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Comparative study on strength and permeability of cement mortar using micro and nano particles

[R.Nirmala, R.Singaravadivelan]

Abstract— Recently, Nano particles have been gaining increasing attention in many fields to fabricate new materials with novel functions due to their unique physical and chemical properties. It has been found that physical properties of mortar, particularly strength and permeability significantly depend on its pore structure. Ultra-fine particles of Nano composites provide more homogenous distribution of hydrated products of concrete. This effect of micro and Nano particles enhances the durability of cement composites as well as the strength. In the present investigation, micro level materials such as Rice husk Ash (RHA) and Marble powder as a replacement of cement and Manufactured sand (M-Sand) quarry dust as a replacement of fine aggregate have been studied. In addition, influence of Nano particles on different properties of cement mortar was investigated with Rice husk ash as a well-known active pozzolano. Nano particles such as Al_2O_3, Fe_2O_3 of different percentage (0.5%, 1%, 1.5%, 2%) by weight of cement was replaced and their influence on Mechanical properties, chloride permeability, porosity, and corrosion resistant properties of the specimens were determined. Further, the grain structures were examined through Scanning Electron Microscopy. From the results it was found that the addition of Nano and Micro particles improved the split and compressive strength, reduced the porosity and permeability leads to homogenous and compact microstructure and hence enhanced the durability.

***Keywords*—OrdinaryPortlandCement,Rice Husk Ash, Marble Powder, Nano Materials**

Introduction

Permeability is the one of the major problem in concrete. Permeability refers to the amount of water migration through concrete, when the water is under pressure, and also to the ability of concrete to resist penetration. Permeability will make the concrete vulnerable to external media attack. These media include water,chemicals,sulphates and etc., The external media once capable of penetrating into concrete it will deteriorate the life span of the particular concrete structure. Therefore, permeability is a very important characteristic of that need to be achieved in my application.

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Objectives of the Research

The main objectives of the research are:

- To make the M-Sand as a value added material in construction field.
- To understand the behaviour of cement paste, when the portion of the cement is replaced with risk husk ash, marble powder, nano-Al_2o_3 and nano-Fe_20_3 powder.
- To investigate the effect micro and nano materials and to find out the optimum percentage of replacement.
- To study the durability properties such as rapid chloride ion penetration test, impressed voltage test, water absorption and sorptivity with and without nano particles.
- To find out the corrosion resistance properties by conducting electrochemical tests such as impedance and tefel measurements.

I. Literature Review

Ali Nazari,

The nano- Fe_2O_3 particles blended concrete had significantly higher compressive strength compare to that of the concrete without nano- Fe_2O_3 particles. It is found that the cement could be advantageously replaced with nano - Fe_2O_3 particles up to maximum limit of 2.0% with average particle sizes of 15nm.the optimal level of nano- Fe_2O_3 particles content was achieved with 1.0% replacement. Partial replacement of cement by nano- Fe_2O_3 particles decreased workability of fresh concrete; therefore use of super plasticizer is substantial.

Li Beixing,et al

MS contain significant quantities of particles smaller than 75µ called rock microfines. This paper present results from a laboratory study on the influence of the MS characteristics, such as rock microfines content, surface roughness, crushing value and rock types of MS particles, on the strength and abrasion resistance of pavement cement concrete (PCC). Resulted show that the increment of limestone microfines amount in MS from 4.3% to 20% by mass increases the compressive and flexural strengths and improves the abrasion resistance of the MS-PCC. The MS-PCC has higher compressive and flexural strengths when the surface roughness of the sand particles is larger and the crushing value is lower. The abrasion resistance of MS-PCC is improved with the increment of surface roughness and deceases of crushing value and Los Angeles abrasion value of sand particles, while has not evident relation with the silicon content of sand.

D.D. Cortes et al

Conventional assessment methods for fine aggregate used in Portland cement concrete are mostly based on round natural sand performance in spite of the increasing use of angular manufactured sands. Two natural and two manufactured sands were selected and tested at different water cement ratios and fine aggregate to cement ratios for the same standard gradation to identify shape-related differences on the mechanical performance of mortars. Three tests were used in this study flowability, stiffness and strength. Results showed that adequate flow and compressive strength were attained when the volume of paste exceeded the volume of voids in the loosely packed aggregate, i.e., just above the maximum void ratio emax of the fine aggregate.

Li Beixing et al

The incorporation of up to 15% limestone fines as a partial replacement for fine aggregate in low-strength MS concrete or 10% limestone fines for in high-strength MS concrete improved compressive strength. For low-strength MS concretes, the resistance to chlorine ion permeability increased and the freeze–thaw resistance decreased linearly with increasing percentage of limestone fines replacement. For high-strength MS concrete, however, limestone fines has little influence on the chlorine ion permeation and freeze–thaw resistance. The abrasion resistance of MS concretes showed an improvement at 7% and 10% limestone fines, and more than 10% of limestone fines considerably increased the abrasion loss.

Ali Ergun et al

The Waste marble powder (WMP) describes the procedures and results of a laboratory investigation of mechanical properties carried out on the concrete specimens containing diatomite and WMP as partial replacement of cement in concrete the raw and waste materials, preparation of concrete specimens with diatomite and WPM in different ratios by weight as replacement for cement.. Test results indicated that the concrete specimens containing 10% diatomite, 5% WPM and 5% WPM +10% diatomite replacement by weight for cement had the best compressive and flexural strength and the replacement of cement with diatomite and WMP separately and together using a super plasticizing admixture could be utilized to improve the mechanical properties of the conventional concrete mixtures.

Valeria Corinaldesi et al

Studies revealed that marble powder showed a very high Blaine fineness value of about 1500 m2/kg, with 90% of particles finer than 50nm and 50% under 7 lm. For rheological studies, several cement pastes were prepared using marble powder, with and without the addition of an acrylic-based super plasticizer. Water to cementations materials ratio was also varied. In order to evaluate the effects of the marble powder on mechanical behavior, many different mortar mixtures were tested, all prepared with sand to cement ratio of 3:1 at about the same workability. Mixtures were evaluated based upon cement or sand substitution by the marble powder. Results obtained show that 10% substitution of sand by the marble powder provided maximum compressive strength at about the same workability.

Huseyin Yılmaz Aruntast et al

He concluded that the waste marble dust added cements (WMDCs) have been obtained by intergrinding WMD with Portland cement clinker at different blend ratios: 2.5%, 5.0%, 7.5% and 10% by weight. 40x 40 x160 mm mortar prisms have been produced with the obtained cements. Strength tests have been carried out on mortar specimen at 7, 28, and 90 days. A 10% WMD can be used as an additive material in production of cement. Use of WMD in production of WMDCs does not affect the setting time. The ratio of WMD in the cements increases the values of specific gravity and specific surface decrease. The compressive strength of WMDC2 is higher than those of PC. The compressive strengths of all WMDCs are higher than those of PCC strengths at all ages. All WMDCs can be used instead of PCC.Cost of cement production can be decreased by use of 10% WMD.

