AN EXPERIMENTAL INVESTIGATION ON THE RELATIONSHIP BETWEEN ELECTRICAL RESISTIVITY AND MECHANICAL AND DURABILITY PROPERTIES OF M_{30} GRADE CONCRETE.

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Abstract - *The durability properties of concrete are evaluated using many test methods. Concrete is a heterogeneous material and the use of different materials and chemical admixtures into it produce different effects which lead to the variations in performance of concrete. There are some of the standard methods of evaluating the mechanical properties of concrete but only a few durability tests. Non-destructive tests on concrete are standardized. The relationship between all mechanical and durability properties are not fully established. Many durability properties of concrete can be attributed to the microstructure of concrete, chemical composition of pore solution and the ability of concrete against the transport properties.*

In the present investigation an attempt is made to compare the mechanical and durability properties of standard and silica fume M_{30} grade concrete with the surface electrical properties i.e., electrical resistivity characteristics.

Key Words: *OPC concrete, silica fume, electrical resistivity, chloride permeability, water permeability.*

1. INTRODUCTION

Cement concrete has become the most indispensable construction material now-a-days. Due to environmental effects and influences, the deterioration of concrete has become the most common phenomenon. Due to the deterioration of concrete, the life span of concrete structure decreases and at the same time, the costs of repairs for the deteriorated concrete structures shoot up. Hence there is always a dire need to have easy and economical methods of finding out the deterioration before it actually takes place. Though there are many non- destructive methods available, the tests on durability of concrete which are simple and economical are yet to be used in the field Widely. The permeability of concrete, the pore solution pore chemical composition are the major cause for transportation of liquids or gases into concrete which finally lead to deterioration of concrete in many ways i.e., corrosion of steel, alkali aggregate reaction, chemical dispersion of concrete etc. Electrical resistivity method is a simple test to find out the potential difference between the electrodes and gives scope for correlating these values to the permeability values i.e., chloride permeability and water permeability as the concrete become denser, the electrical resistivity of concrete increases. Though the strength of concrete depends on so many factors, density/maturity/hydration of cement etc., parameters play important role in imparting strength to the concrete. Therefore an attempt is made in the present study to find out the relation between the mechanical and durability properties of concrete with the electrical resistivity of concrete. Though research has been done in this direction, universally accepted relationships were not established. The present study may add some information which will be helpful for further studies.

It is well known that the Electrical resistivity of concrete is an important value and can be related to some performance characteristics of concrete and can be used as a tool for assessment of quality of concrete(1).

On the other hand the electrical resistivity has been probably, the best known durability indicator for chloride induced deterioration of concrete structures. Because Electrical resistivity can be related to the volume fraction of pores, conductivity of pore solution and can be used to predict the diffusion coefficient of chloride ions and water permeability (2&3).

The four probe method is a well-known method for measuring electrical resistivity though there are various methods for finding out electrical resistivity. This method has an advantage that the electrical resistivity can be simply calculated from measuring results of voltage and electrical current.

2. MATERIALS AND METHODS

In the present investigation the 53 grade OPC, silica fume; natural sand, crushed granite aggregates are used.

Cement and aggregate: Ordinary Portland cement of 53 grade manufactured by Zuari cement company confirming to IS 12269 – 1987 is used. Natural sand conforming to Zone 2, with specific gravity of 2.65, fineness modulus 2.88 and

20mm crushed granite aggregate with specific gravity of 2.7 are used.

Silica fume:

Silica fume, also referred to as microsilica or condensed silica fume, is another material that is used as an admixture. The micro silica is formed when Sio gas produced in the furnace mixes with oxygen, oxidizes to Sio_2, condensing into the pure spherical particles of micro silica that form the major part of the smoke or fume from the furnace.

The XRD Analysis of silica fume:

To find the particle size and ensure that the silica fume used is nanosilica, XRD analysis is carried out and is shown in Fig.1

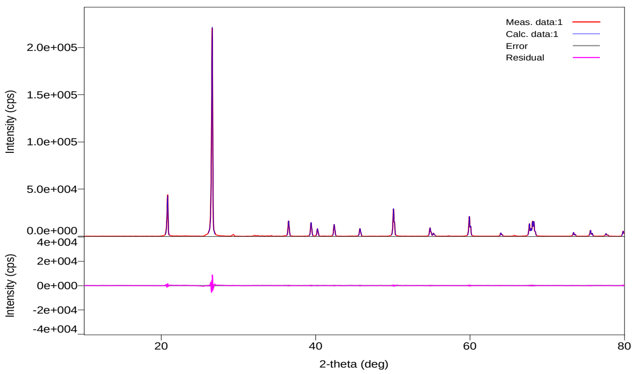


Figure 1. XRD analysis for Silica fume

The silica fume used in the present study is extremely fine with particle size less than 1 micron and with an average diameter of about 0.1 micron about 100 times smaller average cement particles.

