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RAPID CHLORIDE PERMEABLITY TEST OF CONCRETE INCORPORATING SUPPLEMENTARY CEMENTITIOUS MATERIALS

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Abstract:

This research explore the rapid chloride permeability test (RCPT) on normal concrete incorporating supplementary cementitious materials (SCM) . Rapid Chloride permeability test (RCPT) are conducted on cylindrical concrete specimens to recognize durability factors.fly ash and GGBS has been used as supplementary cementitious materials (SCM) and cement has been replaced with FA+GGBS. Compression test has been improved with substitution of supplementary cementitious materials and chloride ion permeability has been reduced with substitution supplementary cementitious materials (SCM) increase of water binder ratio also diminish the permeability value however compression value amplified.

Keywords: RCPT , SCM ,Concrete , water binder ratio , chloride penetrations

1 INTRODUCTION

Industrial by-products of fly ash and slag and ground granulated blast furnace slag invariably contain small quantities of toxic metals. The general practice of using these for land filling, dumping into streams and ponds or even stockpiling, presents serious health hazards. However, when these mineral admixtures are utilized in concrete, the toxic metals become immobilized in the form of insoluble products and thus are rendered harmless. Also, these industrial by- products which are generally pozzolanic or cementitious in composition serve as supplementary cementitious materials and enhance durability & other engineering properties of concrete products and leads to development of an economical concrete.

Tatsuhiko Saeki etal (2002) study on chloride ions ingress and carbonation whether take place simultaneously in concrete, chloride ions that have been fixed in cement hydrates will be unfixed and become soluble due to the deterioration of cement hydrates caused by carbonation. It has been observed that chloride ions concentrate in the region where carbonation has not occurred. Therefore, for concrete subjected to both chloride ions ingress and carbonation the corrosion of steel bars in it may take place at an early stage and the rate of corrosion may also increase. Therefore, when chloride ions ingress and carbonation are co- existed the prediction of the distribution of chloride ions in concrete is essential to the evaluation of concrete durability. [1]

Vagelis GPapadakis etal (2000) research on the durability of Portland cement systems incorporating supplementary cementing materials (SCM; silica fume, low- and high-calcium fly ash) is investigated. Experimental tests simulating the main deterioration mechanisms in

reinforced concrete (carbonation and chloride penetration) were carried out. It was found that for all SCM tested, the carbonation depth decreases as aggregate replacement by SCM increases, and increases as cement replacement by SCM increases.. New parameter values were estimated and existing mathematical models were modified to describe the carbonation propagation and the chloride penetration in concrete incorporating SCM.[2]

Mahdi etal (2011) study about the several factors and test methods for evaluating the durability of concrete. In recent years a great deal of attention has been paid to research and development of relationships of these parameters for production of sustainable concretes: water penetration and Rapid Chloride Penetration Test (RCPT) methods Concrete surface resistivity (SR) test is also a suitable indicator for concrete penetration and chloride ion permeability. It is a non-destructive, simple, rapid and economical method that can also be used on site.. Based on the correlation of concrete resistivity with water penetration and Rapid Chloride Penetration Test (RCPT) results, two new models for relating these parameters are presented. [3]

Lydia Homan Ayman Nureddin etal (2016) research on the effect of moisture transport on chloride penetration in partially saturated concrete. This study includes the development of an experimental setup, analysis of experimental data, and formulation of the governing equations to characterize the moisture-chloride interaction in non-saturated concrete. The analysis of the experimental data indicated that the coupling term in the governing equation is concentration dependent which means that the governing equation is nonlinear.[4]

Faiz U.A. Shaikh etal (2014) study on chloride induced corrosion durability of reinforcing steel in geopolymer concretes containing different contents of sodium silicate (Na2SiO3) and molarities of NaOH solutions. Seven series of mixes are considered in this study. The first series is ordinary Portland cement (OPC) concrete and is considered as the control mix. The rest six series are geopolymer concretes containing 14 and 16 molar NaOH and Na2SiO3 to NaOH ratios of 2.5, 3.0 and 3.5. The higher the amount of Na2SiO3 and higher the concentration of NaOH solutions the better the corrosion resistance of geo polymer concrete is. Similar behaviour is also observed in sorptivity and chloride penetration depth measurements. [5]