S.N.Raman, et al

This paper presents the findings from experimental work undertaken to evaluate the suitability of quarry dust as a partial substitute for sand in high-strength concrete (HSC) containing rice husk ash (RHA). Two grades of HSC mixes, to achieve 60 MPa and 70 MPa at 28 days, were designed with and without the incorporation of RHA. Quarry dust was then used in the mixes containing RHA as a partial substitute for sand, in quantities ranging from 10% to 40%. The slump of the fresh concrete and the compressive strength development were monitored up to 28 days. Based on the results obtained, the mixes containing 20% quarry dust were chosen as the optimum mix design for both grades of concrete, which would then undergo further evaluation of their strength and mechanical properties up to one year. The results obtained in the next stage suggest that even though the use of quarry dust as a partial substitute for sand results in some minor negative effects in the compressive strength.

II.MATERIALS AND METHODS:

Cement: Ordinary Portland cement of 43 grade as per IS 8112 was used for this investigation.
Nano Al_2o_3 & Nano Fe_2o_3: The average particle size 15nm was used as received.
Marble powder (M.P) & Rice husk ash (RHA): This waste materials is classified as highly pozzolano.because it possesses a very high amount of amorphous Cao and average high amount of amorphous Sio2 .it is used as a partial replacement of cement in this work.

M-Sand: it is a by-product from the granite crushing process in quarrying activities. The specific gravity was 2.83

Super plasticizer: Polycarboxylate was used as high range water reducing admixture.

Rebar: Thermo mechanically treated (TMT) rebar o size 12mm diameter and 50mm length was used.

TABLE - 1 Composition of materials

Properties	OPC	M.P	R.H.A	M-Sand
SiO_2 %	20-21	18.43	89.87	67.62
Al_2O_3 %	5.2-5.6	-	0.14	15.43
Fe_2O_3 %	4.4-4.8	-	0.94	5.58
CaO %	62-63	67.79	0.49	3.25
Bulk Density	0.5-0.7	13.78	50kg/m^3	3.25
Specific Gravity	2.5	2.3	2.03	2.68

Mix design:

In the absence of a well-established comprehensive method for the design of mortar mix, it was arrived based on trial and error which is the practice adopted everywhere to get the desired strength. The casted cubes are test for 7 days compressive & 28 days the better concrete mix is chosen to further research for 28 days strength, for other mechanical &durability test. In this study, Mix ratio of the sample 1:3 and water cement ratio: 0.5 was taken and below give the combination table:

Method of test should be carried out as shown below.

1. Strength studies – Compression, Split tensile test.
2. Durability studies- Water absorption, Sorptivity, Rapid chloride penetration test.
3. Corrosion studies- Impressed voltage, AC-Impedance, tafel & weight loss test.

A. *Strength studies*

Compression test:

The compressive strength of concrete is one of the most important properties of concrete. Mortar specimens are to be taken the size 50 mm x 50 mm x 50 mm were cast with different materials. After 48 hours the specimens were demoulded and subjected to curing for 7, 14 &28 days in water curing. For each system triplicate specimens were cast. The cubes are tested in the compression testing machine capacity 1000 kN.The ultimate load which the cube fails was fails was taken.The test setup result below given to the table-3.

Figure: 1 Compression test

Split tensile strength test:

Split tensile strength test was carried out as per ASTM C496-90.Concrete cylinder of size 60mm diameter and 100mm height were cast. During casting, it was compacted by table vibrated. After 48 hours of setting the specimens were demoulded and cured for 7,14 and 28 days in the three different curing conditions. After the curing period was over the specimens were tested. The measurements were taken and tested as per ASTM C496-90 Universal testing machine of 1000 kN capacity. Triplicate specimens were cast and average compressive measurements were reported below the table-3.

Figure:2 Split tensile test

B. *Durability studies*

Water absorption test:

Permeability can be measured by conducting standard test method. In the present investigation percentage of water absorption, permeable voids and total voids has been determined as per ASTM C642-97.Initially upto 30 min, 1,2,3,4,6,24 and 48 hours to increase in weight was measured after wiping out the initial surface water casing dry cloth .After 48 hours of immersion in water the specimens were heated continuously for the period 5 hours. Then the weight of the specimens were taken after a time gap of 14 hours. The specimens were suspended in water and its submerged weight was determined. This test was done as per procedure given in ASTM C642-97 by oven drying method. For this test 50mm x50mm x 50mm cubes were cast 48hours of demoulding .The specimens were kept air& thermal treatment curing. At the end of the curing periods, the specimens were taken from the room temperature and chamber. Then the specimens were dried in on oven at a temperature of 100+10^{o}c for 48hours, and allowed to cool at room temperature. At the end of 48 hours the weight of the specimens were measured to an accuracy of 1gram using standard weighing balance. Then the specimens were kept immersed in water continuously for 48 hours. To determine the percentage of total voids the apparent specific gravity of the specimen has to determined, from the above data percentage of water absorption, permeable voids and total voids and coefficient of water absorption were determined.

Sorptivity test:

Sorptivity is a measure of the capillary forces exerted by the pore structure causing fluids to be drawn into the body of the material (Hall-1989). Cube specimens 50mm x50mm x 50mm were cast with rice husk ash and fly ash mixes for water sorptivity test. The initial mass of the sample was taken and at time 0, the specimen was kept partially immersed to a depth of 5mm in the water. After every 5 minutes the specimen was removed from water, the stop watch stopped, excess water blotted off with a damp paper towel and then the specimen was weighted.It was then replaced in the water and stopwatch started again. The gain in mass per unit area over the density of water is plotted versus the square root of the elapsed time as shown graph-3.

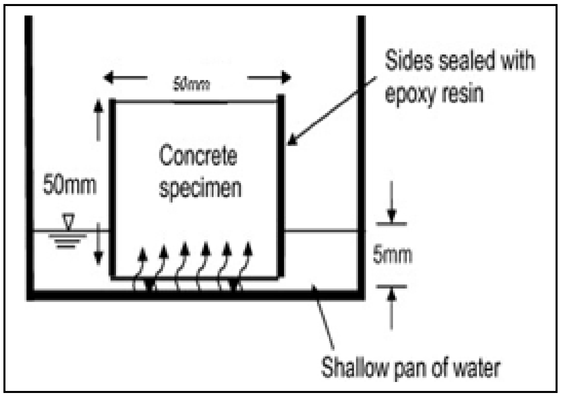

Figure:3 Co-efficient of sorptivity test

Rapid chloride ion penetration test (RCPT):

This test was conducted as per ASTM C1202-09 concrete disc of size 90mm diameter and 50mm thickness were cast and allowed to cure for 28 days. After curing the concrete specimens were subjected to RCPT test by impressing a voltage of 60V.Two halves of the specimens are sealed with PVC container of diameter 90mm.