Table: 1 Chemical properties & physical properties of silica fume.

Property	Amount
SiO2 content	82.20 %
Al2O3 content	0.50 %
Fe2O3 content	0.42 %
CaO content	1.55 %
MgO content	0.00 %
SO3 content	3.03 %
Loss of ignition	5.66 %
Fineness as surface area	29000 (m2/kg)
Specific gravity	2.2

3. MIX PROPORTIONING

In the present investigation M $_{30}$ concrete is used with a water – cement ratio 0.50. The M_{30}grade of concrete mix design is done as per IS 10262: 2009. Concrete mixtures were prepared by varying percentage of replacement of cement with Silica fume i.e., from 5% to 10%.

4. EXPERIMENTAL INVESTIGATION

Electrical resistivity method:

Wenner probe method: This method is one of the widely accepted methods by which, the surface electrical resistivity of concrete is found. The experimental setup consists of four equally spaced electrodes, concrete specimen with necessary electrical connections to read out the input current and the potential drop. Unlike the two point uniaxial method where current and voltage drop are measured from the same set of electrodes, this method applies current through the two exterior electrodes and measures the potential difference between the two inner electrodes. The electrical resistivity of concrete is calculated by using the formula

$$\rho = 2\pi a \frac{V}{I}$$

Where ρ = Electrical resistivity

a = Probe spacing (Cm)
V= potential differences between probes
I= electrical current.

Figure2. Testing of electrical resistivity of concrete cube

Compressive Strength Test:

The compressive strength of concrete is (150mm×150mm×150 mm) tested by means of compression testing machine according to IS 516-1959. The specimens are tested after 14 days, 28 days, 60 days, 90 days.

Rapid Chloride ion penetration test:

The rapid chloride permeability test is conducted as per ASTM C 1202 on water- saturated, 50mm thick, 100mm diameter concrete specimens as which were subjected to a 60v applied DC voltage for 6 hours using the RCPT apparatus. In one reservoir a 3.0% NaCl solution and in the other reservoir is a 0.3M NaOH solution were used .Electrical resistivity of concrete represent moving ions in pore solution and therefore the relationship between electrical resistivity and chloride ion penetration in concrete is reasonable(4). The electrical resistivity provides some information about the interconnected pore network in the concrete and by extension about its resistance to the penetration of chloride ions (5). The total charge passed is determined and this is used to rate the concrete according to the criteria furnished in table 2.

Table: 2 RCPT ratings as (per ASTM C1202)

Charge passed (coulombs)	Chloride ion permeability
>4000	High
2000-4000	Moderate
1000-2000	Low
100-1000	Very low
<100	Negligible

Water permeability:

The determination of water penetration depth is specified by BS EN- 12390-8:2000. In this test, water was applied on the face of the 150mm diameter concrete specimen under a pressure of 5 kg/cm^2 constant pressure maintained for a period of 72 h. After this period, the specimens were taken out and split into halves. The water penetration contour in the concrete surface was marked and then maximum depth of penetration value was recorded as water penetration. This test was conducted after at 28 & 60 days age of concrete cubes.

From RCPT the total charge passed through the concrete is measured and these values indicate the quality of concrete. Electrical resistivity of concrete represents moving ions in pore solution and thus the relationship between electrical resistivity and chloride permeability can be taken as reasonable.

From the depth of penetration, mass of water penetrated, pressure and time the coefficient of permeability of concrete mixtures was calculated using the formula:

$$K = \frac{D2v}{2ht}$$

D= depth of penetration of water

V= fraction of volume of water penetrated

t= time under pressure in m

h= hydraulic head in m

V is calculated by using the expression

$$v = \frac{1000M}{A.d}$$

M = gain in mass (mass of water penetrated)

A = Cross sectional area of concrete (mm^2)

d = depth of penetration in mm.

5. EXPERIMENTAL RESULTS AND DISCUSSION

The M_{30}grade of concrete with 5% and 7.5% of Silica fume was tested for electrical resistivity, compressive strength, Chloride ion penetration and water permeability.

