ISSN: 2278-4632
Vol-10 Issue-12 No.03 December 2020

# DURABILITY OF HIGH PERFORMANCE CONCRETE

Dr. HARISH CHAND GIRI Professor, Dept. of Civil Engineering, Aryan Institute of Engineering & Technology, Bhubaneswar
MD.ARAS ANSARI Assistant Professor, Department of Civil Engineering, Raajdhani Engineering College, Bhubaneswar, Odisha
Dr.SALEEMA PANDA Department of Civil Engineering, NM Institute of Engineering and Technology,Bhubaneswar , Odisha

***Abstract:***

High Performance Concrete (HPC) has become an object of intensive research due to its growing use in the construction practice. In the last decade the use of Supplementary Cementing Materials (SCM) has become an integral part of high strength and high performance concrete mix design. The addition of SCM to concrete reduces the heat of hydration and extends the service life in structures by improving both long-term durability and strength. Some of the commonly used SCM are Flyash, Silica fume, Blast furnace slag and Metakaoline. This paper presents results of the durability characteristic properties of $M_{80}$ and $M_{90}$ grade of high performance concrete with and without supplementary cementing materials. The durability was evaluated using Acid attack test, Alkaline attack test and Sulphate attack test.

***Keywords:*** High Performance Concrete (HPC), Durability, Acid attack test, Alkaline attack test, Sulphate Attack test.

## INTRODUCTION

High Performance Concrete (HPC) is that which is designed to give optimized performance characteristics for the given set of materials, usage and exposure conditions, consistent with requirement of cost, service life and durability. The Ordinary Portland Cement is one of the main ingredients used for the production of concrete and has no alternative in the construction industry. Unfortunately, production OPC involves emission of large amounts of Carbon dioxide ($CO_2$) gas into the atmosphere, a major contributor for Green House Effect and Global Warming. Hence, it is inevitable either to search for another material or partly replace it by SCM which should lead to global sustainable development and lowest possible environmental impact.

1

Another advantage of using SCMs is increase in durability of concrete which consequently results increase in resource use efficiency of ingredients of concrete which are depleting at very fast rate. Long term performance of structure has become vital to the economies of all nations.

The use of fly ash and silica fume is becoming more common because they improve concrete durability and strength, especially where high early age curing temperatures occur. High replacement levels of fly ash are uncommon however, because of resistance to change by the cement industry and because of concerns about the early-age strength and the quality of concretes produced with high cement replacement levels.

HPC will extend the service life of structures in severe environments, there has been a gradual acceptance of HPC. HPC is characterized by a low water/cementitious materials ratio (generally <0.35, high dosages of super-plasticizer and the incorporation of SCMs.

Smith Kevin *et al*., have established a testing regime to optimize the strengths and dura•bility characteristics of a wide range of high-performance concrete mixes. One of the prime methods of optimizing the mixtures was to implement supplemental cementitious materials, at their most advantageous levels. fly ash, slag cement, and microsilica all proved to be highly effective in creating more durable concrete design mixtures. These materials have also shown success in substantially lowering chloride ingress, thus extending the initiation phase of corrosion (Smith Kevin *et al*., 2004).

Swamy (1996), defines that a high performance concrete element is that which is designed to give optimized performance characteristics for a given set of load, usage and exposure conditions, consistent with requirement of cost, service life and durability (Swamy, 1996).

The chemical resistance of the concretes was studied through chemical attack by immersing them in an acid solution. After 90 days period of curing the specimens were removed from the curing tank and their surfaces were cleaned with a soft nylon brush to remove weak reaction products and loose materials from the specimen. The initial weights were measured and the specimens were identified with numbered plastic tokens that were tied around them. The specimens were immersed in 3% $H_2SO_4$ solution and the pH (4) was maintained constant throughout. The solution was replaced at regular intervals to maintain constant concentration throughout the test period. The mass of specimens were measured at regular intervals up to 90 days, and the mass losses were determined (Dinakar *et al*., 2008).