Figure:4 Rapid chloride ion penetration test

Chloride diffusion coefficient:

The amount of chloride ion migrating through the concrete specimens after 28 days of curing was monitored by periodically by removing small aquilots and determining the chloride concentration of the sample until steady state was reached 120h.chloride diffusion coefficients were calculated using Nernst-Einstein equation.

$$D = \frac{JRTL}{ZFC_0 0E}$$

Where, D = is the chloride diffusion coefficient (cm2/s)
J = is the flux of chloride ions (mol/cm^2s)
R = is the gas constant (8.314 J/k mol)
T = is the absolute temperature (300k)
L = is the thickness of the specimen (cm)
Z = is the valiancy of chloride ion (z = 1)
F = is the faraday constant (9.648 x 104 J/V mol)
C0 = is the initial chloride ion concentration (mol/l)
E = is the potential applied (60V)

C. Corrosion studies

Impressed voltage test:

Cylindrical concrete specimens of the size 50mm diameter and 100mm height were casted,with centrally embedded rebar 12mm diameter and 70mm height. During casting, the moulds were mechanically vibrated.After 48 hours, the cylindrical specimens were demoulded and subjected to water curing for 28 days and then impressed voltage test. In the technique the concrete specimens were immersed in 5% Nacl solution and embedded steel in concrete is made anode with respect to an external stainless steel electrode serving as cathode by applying a constant positive potential of 12V to the system from a DC source.The variation of current is recorded with time.For each specimen, the time taken for initial crack and the corresponding maximum anodic current flow was recored.

Figure:5 Impressed voltage test

AC Impedance measurements:

An electrochemical impedance measurement is an appropriate method for corrosion studies particularly for corrosion rate determination mechanistic studies,passivation and passivity process and for investigation in inhibited systems.R_t represent solution resistance.Rct or Rt give charge transfer resistance and cdl represent the double layer capacitance.using stern- geary equation Icorr is obtained from Rt since,

$$I\ corr = \frac{ba \times bc}{2.303\,(ba+bc)} \times \frac{1}{Rt}$$

Thus, the cell impedance "z" consist of real (z) and (-z) parts.A plot of z vs –z various frequencies is a semicircle. At high frequency ,z corresponds to R and low frequency z corresponds to (Rs+Rc) and the difference between the two values gives Rt. The double layer capacitance (Cdl) can be calculated from the frequency (w) at the top of the semicircle (-z max).

$$F\,(-z\max) = \frac{1}{2\,\pi\,\times cdl \times Rt}$$

This is the only AC method used the present investigation.
Gravimetric weight loss method:
At the end of the exposure period the concrete cubes were split open and the rebar samples embedded below the notch were carefully taken out and visually examined for any corrosion products and percentage of area rusted. Then all the rebar were picked in inhibited hydrochloric acid as per method to remove the rust. Final weight of the rebar were measured. From the initial and final weight loss in weight due to corrosion was determine by the following equation

$$corrosion\ rate\ = \frac{87.6W}{DAT}$$

Where, w = is the weight loss (mg)
D = is the density of the material (gcm^{-3})
T = time duration (h)
A = area of the steel (cm^{-2})

III.Conclusions

- As the nano particles content is increased upto 1% weight of the cement, the compressive and split tensile strength of mortar specimens is increased. This is due to the enhanced formation of hydrated products in the presence of Nano alumina & Nano iron oxide and mineral admixtures.
- As the nano particles content is increased upto 1% weight of the cement, the permeability of motar specimens is decreased. This is due to addition of ultrafine particles of nano materials fill the voids of microstructure in the concrete.
- The corrosion resistance of mortar specimens is increased and rate of corrosion was reduced, when the nanoparticles content is added.

From the above studies it is concluded that concrete containing both micro and nano particles was found to better then all other systems.

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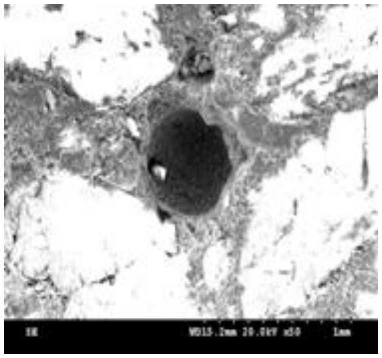
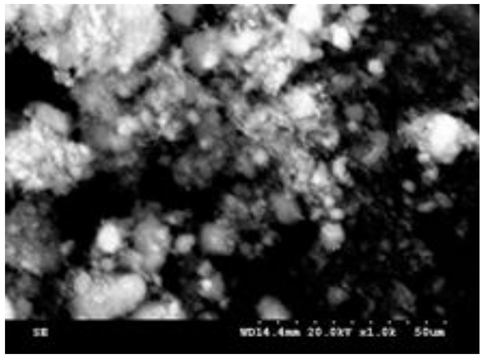
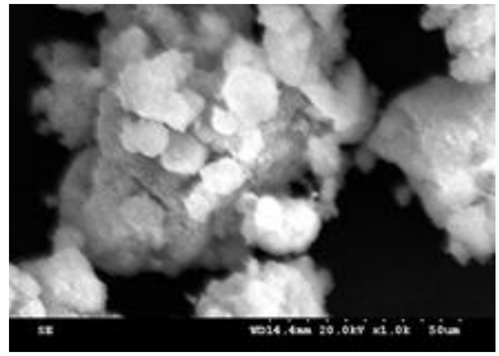


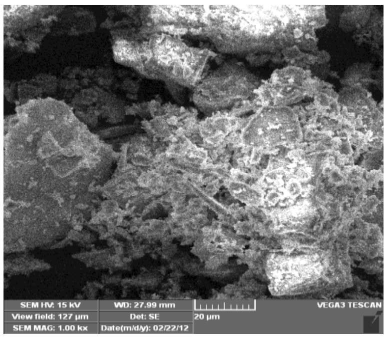
OPC



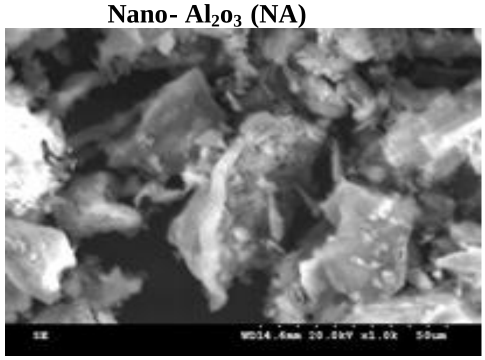
Nano- Al_2o_3 (NA)



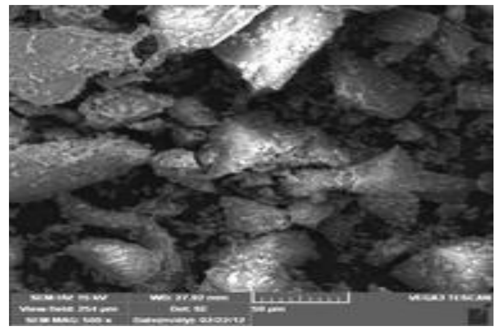
Nano- Fe_2o_3 (NF)



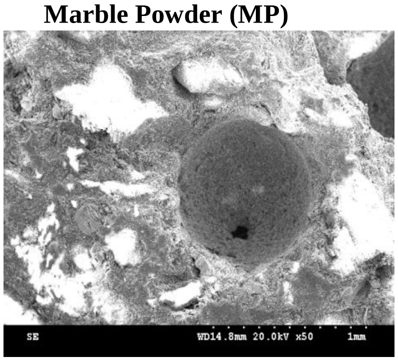
Marble Powder (MP)