Carlos Eduardo etal (2020) research on the reinforcement corrosion due to chlorides action is the main cause degradation of reinforced concrete structures in marine environment, concrete electrical resistivity has been used as a non-destructive methodology in order to evaluate the service life of these structures, since it is a simple and fast field methodology results However, observing the literature and standards about this issue it was noted significant differences between the values presented for stablish this correlation [6]

2 EXPERIMENTAL PROGRAMME

The various tests were performed to on the material used for the mix of conventional concrete to determine their basic properties. The materials used are cement, ground granulated blast furnace (GGBS), fine sand (River sand), coarse aggregates (10mm and 20mm), water and super plasticizer.

2.1 Cement

Ordinary Portland Cement (OPC) of Ambuja brand is the cement best suited to general concreting purposes and hence OPC 43 grade confirming to IS: 8112-2007 is used. The cement is kept in an airtight container and stored in the humidity controlled room to prevent cement from being exposed to moisture

Table 2.1: Physical Properties of Cement

S. No	Physical property	Obtained Value	IS: 8112-2007 Specifications
1	Fineness (retained on IS sieve 90 - µm sieve)	8.6	-
2	Normal Consistency (%)	28	-
3	Initial setting time (minutes)	119	≥ 30 min
4	Final setting time (minutes)	285	≤ 600 min
5	Specific gravity	3.15	-

Table 2.2: Compressive Strength of Cement

S No.	days	Compressive strength (N/mm^2)	IS: 8112-2007
1	3rd day	21.5	23
2	7th day	34.53	33
3	28th day	45.60	43

2.2 Ground Granulated Blast Furnace (GGBS)

The Ground-granulated blast-furnace slag (GGBS) used in the research work is manufactured by JSW cement ltd., Maharashtra in India.

Ground-granulated blast-furnace slag (GGBS) is obtained by quenching molten iron slag. Basically it is a by-product of iron and steel-making plant obtained from a blast furnace in water or steam, to produce a glassy, granular product that is then dried and ground into a fine powder. Ground -granulated blast furnace is highly cementitious material and has assists in forming CSH (calcium silicate hydrates) which is a strength increasing compound that also enhances durability and appearance of the concrete. GGBS is used to make durable concrete structures in combination with ordinary Portland cement and other pozzolanic material.

Two major uses of GGBS are in the production of quality-improved slag cement, namely Portland Blast furnace cement (PBFC) and high-slag blast-furnace cement (HSBFC), with GGBS content ranging typically from 30 to 70%; and in the production of ready-mixed or site-batched durable concrete.

Concrete made with GGBS cement sets more slowly than concrete made with ordinary Portland cement, depending on the amount of GGBS in the cementitious material, but also continues to gain strength over a longer period. This results in lower rate of generation of heat of hydration and lower temperature rises, and makes avoiding cold joints easier, but may also affect construction schedules where quick setting is required.

The hydration mechanism of GGBS and Portland cement is slightly more complex than that of ordinary Portland cement. This reaction involves the activation of the GGBS by alkalis and sulphates to form its own hydration products. Some of these combine with the Portland cement products to form further hydrates which have a pore blocking effect. The result is a hardened cement paste with more of the very small gel pores and fewer of the much larger capillary pores for the same total pore volume. Generally, the rate of strength development is slower than for a Portland cement mortar. Although GGBS is a hydraulically latent material, in the presence of lime contributed from cement, a secondary reaction involving glass (Calcium Alumina Silicates) components sets in. As a consequence of this, cementations compounds are formed. They are categorized as secondary C-S-H gel. The interaction of GGBS and Cement in presence of water is described below:

Product of hydration of OPC:

$$\text{OPC } (C_3S/C_2S) + H_2O \longrightarrow \text{C-S-H} + Ca(OH)_2$$

Product of hydration of GGBS:

$$\text{GGBS } (C_2AS/C_2MS) + H_2O \longrightarrow \text{C-S-H} + SiO_2$$

Reaction of Pozzolanic material:

$$SiO_2 + Ca(OH)_2 + H_2O \longrightarrow \text{C-S-H}$$

The generation of secondary gel results in formation of additional C-S-H, a principal binding material. This is the main attribute of GGBS, which contributes to the strength and durability of the structure.

