International Journal of Structural and Civil Engineering Research

ISSN 2319 – 6009 www.ijscer.com
Vol. 1, No. 1, November 2012

Research Paper

DURABILITY OF HIGH PERFORMANCE CONCRETE CONTAINING SUPPLEMENTARY CEMENTING MATERIALS USING RAPID CHLORIDE PERMEABILITY TEST

M Vijaya Sekhar Reddy[1*], I V Ramana Reddy[2], K Madan Mohan Reddy[1] and Abibasheer Basheerudeen[3]

Corresponding Author: **M Vijaya Sekhar Reddy, ✉ skitce.hod@gmail.com.*

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 SCMs 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 SCMs. The durability was evaluated using Rapid Chloride Permeability Test.

Keywords: High Performance Concrete (HPC), Supplementary Cementing Materials (SCMs), Superplasticizer, Durability, Rapid chloride permeability test

INTRODUCTION

Durability of concrete plays an important role in the service life of RCC structures. It can be enhanced by improving impermeability, resistance to chloride ion diffusion and abrasion resistance. one of the ways to achieving this is by adding superplasticizers and supplementary cementing materials. Also, High Performance Concrete (HPC) can be produced by minimizing the water cement ratio with the help of superplasticizers and carefully selecting SCMs such as fly ash, ground granulated blast furnace slag, Metakaoline and Silica fume. Many researchers have demonstrated the beneficial effects of using Ground Granulated Blast Furnace Slag (GGBS) and flyash as cement replacement materials and obtained a reduction in the rate

1 Department of Civil Engineering, Srikalahasteeswara Institute of Technology, Srikalahasti, Andhra Pradesh, India.
2 Department of Civil Engineering, Sri Venkateswara University College of Engineering, Tirupati, Andhra Pradesh, India.
3 Department of Civil Engineering, MES Institute of Technology and Management, Chathanoor, Kollam.

of penetration of chloride ions concrete reducing the potential of chloride induced corrosion (Bhaskar *et al*., 2012).

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).

One of the main reasons for deterioration of concrete in the past is that too much emphasis is placed on concrete compressive strength rather than on the performance criteria. The deterioration of reinforced concrete structures usually involves the transport of aggressive substances from the surrounding environment followed by physical and chemical actions in its internal structure. The transport of aggressive gases and/or liquids into concrete depends on its permeation characteristics. As the permeation of concrete decreases its durability performance, in terms of physio-chemical degradation, increases. Therefore, permeation of concrete is one of the most critical parameters in the determination of concrete durability in aggressive environments (VaishaliG Ghorpade and Sudarsana Rao, 2011).

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 (OPC) 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. 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 (Khadiraranaikar *et al*., 2012).

Durability of concrete is the ability of concrete fully functional over an extended period under prevailing service conditions for the purpose for which it has been designed. The durability of concrete is classily related to its permeability. The permeability dictates the rate at which aggressive agents can penetrate to attack the concrete and the steel reinforcement. Corrosion related damage to the concrete structure is a major problem associated with high cost of repairs; sometimes replacement of structure. HPC is the key to achieve impermeable, durable and improved protection of embedded steel (Khadiraranaikar *et al.*, 2012).

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

Fly ash

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.

Metakaoline

The Metakaoline was obtained from M/s. 20 Microns 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.

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	28 days
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	
Fly ash	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

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

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

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 standards cylindrical disc specimens of size 100 mm diameter and 50 mm thick after 90 days water curing were used in this test. As per ASTMC 1202 (1997). The test results of M_{80} and M_{90} HPC mixes of Binary and Ternary systems of concrete were compared with and without SCMs.

Rapid Chloride Permeability Test

The rapid chloride permeability test for different concrete mixtures was carried out as per ASTM C1202 (1997). Standard cylindrical disc specimens of size 100 mm diameter and 50 mm thick after 90 days water curing were

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

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/m^3	585.4	651.572	942.16	153	146.350	10.537
Ratio in %	1	1.113	1.609	0.261	0.25	0.018

used. This test method covers the determination of the electrical conductance of concrete to provide a rapid indication of its resistance to penetration of chloride ions.

The apparatus consists of variable DC power supply which feeds constant stabilized voltage to the cells. The cells are made up of polymethyl methacrylate. The concrete specimens are kept in between the cells. The cells are connected to main instrument through 3 pin plug and socket for voltage feeding. The charge of current flowing through the specimen is measured by using an accurate digital current meter. The cells have grooved recess on one face and closed at other end. The specimen can be fit into the open faces of the cells. One of the cells is filled with sodium chloride (NaCl) solution 2.4 M concentration and the other is filled with 0.3 M Sodium hydroxide (NaOH-0.3 M) solution.

The cylindrical disc specimen are coated with quick setting epoxy on their curved faces and mounted in the open spaces of the two cells. After checking the leak proofness, a 60V potential difference is applied between the electrodes. The electrochemical cell in the assembly results in migration of the chloride ions from sodium hydroxide solution through the pores of the concrete specimen. The current passed was noted at every 30 min over a period of 6 hr and the total electric charge passed through the specimen is calculated using the expression. The Table 8 shows the rating of chloride permeability according to ASTM C1202 (1997).

Table 8: Rating of Chloride Permeability

Charge Passing in Coulombs	Chloride Permeability Rating
Greater than 4000	High
2001 to 4000	Moderate
1001 to 2000	low
100 to 1000	Very low
Less than 100	Negligible

The following formula, based on the trapezoidal rule can be used to calculate the average current flowing through one cell.