Kazuyuki and Mitsunori (1994), have studied the effect of fly ash and silica fume on the properties of concrete subjected to acidic attack and sulphate attack. Changes in physical and chemical properties in the mortars with different replacements by fly ash and silica fume when immersed in 2% $H_2SO_4$, 10% $Na_2SO_4$ and 10% $MgSO_4$ solutions for 3 years were investigated (Kazuyuki and Mitsunori, 1994).

One of the main causes of deterioration in concrete structures is the corrosion of concrete due to its exposure to harmful chemicals that may be found in nature such as in some ground

ISSN: 2278-4632
Vol-10 Issue-12 No.03 December 2020

waters, industrial effluents and sea waters. The most aggressive chemicals that affect the long term durability of concrete structures are the chlorides and sulfates. The chloride dissolved in waters increase the rate of leaching of portlandite and thus increases the porosity of concrete, and leads to loss of stiffness and strength. Calcium, sodium, magnesium, and ammonium sulfates are in increasing order of hazard harmful to concrete as they react with hydrated cement paste leading to expansion, cracking, spalling and loss of strength (Wee *et al*., 2000).

## MATERIALS USED IN THE PRESENT STUDY

### Cement

Ordinary Portland cement Zuari-53 grade conforming to (IS: 12269, 1987) were used in concrete. The physical properties of the cement are listed in Table 1.

### Aggregates

A crushed granite rock with a maximum size of 20 mm and 12 mm with specific gravity of 2.60 was used as a coarse aggregate. Natural sand from Swarnamukhi River in Srikalahasthi with specific gravity of 2.60 was used as fine aggregate conforming to zone-II of (IS 383 (1970). The individual aggregates were blended to get the desired combined grading.

### Water

Potable water was used for mixing and curing of concrete cubes.

### Supplementary Cementing Materials

*Flyash*

Fly ash was obtained directly from the M/s Ennore Thermal Power Station, Tamil Nadu, India. The physicochemical analysis of sample was presented in Table 2.

***Silica Fume***

The silica fume used in the experimentation was obtained from Elkem Laboratory, Navi Mumbai. The chemical composition of silica fume is shown in Table 3.

**Table 1: Physical Properties of Zuari-53 Grade Cement**

| S. No. | 1 | 2 | 3 | 4 | 5 | | |
|---|---|---|---|---|---|---|---|
| Properties | Specific Gravity | Normal Consistency | Initial Setting time | Final Setting time | Compressive Strength (Mpa) | | |
| | | | | | 3 days | 7 days | 28days |
| Values | 3.15 | 32% | 60 min | 320 min | 29.4 | 44.8 | 56.5 |

**Table 2: Physicochemical Properties of Flyash Sample**

| Sample | Specific Gravity | Specific Surface area ($m^2/g$) | Moisture Content (%) | Wet Density (g/cc) | Turbidity (NTU) | pH | |
|---|---|---|---|---|---|---|---|
| Flyash | 2.20 | 1.24 | 0.20 | 1.75 | 459 | 7.3 | |
| | Chemical Composition, Elements (weight %) | | | | | | |
| | $SiO_2$ | $Al_2O_3$ | $Fe_2O_3$ | CaO | $K_2O$ | $TiO_2$ | $Na_2O_3$ | MgO |
| | 56.77 | 31.83 | 2.82 | 0.78 | 1.96 | 2.77 | 0.68 | 2.39 |

ISSN: 2278-4632
Vol-10 Issue-12 No.03 December 2020

| Table 3: Chemical Composition of Silica Fume | | | | | | |
|---|---|---|---|---|---|---|
| **Chemical Composition** | **Silica ($SiO_2$)** | **Alumina ($Al_2O_3$)** | **Iron Oxide ($Fe_2O_3$)** | **Alkalies as ($Na_2O + K_2O$)** | **Calcium Oxide (CaO)** | **Magnesium Oxide (MgO)** |
| Percentage | 89.00 | 0.50 | 2.50 | 1.20 | 0.50 | 0.60 |

### *Metakaoline*

The Metakaoline was obtained from M/s. 20 μ Limited, Baroda, India. The chemical composition of Metakaoline is shown in Table 4.