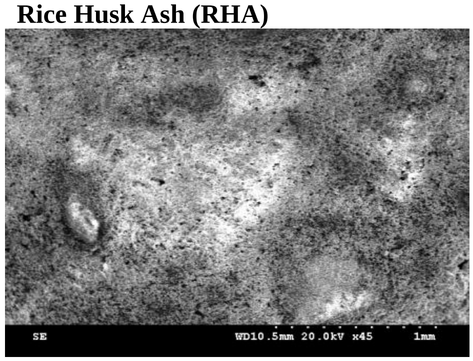
Rice Husk Ash (RHA)



Manufacture Sand (M-Sand)

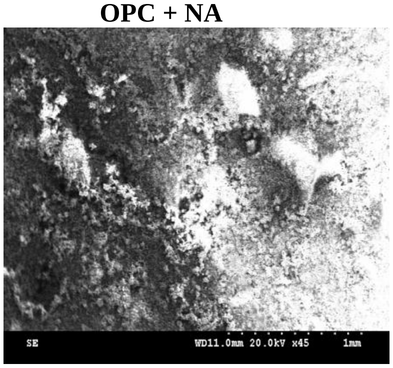


OPC + NA



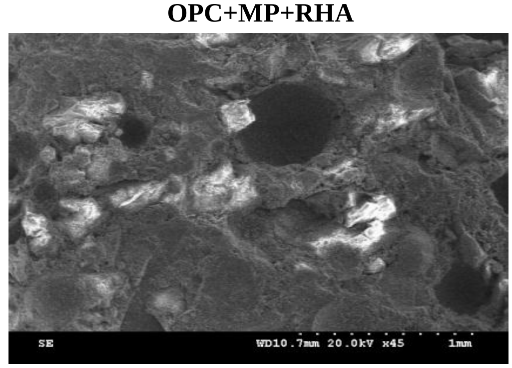
OPC+RHA+NA

OPC+MP+RHA



OPC + MP+RHA+NA

OPC+MP+RHA+NF



OPC+NF

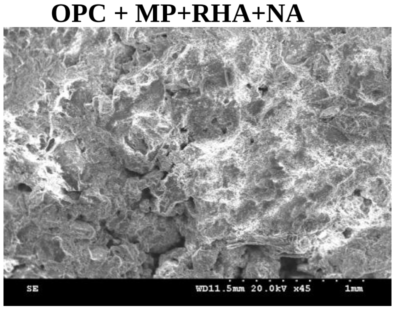
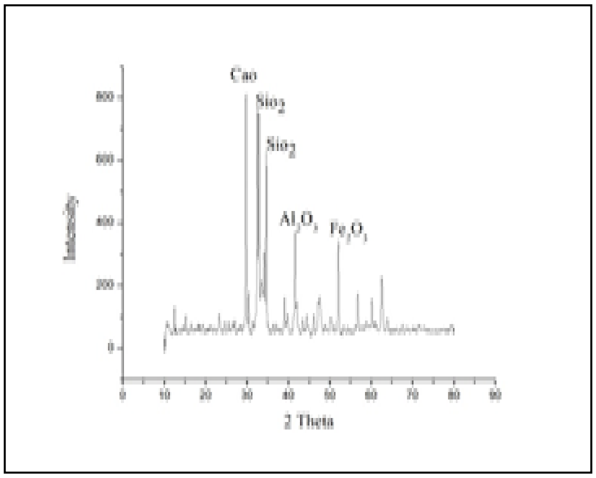
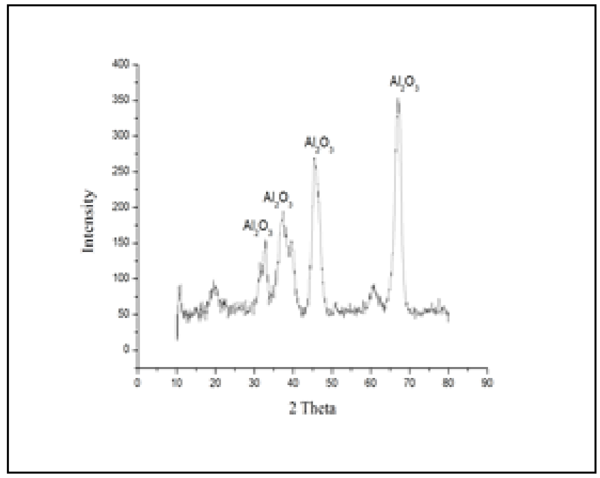


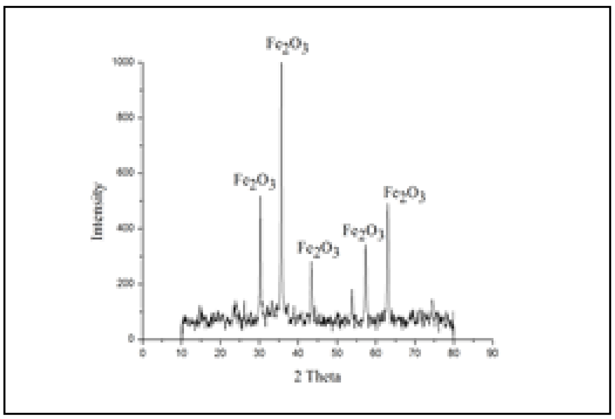
Figure: 6 Characterization studies on Scanning Electron Microscopic test on different system.