LEGEND:

Table3shows the percentages of Silica fume for M_{30} grade concrete

Mix Designation	Binding materials
A1	100% cement
A2	5% silica fume+95% cement
A3	7.5% Silica fume+ 92.5% cement
A4	10% Silica fume+ 90% cement

Effect of silica fume on compressive strength:

The concrete specimens with partial replacement of silica fume were tested by using CTM and the test results are furnished in table no:3, fig 2 gives the graph showing in compressive strength of different concrete mixtures at 14,28,60 and 90 days.

Table-4 Effect of silica fume on compressive strength of concrete

Mix designation	Proportions of binding materials	Compressive strength N\mm^2			
		14d	28d	60d	90d
A1	100% cement	21.66	27.4	37.88	40.30
A2	95% cement+5 % silica fume	21.70	33.2	38.48	39.81

A3	92.5% cement+7.5% silica fume	26.31	33.42	39.40	42.33
A4	90% cement+10% silica fume	28.94	36.90	41.22	44.8

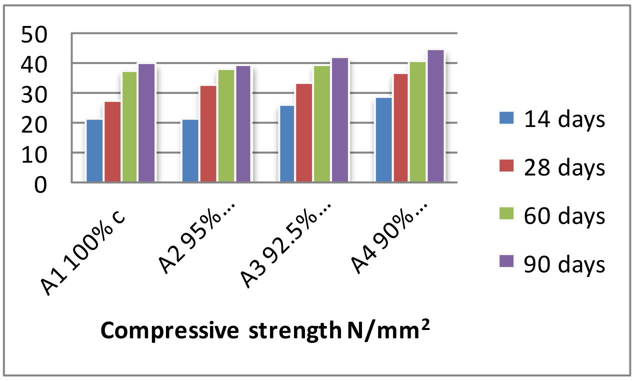
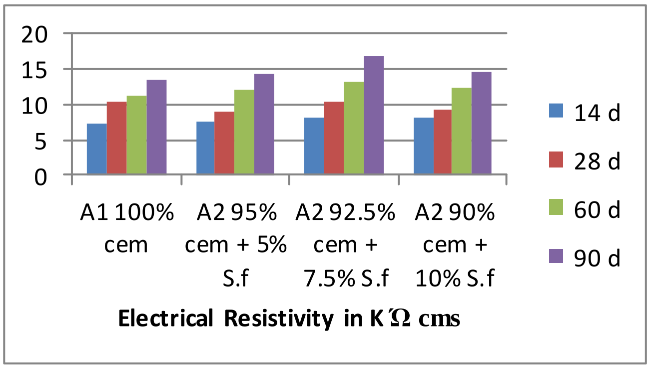


Table 5 : Electrical resistivity of concrete at different ages

Mix Designation	Binding Proportion	Electrical resistivity in k Ω Cms			
		14d	28d	60d	90d
A1	100% cement	7.23	10.35	11.30	13.59
A2	95%cement +5% SF	7.68	8.91	12.02	14.22
A3	92.5 cement + 7.5 SF	8.24	10.40	13.32	16.83
A4	90% cement +10% SF	8.01	9.34	12.36	14.52



It is observed from Table 4 and 5 that the concrete resistivity increases with time. It is also observed that concrete electrical resistivity increases with increase in compressive strength. The electrical resistivity of concrete claimed to be one of the main parameters characterizes the possibility of displacement of charged particles under the influence of an external electrical field. Concrete electrical resistivity increases with time as a result of cement hydration (6).

In electrical resistivity method i.e., in the four probe wenner method the current passed and the voltage difference that is potential difference between the middle probes is measured. The electrical resistivity gives some information about the inter connected pore network in the concrete and by extension about its resistance to the penetration of chloride.

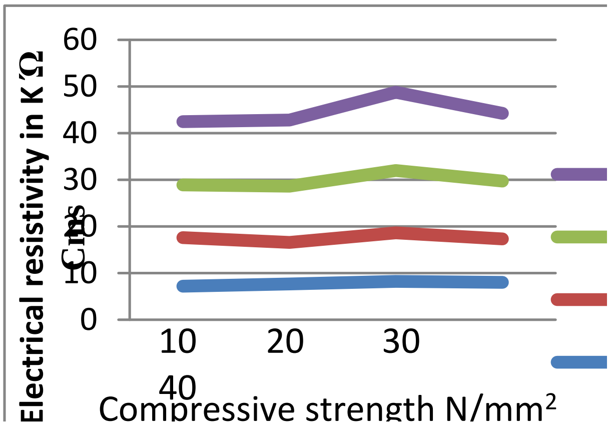


Fig 6 Electrical resistivity of concrete V_s Compressive strength of concrete .