### *Blast Furnace Slag*

The blast furnace slag was obtained from Sesa Goa Limited Goa. The chemical composition of Blast Furnace Slag is shown in Table 5.

### *Super Plasticizer*

VARAPLAST PC100: A high performance concrete superplasticizer based on modified polycarboxilic ether, supplied from M/s Akarsh specialities, Chennai.

## RESULTS AND DISCUSSION

In the present work, proportions for high performance concrete mix design of $M_{80}$ and $M_{90}$ were carried out according to IS: 10262 (2009) recommendations. The mix proportions are presented in Tables 6 and 7.

The tests were carried out as per IS: 516 (1959). The 150 mm cube specimens of various concrete mixtures were cast to test compressive strength. The cube specimens after de-moulding were stored in curing tanks

| Table 4: Chemical Composition of Metakaoline | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Chemical Composition** | **$SiO_2$** | **$Al_2O_3$** | **$Fe_2O_3$** | **$TiO_2$** | **CaO** | **MgO** | **$SO_3$** | **$Na_2O$** | **$K_2O$** | **LOI** |
| Mass Percent-age (%) | 52 to 54 | 42 to 44 | <1 to 1.4 | <3 | 0.1 | <0.1 | <0.1 | <0.05 | <0.4 | <1 |

| Table 5: Chemical Composition of Blast Furnace Slag | | | | | | |
|---|---|---|---|---|---|---|
| **Oxides** | **$SiO_2$** | **$P_2O_5$** | **CaO** | **MnO** | **FeO** | **$Fe_2O_3$** |
| Mass Percentage | 11 | 10 | 51 | 08 | 10 | 04 |

| Table 6: Mix Proportion for $M_{80}$ Concrete | | | | | | |
|---|---|---|---|---|---|---|
| | **Cement** | **Fine aggregate** | **Coarse aggregate (20 mm 20% and 12.5 mm 80%)** | **Water** | **Secondary Cementing Materials** | **Super plasticizer** |
| Composition in kg/$m^3$ | 539 | 685.274 | 986.126 | 153 | 135 | 9.70 |
| Ratio in % | 1 | 1.271 | 1.829 | 0.283 | 0.250 | 0.018 |

ISSN: 2278-4632
Vol-10 Issue-12 No.03 December 2020

**Table 7: Mix Proportion for $M_{90}$ Concrete**

| | Cement | Fine aggregate | Coarse aggregate (20 mm 20% and 12.5 mm 80%) | Water | Secondary Cementing Materials | Super plasticizer |
|---|---|---|---|---|---|---|
| Composition in Kg/m³ | 585.4 | 651.572 | 942.16 | 153 | 146.350 | 10.537 |
| Ratio in % | 1 | 1.113 | 1.609 | 0.261 | 0.25 | 0.018 |

and on removal of cubes from water the compressive strength were conducted at 7 days, 28 days and 90 days. The test results were compared with individual percentage replacements (Binary System) and combinations of admixtures (Ternary System) for two grades of concrete ($M_{80}$ and $M_{90}$).

## ACID ATTACK TEST

The concrete cube specimens of various concrete mixtures of size 150 mm were cast and after 28 days of water curing, the specimens were removed from the curing tank and allowed to dry for one day. The weights of concrete cube specimen were taken. The acid attack test on concrete cube was conducted by immersing the cubes in the acid water for 90 days after 28 days of curing. Hydrochloric acid (HCl) with pH of about 2 at 5% weight of water was added to water in which the concrete cubes were stored. The pH was maintained throughout the period of 90 days. After 90 days of immersion, the concrete cubes were taken out of acid water. Then, the specimens were tested for compressive strength. The resistance of concrete to acid attack was found by the percent loss of weight of specimen and the percent loss of compressive strength on immersing concrete cubes in acid water. Figures 1 and 2 represents the percentage loss in strength of $M_{80}$ and $M_{90}$ due to Acidity respectively. Figures 3 and 4 represents the percentage loss in weight of $M_{80}$ and $M_{90}$ due to acidity, respectively.