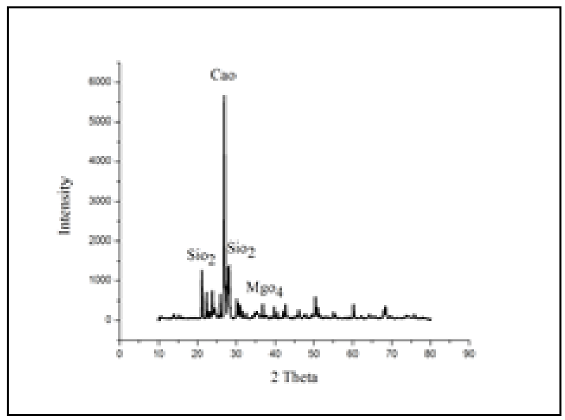
OPC



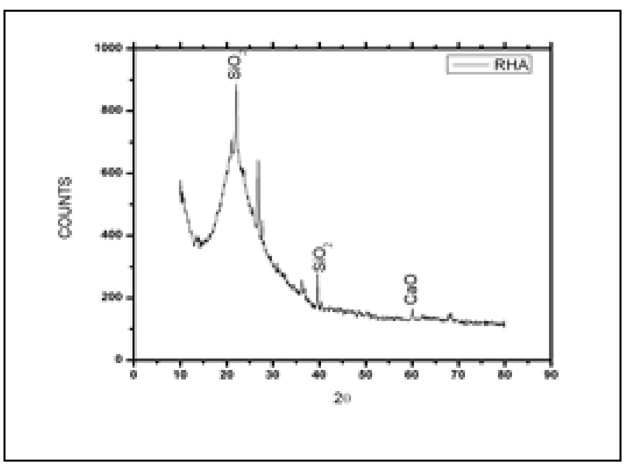
Nano – Al_2o_3



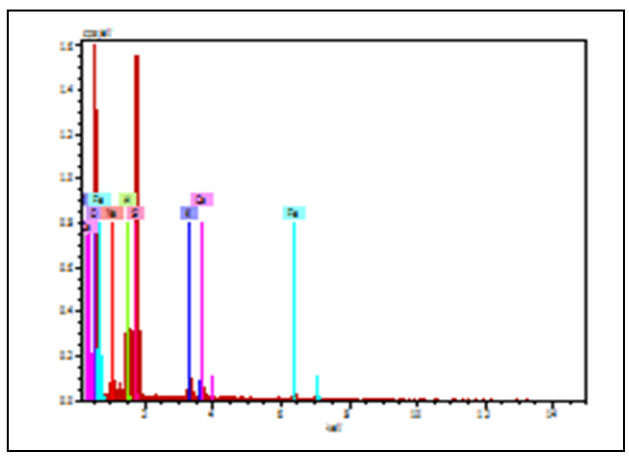
Nano – Fe_2o_3



MP



RHA



M - SAN

Graph: 1 shows on X-ray diffraction (XRD) test for different material

System	OPC	F.A	M.S	M.P	R.H.A	N.A	N.F	W/C	S.P	Remarks
CM	80	240	-	-	-	-	-			OPC
S-1	64			16						OPC+M.P
S-2	74				8					OPC+R.H.A
S-3	79.2					0.8				OPC+N.A
S-4	63.2			8		0.8				OPC+M.P+N.A
S-5	73.2	60	180			0.8		0.5	1.6	OPC+R.H.A+N.A
S-6	79.2						0.8			OPC+N.F
S-7	63.2						0.8			OPC+M.P+N.F
S-8	73.2						0.8			OPC+R.H.A+N.F
S-9	56			16	8					OPC+M.P+R.H.A
S-10	56			16	8	0.8				OPC+M.P+R.H.A+N.A
S-11	56			16	8		0.8			OPC+M.P+R.H.A+N.F

Table: 2 Mix combination in grams

S.NO	Sample	Compressive strength			Split tensile strength		
		7 Days	14 Days	28 Days	7 Days	14 Days	28 Days
1	OPC	12	20.12	43.19	7.71	8.77	9.322
2	OPC +M.P	13.8	21.19	43.26	7.958	9.054	10.298
3	OPC+RHA	14.48	21.3	44.34	8.028	9.519	10.61
4	OPC+Al_2o_3	23	29.64	49.99	9.054	10.575	11.14
5	OPC+M.P+Al_2o_3	27.16	29.16	54.96	11.24	11.565	12.904
6	OPC+RHA+Al_2o_3	27.22	30.52	55.84	11.14	11.968	13.22
7	OPC+Fe_2o_3	23.24	32.4	52.8	10.26	10.616	12.13
8	OPC+M.P+Fe_2o_3	22.72	32.32	56	9.83	10.753	13.36
9	OPC+RHA+Fe_2o_3	24.76	34	59.944	11.98	12.6	14.2
10	OPC+M.P+RHA	15.08	21.93	44.55	8.035	9.64	10.82
11	OPC+M.P+RHA+Al_2o_3	28.16	31.16	59	9.516	10.7	11.88
12	OPC+M.P+RHA+Fe_2o_3	28.25	31.9	60	11.55	13.9	14.5

Table: 3 shows on Test result on compressive and split tensile 7, 14 &28 days

Mix type	Charge passed/Coulombs
OPC	2577
OPC+M.P	2492
OPC+RHA	2134
OPC+Al_2O_3	450.9
OPC+M.P+ Al_2O_3	312.9
OPC+RHA+ Al_2O_3	302.4
OPC+Fe_2O_3	333
OPC+M.P+ Fe_2O_3	312.3
OPC+RHA+ Fe_2O_3	306
OPC+M.P+RHA	263.7
OPC+M.P+RHA+ Al_2O_3	246.6
OPC+M.P+RHA+ Fe_2O_3	182.7

S.No	Free chloride (ppm)	Flux of chloride ions J=ppm/35.45x1000xAxT	Steady state diffusion coefficient D=JRTL/ZFC$_o$E (m^3/sec)
OPC	1276	8.47 x10^{-5}	3.55x10^{-5}
OPC+M.P	1311	8.71x10^{-5}	5.80x10^{-5}
OPC+RHA	886	5.88x10^{-5}	1.48x10^{-5}
OPC+Al_2O_3	166	1.10x10^{-4}	4.64x10^{-7}
OPC+M.P+ Al_2O_3	138	9.16x10^{-5}	3.84x10^{-7}
OPC+RHA+ Al_2O_3	1276	8.47x10^{-5}	3.53x10^{-7}
OPC+Fe_2O_3	319	6.65x10^{-5}	2.79x10^{-7}
OPC+M.P+ Fe_2O_3	283	1.88x10^{-5}	7.90x10^{-8}
OPC+RHA+ Fe_2O_3	319	2.11x10^{-5}	8.89x10^{-8}
OPC+M.P+RHA	212	1.41x10^{-5}	5.92x10^{-8}
OPC+M.P+RHA+ Al_2O_3	177	1.17x10^{-5}	4.94x10^{-8}
OPC+M.P+RHA+ Fe_2O_3	212	1.41x10^{-5}	5.92x10^{-8}

Table: 5 shows on Chloride diffusion coefficient

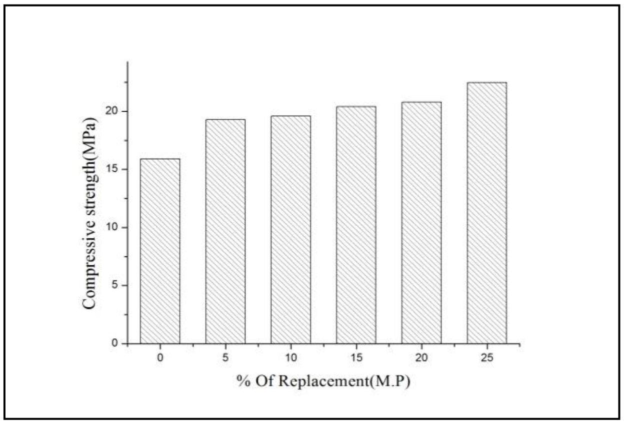
System	Impressed voltage		Durability factor
	Weight loss(g)	Corrosion rate	
OPC	5.142	5.312x10^{-3}	---
OPC+M.P	4.93	5.103 x10^{-3}	3.0
OPC+RHA	4.4	4.55 x10^{-3}	6.0
OPC+Al_2O_3	3.33	2.502x10^{-3}	5.2
OPC+M.P+ Al_2O_3	2.980	1.898x10^{-3}	6.4
OPC+RHA+ Al_2O_3	2.429	1.429x10^{-3}	7.3
OPC+Fe_2O_3	3.152	2.008x10^{-3}	6.2
OPC+M.P+ Fe_2O_3	2.04	1.299x10^{-3}	7.6
OPC+RHA+ Fe_2O_3	1.082	6.893x10^{-4}	8.7
OPC+M.P+RHA	4.9	4.058x10^{-3}	2.3
OPC+M.P+RHA+ Al_2O_3	0.969	5.350x10^{-4}	8.9