The optimum dosage of mineral admixture used in the study is fixed to maximum 30% by weight of cement and Ground-Granulated Blast-Furnace Slag (GGBS) varying 0%, 5%, 10%, 15%, 20%, 25% and 30% is used with Fly ash as partial replacement of cement in concrete.

Table 2.3: Properties of Ground-Granulated Blast-Furnace Slag (GGBS)

S. No.	PROPERTY	VALUES
1	Colour	Off white
2	Specific Gravity	2.92
3	Bulk Weight (ton per m^3)	1.0-1.3

2.3 Fly Ash

The fly ash used in the present study is of Class F obtained from Suratgarh Super thermal power plant, India complying with Indian standard code IS 3812 (Part 1) 2003.

Table 2.4: Physical Properties of Fly Ash

S. No	Property	Test values
1	Color	Light gray
2	Bulk Density(Kg/m3)	720
3	Fineness, m2 /kg	270
4	Soundness, %	0.03
5	Specific gravity	2.45

Table 2.5: Chemical Properties of Fly Ash

S. No	Chemical Property	Percentage By Weight(%)
1	Silica (SiO_2)	63.42
2	Iron oxide (Fe_2O_3)	8.05
3	Alumina (Al_2O_3)	22.5
4	Calcium oxide(CaO)	3.4
5	Loss on Ignition	2.5
6	Salphur(SO_3)	<0.01
7	Chlorides (Cl)	0.04

2.4 Fine Aggregates

Natural river sand is used in this research for preparation of self-compacting concrete. It is available at Binawas, Jodhpur, Rajasthan. The various test required to be performed on fine aggregate were as per IS 383-1970 code.

Table 2.6: Physical Properties of Fine Aggregates

S. No	Property	Value obtained
1	Specific gravity	2.42
2	Bulk density	1580
3	Fineness modulus	2.50
4	Water absorption	2.1%
5	Gradation	Zone II as per IS 383-1970

Table 2.7: Sieve Analysis of Fine Aggregate

S No	IS Sieve	Cumulative Wt. Retained	Cumulative Wt. Retained (%)	Cumulative Wt. Passing (%)	Zone II (IS 383 - 1970)
1	4.75 mm	0.014	1.4	98.6	90-100
2	2.36 mm	0.036	3.6	96.4	75-100
3	1.18 mm	0.201	20.1	79.9	55-90
4	600 µ	0.447	44.7	55.3	35-59
5	300 µ	0.832	83.2	16.8	8-30
6	150 µ	0.974	97.4	2.6	1-10

Sum of cumulative weight retained (%)	250.4		

2.5 Coarse Aggregates

The coarse aggregate which is available at Kakani in jodhpur is used in this research work and two size of coarse aggregates are used (10mm) and (20mm). The various test required for the characterizing the coarse aggregate was performed as per IS 383-1970 code.

Table 2.8: Physical Properties of Coarse Aggregates

S. No	Property	Value obtainedFor 10 mm size	Value obtainedFor 20 mm size
1	Specific gravity	2.72	2.72
2	Bulk density	1560	1610
3	Fineness modulus	5.94	7.05
4	Water absorption	1.3%	1.5%
5	Gradation	10 mm size	20 mm size

Table 2.9: Sieve Analysis of Coarse Aggregates (10 mm)