**Figure 1: Percentage Loss in Strength of $M_{80}$ Due to Acidity**

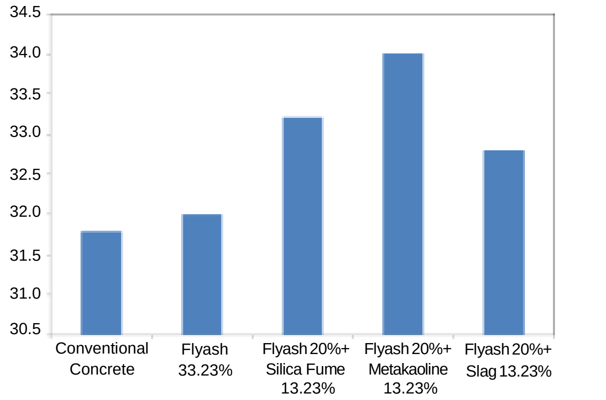
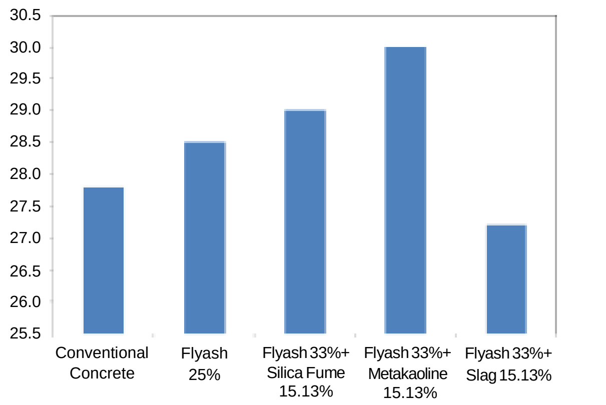



**Figure 2: Percentage Loss in Strength of $M_{90}$ Due to Acidity**



ISSN: 2278-4632
Vol-10 Issue-12 No.03 December 2020

**Figure 3: Percentage Loss in Weight of $M_{80}$ Due to Acidity**

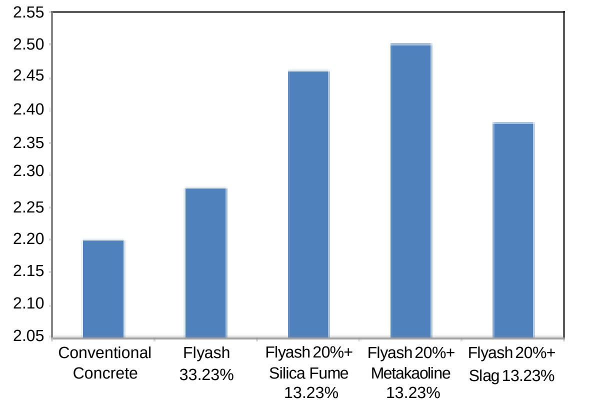
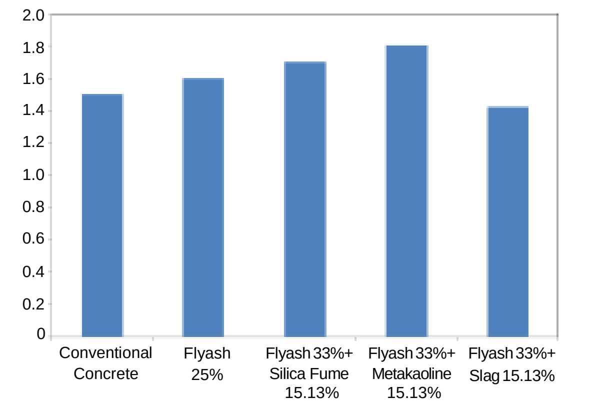