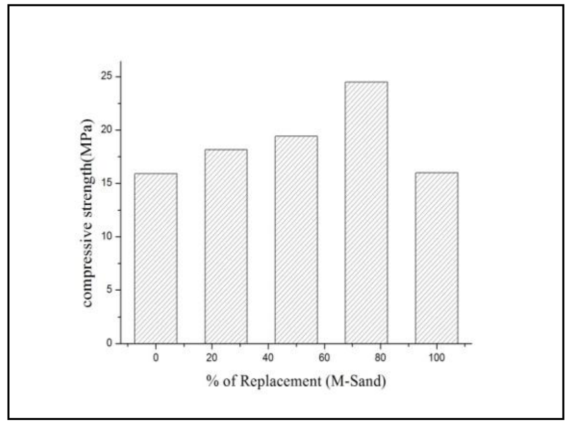
System	I corr	C.R	R_S	R_{ct}	C_{dl}
CM	$4.28X10^{-3}$	$4.96X10^{-2}$	$8.284X10^{3}$	$6.093X10^{3}$	$1.345X10^{-4}$
S-1	$2.646X10^{-3}$	$3.067X10^{-2}$	$9.288X10^{3}$	$9.859X10^{3}$	$6.337X10^{-5}$
S-2	$2.601X10^{-3}$	$3.014X10^{-2}$	$2.491X10^{4}$	$1.003X10^{4}$	$6.635X10^{-5}$
S-3	$1.766X10^{-3}$	$2.047X10^{-2}$	$1.290X10^{4}$	$1.477X10^{4}$	$8.789X10^{-5}$
S-4	$1.766X10^{-3}$	$2.047X10^{-2}$	$1.290X10^{4}$	$1.477X10^{4}$	$8.789X10^{-5}$
S-5	$2.601X10^{-3}$	$3.014X10^{-2}$	$2.491X10^{4}$	$1.003X10^{4}$	$6.635X10^{-5}$
S-6	$4.180X10^{3}$	$4.848X10^{-2}$	$7.392X10^{3}$	$6.24X10^{3}$	$1.78X10^{-4}$
S-7	$2.276X10^{-3}$	$2.636X10^{2}$	$8.488X10^{3}$	$1.147X10^{3}$	$3.52X10^{-5}$
S-8	$9.274X10^{-3}$	$1.075X10^{-2}$	$1.816X10^{4}$	$2.813X10^{4}$	$1.059X10^{-5}$
S-9	$2.631x10^{-3}$	$2.678x10^{-2}$	$2.802x10^{4}$	$1.129x10^{4}$	$1.059x10^{-4}$
S-10	$2.152x10^{-3}$	$2.459x10^{-2}$	$1.792x10^{4}$	$1.212x10^{4}$	$9.742x10^{-5}$
S-11	$4.903x10^{-4}$	$5.682x10^{-3}$	$2.814x10^{4}$	$5.321x10^{4}$	$2.908x10^{-5}$

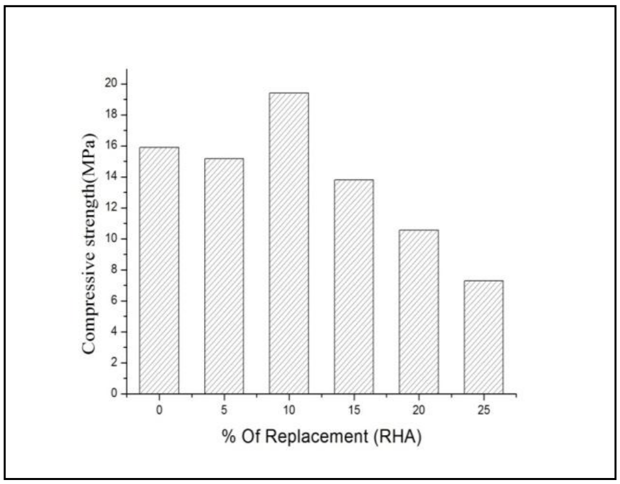
Table:7 Test result on Impedance values

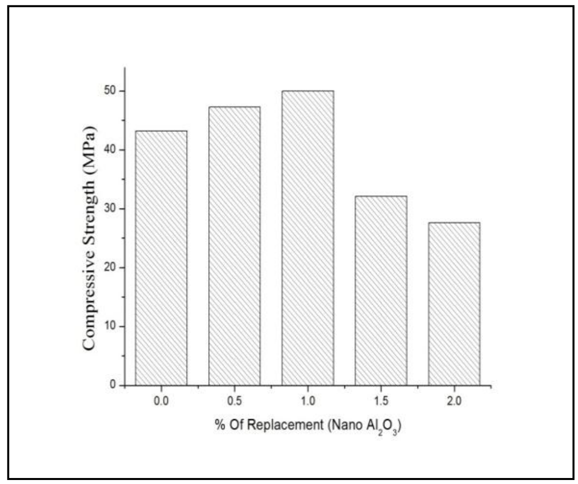
System	I corr	C.R	BC	OCP	C.R
Control	$2.741x10^{-3}$	146	83	210	$3.77X10^{-3}$
System-1	$1.000x10^{-4}$	174	117	159.2	$1.159X10^{-3}$
System-2	$9.79x10^{-5}$	109	66	305	$1.134X10^{-3}$
System-3	$3.216x10^{-4}$	85	73	353	$3.727X10^{-3}$
System-4	$8.641x10^{-5}$	87	53	308	$1.00X10^{-3}$
System-5	$2.242X10^{-5}$	98	67	305	$9.553X10^{-4}$
System-6	$3.132x10^{-4}$	66	54	388	$3.629X10^{-3}$
System-7	$9.01x10^{-5}$	46	37	296	$1.104X10^{-3}$
System-8	$7.635X10^{-5}$	58	49	370	$8.849X10^{-4}$
System-9	$1.199x10^{-4}$	77	67	473	$1.389x10^{-3}$
System-10	$1.115x10^{-4}$	71	54	479	$1.292x10^{-3}$
System-11	$3.83x10^{-5}$	170	91	376	$4.444x10^{-4}$