S No	IS Sieve	Cumulative wt. retained	Cumulative wt. retained (%)	Cumulative wt. passing (%)	10 mm single size (IS 383 - 1970)
1	12.5 mm	0	0	100	100
2	10 mm	0.519	3.18	96.82	85-100
3	4.75 mm	4.572	91.44	8.56	0-20
4	2.36 mm	5	100	0	0-5
5	1.18 mm	5	100	0	-
6	600 µ	5	100	0	-
7	300 µ	5	100	0	-
8	150 µ	5	100	0	-
Sum of cumulative wt. retained (%)			594.62		

Table 2.10: Sieve Analysis of Coarse Aggregates (20 mm)

S No	IS Sieve	Cumulative wt. retained	Cumulative wt. retained(%)	Cumulative wt. passing (%)	20 mm single size(IS 383 - 1970)
1	40 mm	0	0	100	100
2	20 mm	0.503	10.06	89.94	85-100
3	10 mm	4.759	95.18	4.82	
4	4.75 mm	4.980	99.6	0.4	0-20
5	2.36 mm	5	100	0	0-5
6	1.18 mm	5	100	0	-
7	600 µ	5	100	0	-
8	300 µ	5	100	0	-
9	150 µ	5	100	0	-

Sum of cumulative wt. retained (%)	704.84		

2.6 Water

Normally cement requires about 3/10 of its weight of water for hydration. Water is an important ingredient in concrete as it actively participates in chemical reaction with cement. It also improves the workability. Since it helps to form the strength giving cement gel, the quantity and quality of water required is to be looked into carefully. But addition of water must be kept to the minimum since adding too much water reduces the strength of concrete and also causes segregation and bleeding.

2.7 Super Plasticizer

Master Glenium 27 is a polycarboxylic ether based, high range water reducing new generation super plasticizer chemical admixture. This super plasticizer also Different from traditional super plasticizers (NSF or MSF), keeps concrete consistency without set retarding in low water/cement ratio.

Table 2.11: Property of Super Plasticizer

S No	Property	Values
1	Structure of material	Polycarboxylic ether based
2	Color	Brown
3	Density	1.023-1.063 kg/liter
4	pH	7 □ 1
5	Chlorine content % (EN 480-10)	< 0.1
6	Alkaline Content % (EN 480 - 12)	< 3

2.8 Workability Tests

The slump test or slump cone test and compaction factor methods are the most common test methods used on concrete to determine the workability of freshly mixed concrete which is done in laboratory on various mixes accordingly to IS-1199-1959.

Table 2.12: Workability of Conventional Concrete

Sr No.	MIX	Water-Binder Ratio	Workability of Fresh concrete	
			Slump, mm	C.F.
1	M1	0.42	103	0.93
2	M2	0.44	105	0.95
3	M3	0.43	100	0.89
4	M 4	0.40	106	0.95
5	M 5	0.41	98	0.87
6	M6	0.40	101	0.9
7	M 7	0.39	97	0.84

2.9 Conventional concrete

The concrete mix is designed for M40 grade of concrete with cement, fine aggregates, coarse aggregate of nominal size 20 mm & 10 mm and water by use of code 10262:2009 'The percentages of fly ash varied as 0%, 5%, 10%, 15%, 20%, 25% and 30% while percentage of

GGBS content varied as 30%, 25%, 20%, 15%, 10%, 5% and 0% respectively as partially replacement of cement in concrete.

Table 2.13 : Mix Proportion for Each Batch in Kg

Mix	Cement	GGBS	FA	S	W/B Ratio	CA - 20 mm	CA - 10 mm	Water	Plasticizer
M 1	7.91	3.39	0.00	18.376	0.400	4.755	11.095	4.52	0.080
M2	7.91	2.83	0.57	18.376	0.440	4.755	11.095	4.98	0.076
M 3	7.91	2.26	1.13	18.376	0.420	4.755	11.095	4.75	0.079
M4	7.91	1.70	1.70	18.376	0.410	4.755	11.095	4.64	0.079
M 5	7.91	1.13	2.26	18.376	0.390	4.755	11.095	4.41	0.074
M6	7.91	0.57	2.83	18.376	0.380	4.755	11.095	4.30	0.076
M7	7.91	0.00	3.39	18.376	0.380	4.755	11.095	4.29	0.082

2.10 Compressive strength test

The cube size 150X150X150 mm was tested after 7 days, 14 days and 28 days curing period as per IS 516: 1959. The cube compressive strength was calculated by following formula.