**Figure 4: Percentage Loss in Weight of $M_{90}$ Due to Acidity**




## ALKALINE ATTACK TEST

To determine the resistance of various concrete mixtures to alkaline attack, the residual compressive strength of concrete mixtures of cubes immersed in alkaline water having 5% of sodium hydroxide (NaOH) by weight of water was found. The concrete cubes which were cured in water for 28 days were removed from the curing tank and allowed to dry for one day. The weights of concrete cube specimen were taken. Then the cubes were immersed in alkaline water continuously for 90 days. The alkalinity of water was maintained same throughout the test period. After 90 days of immersion, the concrete cubes were taken out of alkaline water. Then, the specimens were tested for compressive strength. The resistance of concrete to alkaline attack was found by the percent loss of weight of specimen and the percent loss of compressive strength on immersion of concrete cubes in alkaline water. Figures 5 and 6 represents the Percentage loss in strength of $M_{80}$ and $M_{90}$ due to Alkalinity respectively. Figures 7 and 8 represents the Percentage loss in weight of $M_{80}$ and $M_{90}$ due to alkalinity, respectively.

**Figure 5: Percentage Loss in Strength of $M_{80}$ Due to Alkalinity**

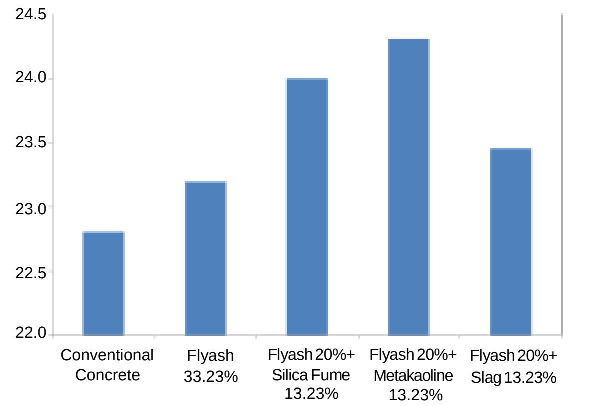
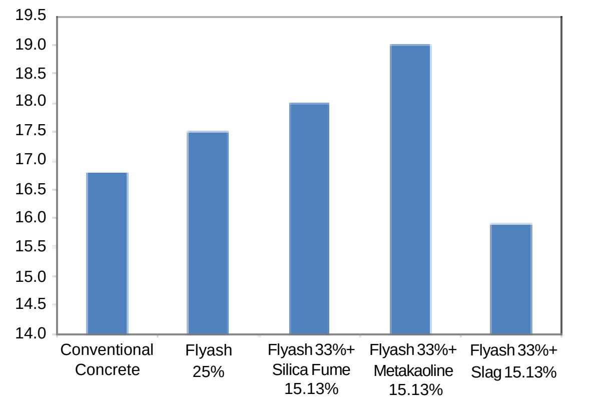



**Figure 6: Percentage Loss in Strength of $M_{90}$ Due to Alkalinity**



ISSN: 2278-4632
Vol-10 Issue-12 No.03 December 2020

**Figure 7: Percentage Loss in Weight of $M_{80}$ Due to Alkalinity**

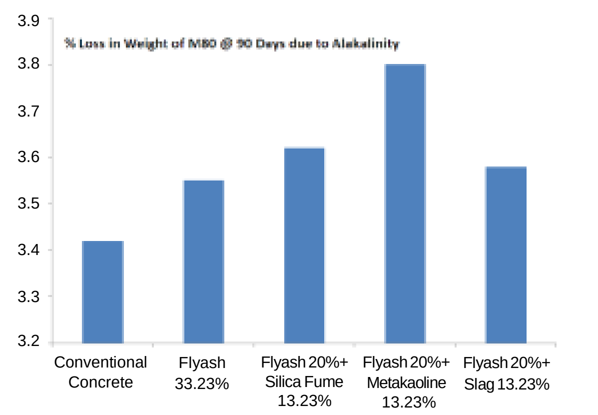
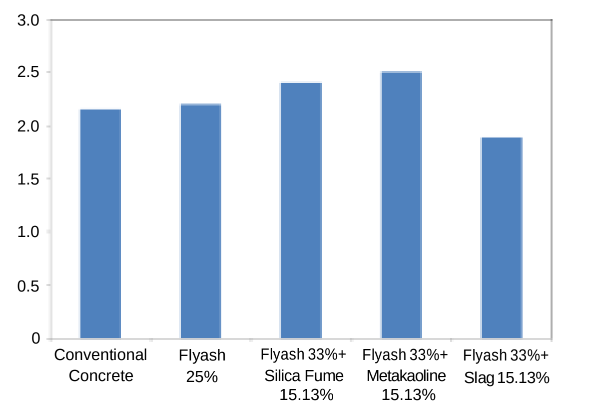