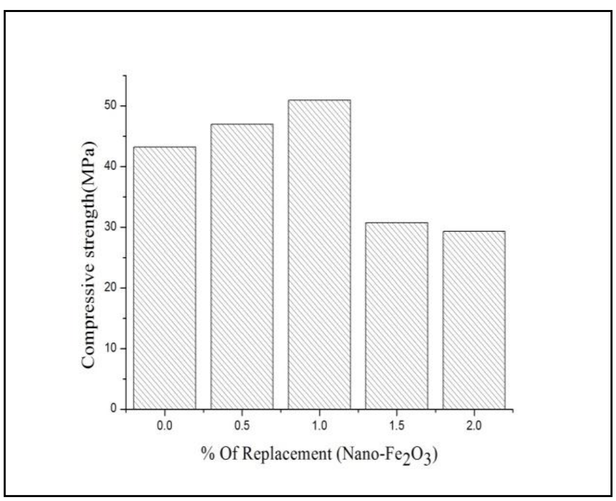
Table: 8 Test result on tafel values



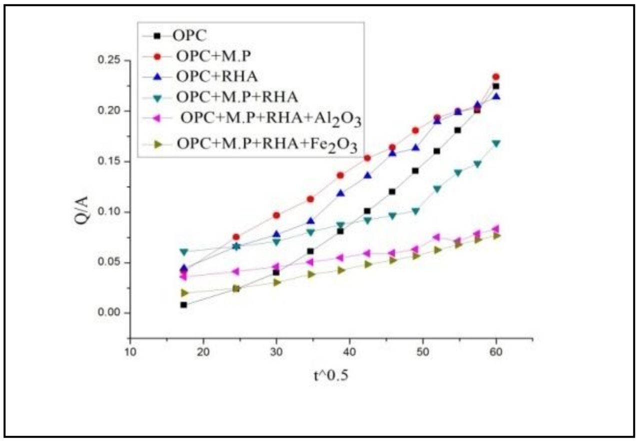




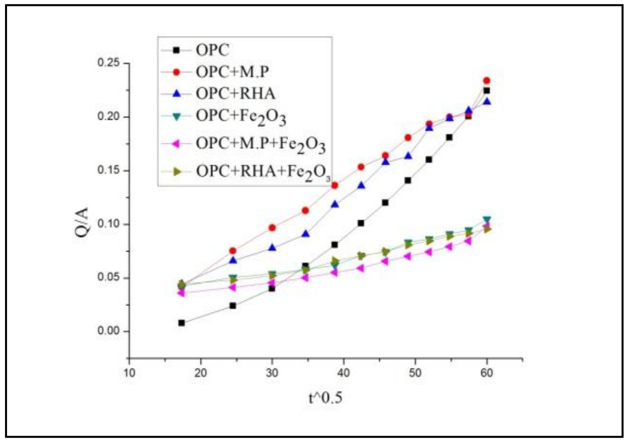




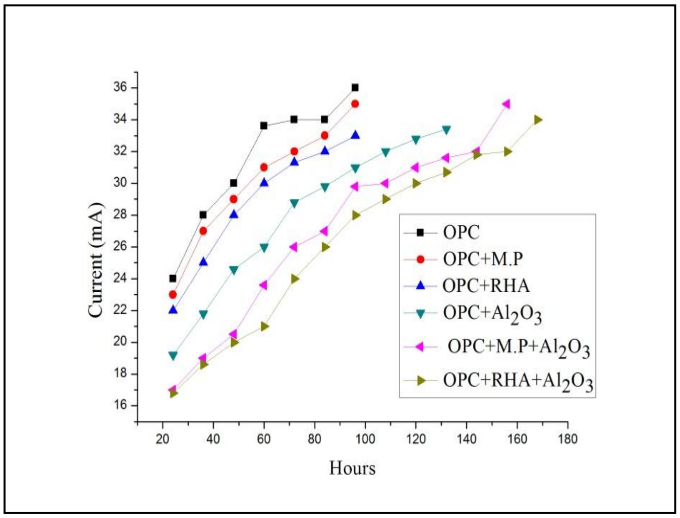
Graph: 2 Optimum replacement of Fine aggregate and Cement on different materials



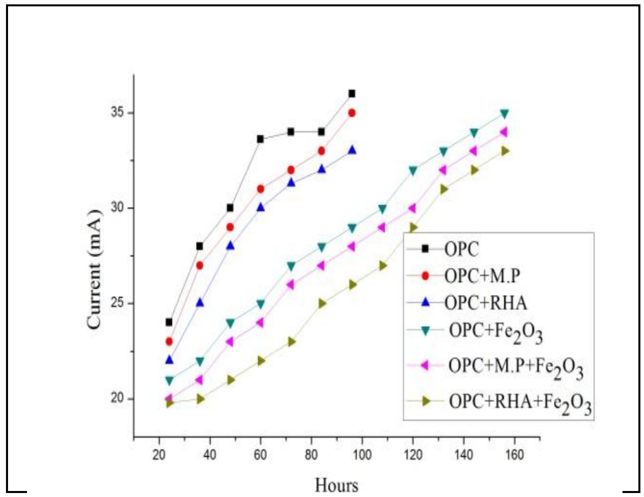
Sorptivity test for single vs combine system



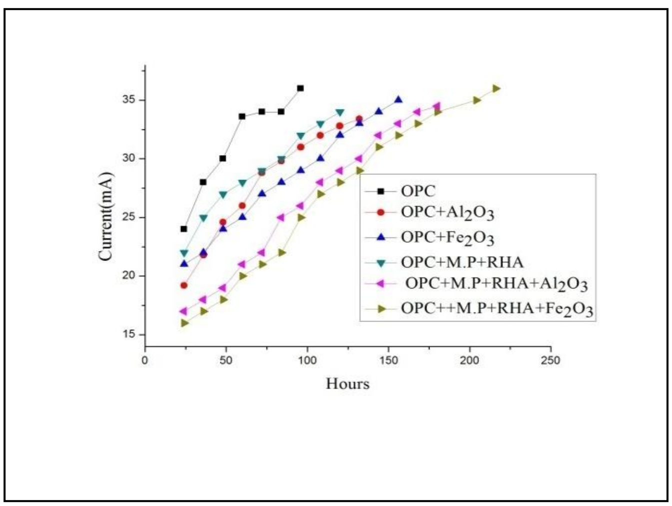
Sorptivity test for control vs Nano Fe_2o_3