Total Charge Passed in Coulomb's (Qc)

$$Q = 900(I_0 + 2I_{30} + 2I_{60} + 2I_{90} + 2I_{120} + \ldots + 2I_{300} + 2I_{330} + I_{360})$$

where

Q = current flowing through one cell (coulombs)

I_0 = Current reading in amperes immediately after voltage is applied, and

I_t = Current reading in amperes at t minutes after voltage is applied

The object of the test was to evaluate the durability performance of M_{80} and M_{90} mixes and compared with conventional concrete. The rapid chloride permeability test results of M_{80} and M_{90} were represented in Table 9 and corresponding graphical pictures were shown in Figures 1 and 2, respectively.

Table 9: Rapid Chloride Permeability Test Results of M_{80} and M_{90} Mixes

Grade of Con-crete	Percentage Replacement of SCMs	Total Charge Passed Through in Columb's @90 Days
M_{80}	Conventional Concrete	1205.00
	Fyash 33.23%	369.00
	Flyash 20% + Silica Fume 13.23%	325.00
	Flyash 20%+ Metakaoline 13.23%	310.00
	Flyash 20%+ Slag 13.23%	348.00
M_{90}	Conventional Concrete	1109.00
	Flyash 25%	262.00
	Flyash 33% + Silica Fume 15.13%	257.00
	Flyash 33% + Metakaoline 15.13%	248.00
	Flyash 33% + Slag 15.13%	268.00

Figure 1: Rapid Chloride Permeability Test Results of M_{80} Mix

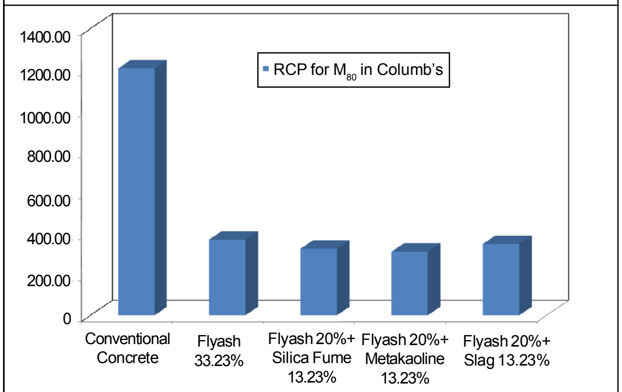
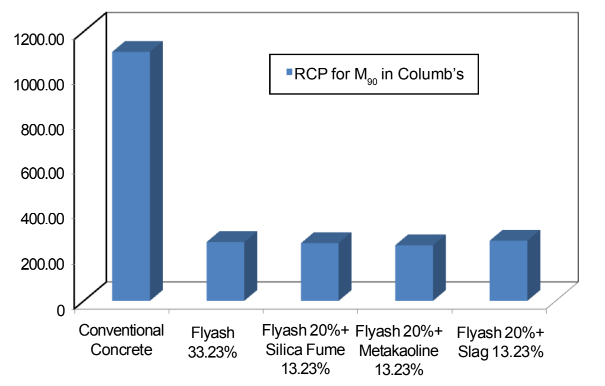


Figure 2: Rapid Chloride Permeability Test Results of M_{90} Mix



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. Rapid Chloride Permeability test results reveals that the total charge passed in Coulomb's is very low for M_{80} HPC mix with replacement of 20% Flyash and 13.23% of Metakaoline. But the total charge passed in Coulomb's for conventional concrete is low.
4. Rapid Chloride Permeability test results reveals that the total charge passed in Coulomb's is very low for M_{90} HPC mix with replacement of 33%% Flyash and 15.13% of Metakaoline. But the total charge passed

in Coulomb's for conventional concrete is low.

5. The addition of SCMs causes pozzolanic reaction and thus resulting in improvement of pore structure of concrete leading to lower permeability, causing higher resistance to chloride ion penetration at the higher percentage replacement compared to conventional concrete.

REFERENCES

1. Bhaskar S, Ravindra Gettu B, Bharatkumar H and Neelamegam M ((2012), "Strength, Bond and Durability Related Properties of Concretes With Mineral Admixtures, *Indian Concrete Journal*, Vol. 86, No. 2, pp. 9-16.
2. 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.
3. Swamy R N (1996), "High Performance Durability Through Design", *International Workshop on HighPerformance Concrete*, *ACI-SP*, Vol. 159, No. 14, pp. 209-230.
4. Vaishali G Ghorpade and Sudarsana Rao H (2011), "Chloride Ion Permeability Studies of Metakaoline based, High Performance Concrete", *International Journal of Engineering Science and Technology (IJEST),* Vol. 3, No. 2, pp.1617-1623.
5. Khadiraranaikar R B, Chandrabansi G B and Md. Asif Maruf (2012), "Durability of High Performance Concrete Congaing Rice Husk Ash using Rapid Chloride Penetration Test", in *Proceedings of International Conference on Sustainability Challenges and Advances in Concrete Technology (SCACT),* Organized by Department of Civil Engg., PSG College of Technology, Coimbatore, India.
6. IS: 12269 (1987), "Specification for 53 Grade Ordinary Portland Cement", Bureau of Indian Standards, New Delhi, India.
7. IS: 383 (1970), "Specifications for Coarse and Fine Aggregates for Natural Sources of Concrete", Bureau of Indian Standards, New Delhi.
8. IS: 10262 (2009), "Concrete Mix Proportioning-Guidelines", Bureau of Indian Standards , New Delhi.
9. Standard Test Method for Electrical Indication of Concrete's Ability to Resist Chloride Ion Penetration, ASTMC 1202-97, *Annual Book of ASTM Standards*, Vol. 4, No. 2, pp.639-644.