**Figure 8: Percentage Loss in Weight of $M_{90}$ Due to Alkalinity**




## SULPHATE ATTACK TEST

The resistance of concrete to sulphate attacks was studied by determining the loss of compressive strength or variation in compressive strength of concrete cubes immersed in sulphate water having 5% of sodium sulphate ($Na_2SO_4$) and 5% of magnesium sulphate ($MgSO_4$) by weight of water and those which are not immersed in sulphate water. The concrete cubes of 150 mm size after 28 days of water curing and dried for one day were immersed in 5% $Na_2SO_4$ and 5% $MgSO_4$ added water for 90 days. The concentration of sulphate water was maintained throughout the period. After 90 days immersion period, the concrete cubes were removed from the sulphate waters and after wiping out the water and girt from the surface of cubes tested for compressive strength following the procedure prescribed in IS: 516 (1959). This type of accelerated test of finding out the loss of compressive strength for assessing sulphate resistance of concrete (Mehta and Burrows, 2001). Figures 9 and 10 represents the percentage loss in weight of $M_{80}$ and $M_{90}$ due to sulphate respectively.

**Figure 9: Percentage Loss in Strength of $M_{80}$ Due to Sulphate**

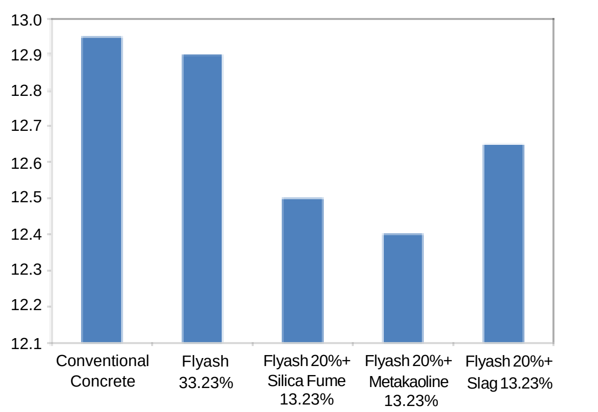
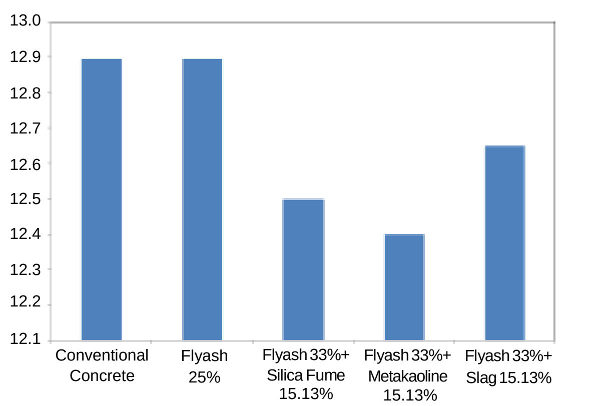