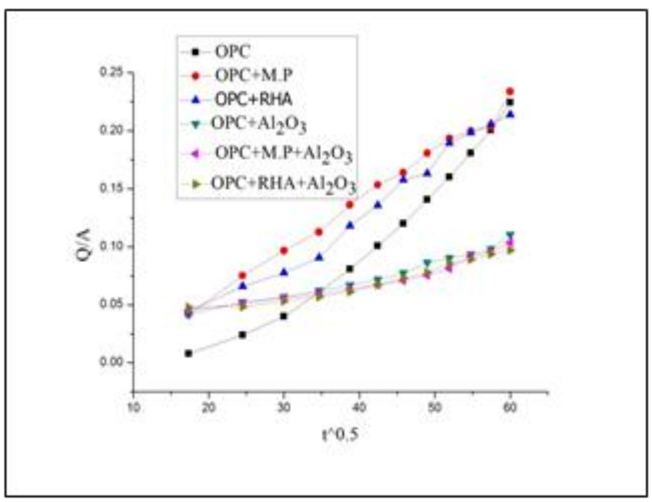
Impressed test –mortar



Impressed test – motar contains micro and nano particles

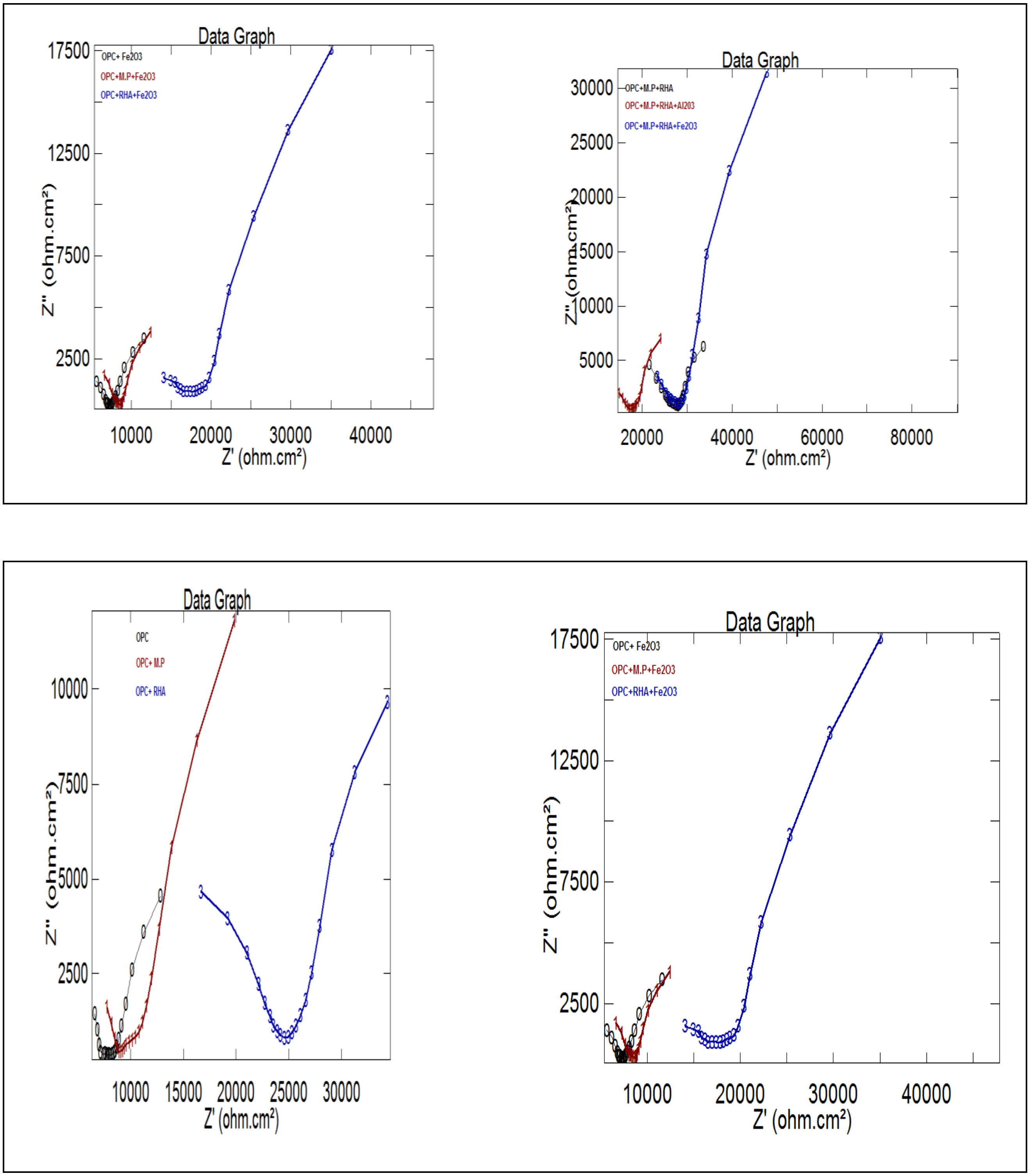


Impressed test – micro particles contains nano iron oxide

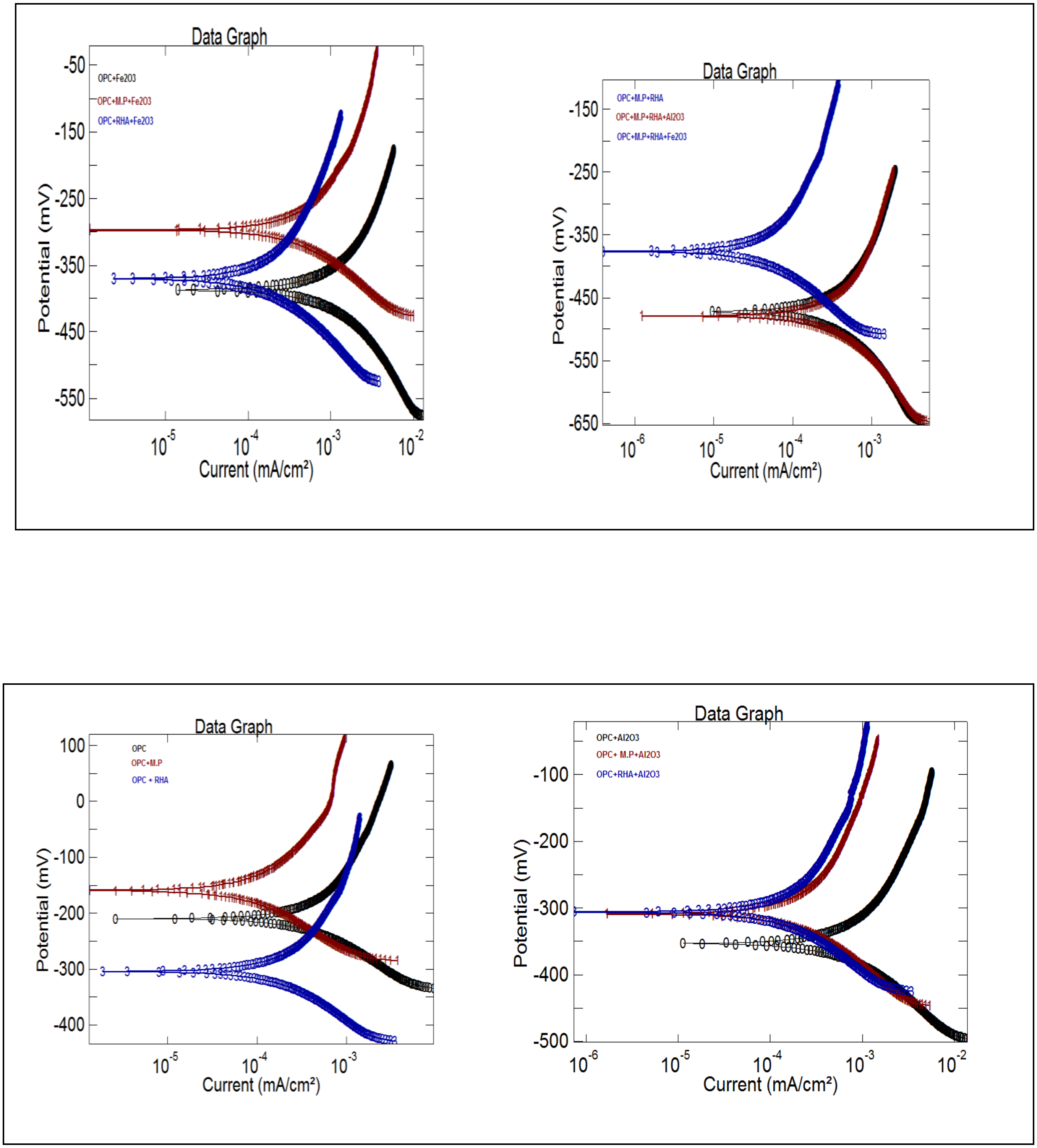


Sorptivity test for control vs Nano alumina system

Graph:3



Graph: 4 Impedance test on Nyquist plot of different system



Graph: 5 Nano behavior of different system on tafel test