70%OPC | 30% | 938.3 | 939.55 | 2.9 |
| 4 | 30% FCA+10% L+60%OPC | 40% | 946 | 947.75 | 4.07 |
| 5 | 40% FCA+10% L+50%OPC | 50% | 951.45 | 953.7 | 5.23 |

**Chart 12 Sorptivity Test For M-30 & M-35**



## VII. CONCLUSION

Based on experimental investigation, following observations are made on the fresh property, hardened properties and durability of Self Compacted Concrete:-

- Maximum increase in strength and durability properties determined in concrete mix containing 30% FCA and 10% lime.
- Workability increased fresh density raised slightly because of inclusion of Ferrochrome ash with lime.
- The Compressive , flexural and tensile strength of concrete containing FCA with lime, substitution OPC up to 50% improved significantly at all age.
- Ferrochrome ash in conjunction with lime has positive impact whereas Replacement of OPC by Ferrochrome ash alone has negative impact on compressive strength.
- Sorpitivity of concrete mixes containing Ferrochrome ash and lime found less than control mix at all ages.
- Results of compressive strength, flexural strength, tensile strength and sorptivity study conformed one another.
- It can be broadly concluded from the current study that Ferrochrome ash in conjunction with lime is a useful raw material for partial replacement of OPC up to 50% in Self Compacted Concrete.
- The use of powder additions helps build SCC a green alternative. Also the practice of use of powder additions to self compacting concrete mix will helps to reduce the cement consumption, which reduce the greenhouse gas emissions during cement manufactures.

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