Effect of silica fume on RCPT Concrete:

The RCPT of M_{30} grade concrete mixes replacing OPC by silica fume from 5% to 10% is investigated. The results of RCPT of A1, A2, A3&A4 concrete mixtures tested at all curing days are represented in table-6. A graphical representation of age versus RCPT as shown in fig.

Mix designation	Proportion of Binding Materials	Total charge passed in coulombs		
		28 days	60 days	90 days
A1	100%	2849	1854	1644
A2	95%cement+5% silica fume	2447	1519	1438
A3	92.5%cement+ 7.5% silica fume	2044	1359	1207
A4	90%cement + 10% silica fume	2336	1458	1303

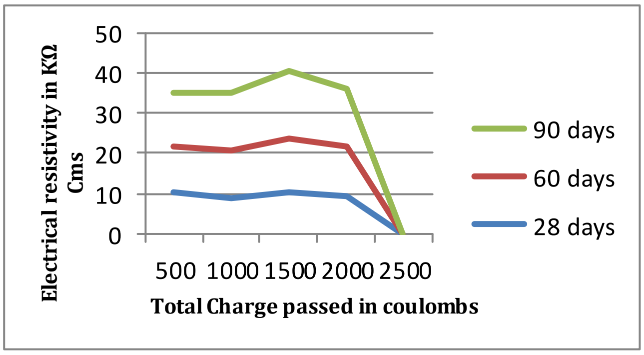


Fig 6 Relationship between electrical resistivity & RCPT

Water permeability Test:

Effect of silica fume on water permeability test of concrete:

The Water penetration test M_{30} grade concrete mixes replacing OPC by Silica fume at 5% to10% were investigated. The results of water penetration of A1, A2, A3 & A4 concrete mixtures tested at 28, 60 days are shown in table 7.

Mix Notation	Proportion of binding materials	Coefficient of permeability of water M/sec.	
		28 days	60 days
A1	100%	0.59×10^{-11}	0.32×10^{-11}
A2	95%cement+5% silica fume	0.75×10^{-11}	0.14×10^{-11}
A3	92.5%cement+ 7.5% silica fume	0.21×10^{-11}	0.054×10^{-11}
A4	90%cement + 10% silica fume	0.34×10^{-11}	0.12×10^{-11}

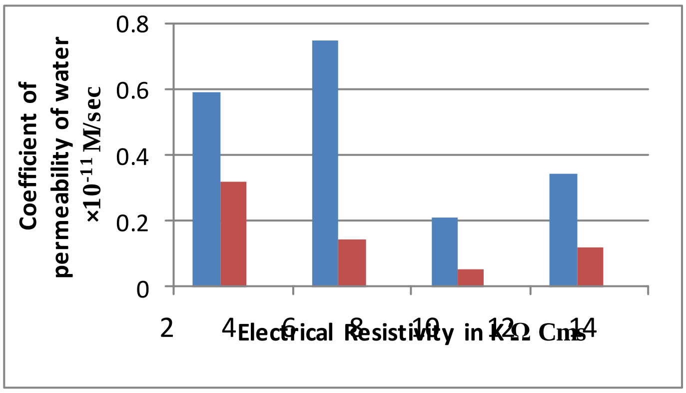


Fig 7 : Relationship between electrical resistivity & water permeability

It is observed from the table that the concrete with silica fume has lower water permeability than conventional concrete. Silica fume concrete with 7.5% of OPC replaced by silica fume gives lowest water permeability. The electrical resistivity is also high for silica fume concrete having higher compressive strength.

6. CONCLUSION

1. The results of the present investigation show that there is no definite relation between the compressive strength and the electrical resistivity of M_{30} concrete with different admixtures.
2. The electrical resistivity increases with increase in compressive strength.
3. The electrical resistivity is very high in concrete with silica fume when compared to the conventional concrete.
4. The chloride permeability of silica fume concrete is very less compared to conventional concrete.
5. Electrical resistivity of concrete increases with decrease in the charge passed through or chloride permeability of concrete.
6. Water permeability decreases in concrete with silica fume when compared to conventional concrete.
7. The increase in concrete electrical resistivity with decrease in permeability is high in silica fume concrete compared to conventional concrete.

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