**Figure 10: Percentage Loss in Strength of $M_{90}$ Due to Sulphate**



## CONCLUSION

1. In high performance concrete mix design as water/cement ratio adopted is low, super plasticizers are necessary to maintain required workability. As the percentage of mineral admixtures is increased in the mix, the percentage of super plasticizer should also be increased, for thorough mixing and for obtaining the desired strength.
2. In $M_{80}$ and $M_{90}$ grades of concrete as the water-cement ratios of 0.283 and 0.261 are insufficient to provide the good workability, hence super plasticizer are necessary for $M_{80}$ and $M_{90}$ grades of concrete.
3. It is observed from the results the maximum percentage loss in weight and percentage reduction in compressive strength due to Acids for $M_{80}$ grade concrete are 2.5%, 34% with replacement of 20% Flyash and 13.23% metakaoline and the minimum percentage loss in weight and strength are 2.38%, 32.8% with replacement of 20% flyash, 13.23% blast furnace slag. There is considerable reduction in loss of weight and strength only with flyash replacement.
4. Present investigation shows that the maximum percentage loss in weight and percentage reduction in compressive strength due to Alkalinity for $M_{80}$ grade concrete are 3.8%, 24.3% with replacement of 20% flyash and 13.23% blast furnace slag and the minimum percentage loss in weight and strength are 3.55%, 23.2% with replacement of 20% flyash and 13.23% of silica fume. There is considerable reduction in loss of weight and strength only with Flyash replacement.
5. From results the maximum percentage loss in weight and percentage reduction in compressive strength due to Acids for $M_{90}$ grade concrete are 1.8%, 30% with replacement of 33% Flyash and 15.13% of Metakaoline and the minimum percentage loss in weight and strength are 1.42%, 27.2% with replacement of 33% flyash and 15.13% Blast furnace slag. There is considerable reduction in loss of weight and strength only with flyash replacement.
6. Present study reveals that the maximum percentage loss in weight and percentage reduction in compressive strength due to Alkalinity for $M_{90}$ grade concrete are 2.5%, 19% with replacement of 33% Flyash and 15.13% of metakaoline and the minimum percentage loss in weight and strength are 1.89%,15.9% with replacement of 33% Flyash and 15.13% Blast Furnace Slag. There is considerable reduction in loss of weight and strength only with flyash replacement.
7. It is identified that the maximum percentage reduction in compressive strength due to Sulphates of $M_{80}$ grade concrete is 12.65% with replacement of 20% flyash and 13.23% blast furnace slag and the minimum percentage reduction in strength is 12.4% with 33% flyash, 15.13% metakaoline.
8. It is identified that the maximum percentage reduction in compressive strength due to Sulphates of $M_{90}$ grade concrete is 14.9% with replacement of 33% flyash and 15.13% blast furnace slag and the minimum percentage reduction in strength is 13.2% with 33% flyash, 15.13% metakaoline.

## REFERENCES

1. Dinakar P, Babu K G and Manu Santhanam (2008), “Durability Properties of High Volume Fly Ash Self Compacting Concretes”, *Cement & Concrete Composites*, Vol. 30, pp. 880-886.
2. IS: 12269 (1987), “Specification for 53 Grade Ordinary Portland Cement, Bureau of Indian Standards”, New Delhi, India, 1989.
3. IS: 383 (1970) “Specifications for Coarse and Fine Aggregates for Natural Sources of Concrete, Bureau of Indian Standards, New Delhi.
4. IS: 10262 (2009), “Concrete Mix Proportioning-Guidelines”, Bureau of Indian Standards , New Delhi.
5. IS: 516 (1959), “Methods of Tests for Strength of Concrete”, Bureau of Indian Standards, New Delhi.
6. Kazuyuki Torii and Mitsunori Kawamura (1994), Effects of fly ash and silica fume on the resistance of mortar to sulfuric acid and sulfate attack, *Cement and Concrete Research*, Vol. 24, No. 2, pp. 361-370.
7. Mehta P K and Burrows R W (2001), “Building Durable Structures”, in *The 21st Century, Concrete International*, Vol. 23, No. 3, pp. 57-63.
8. Smith Kevin M, Schokker Andrea J and Tikalsky Paul J (2004), “Performance of Supplementary Cementitious Materials In Concrete Resistivity and Corrosion Monitoring Evaluations”, *ACI Materials Journal*, Vol. 101, No. 5, pp. 385-390.
9. Swamy R N (1996), “High Performance Durability Through Design”, *International Workshop on High Performance Concrete*, *ACI-SP*, Vol. 159, No. 14, pp. 209-230.
10. Wee T H, Suryavanshi A K, Wong S F and Rahman A K (2000), “Sulfate Resistance of Concrete Containing Mineral Admixtures”, *ACI Material Journal,* Vol. 97, pp. 536-549.