$f_c = P_c / A$

f_c = Cube compressive strength (N/mm^2)

P_c = Maximum load on cube at failure (N)

A = Loaded Cross Section area of the cube (mm^2)

Table 2.14 : Compressive Strength (in MPa) Cube Specimen at 3rd Day

S No	Mix	Specimen 1	Specimen 2	Specimen 3	Mean value	SD
1	M 1	22.87	23.19	24.26	23.44	0.73
2	M2	20.67	21.28	21.87	21.27	0.6
3	M3	22.42	22.94	21.88	22.41	0.53
4	M4	20.55	20.88	19.38	20.27	0.79
5	M 5	23.73	22.81	24.14	23.56	0.68
6	M 6	22.39	22.63	21.41	22.14	0.65
7	M 7	19.74	20.17	20.55	20.15	0.41

Table 2.15 : Compressive Strength (in MPa) Cube Specimen at 14th Day

S No	Mix	Specimen 1	Specimen 2	Specimen 3	Mean value	SD
1	M1	39.11	38.78	38.46	38.784	0.33
2	M 2	35.58	35.47	34.91	35.320	0.36

3	M 3	34.67	35.16	33.31	34.380	0.96

Table 2.16 : Compressive Strength (in MPa) Cube Specimen at 28th Day

S. No	Mix	Specimen 1	Specimen 2	Specimen 3	Mean value	SD
1	M1	49.37	49.82	48.56	49.250	0.64
2	M 2	47.45	46.89	48.01	47.450	0.56
3	M3	49.07	48.48	47.43	48.325	0.83
4	M4	46.34	46.77	45.64	46.251	0.57
5	M 5	45.51	45.14	45.09	45.247	0.23
6	M 6	46.37	45.27	44.11	45.250	1.13
7	M 7	44.78	44.1	44.65	44.510	0.36

Figure 1: Compression Strength at 3rd ,7th and 28day (N/mm2)

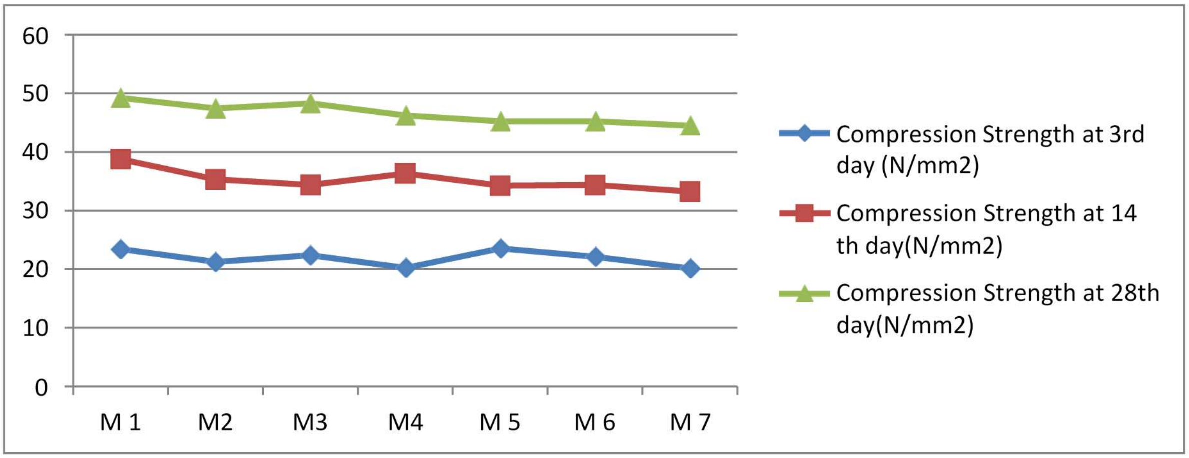
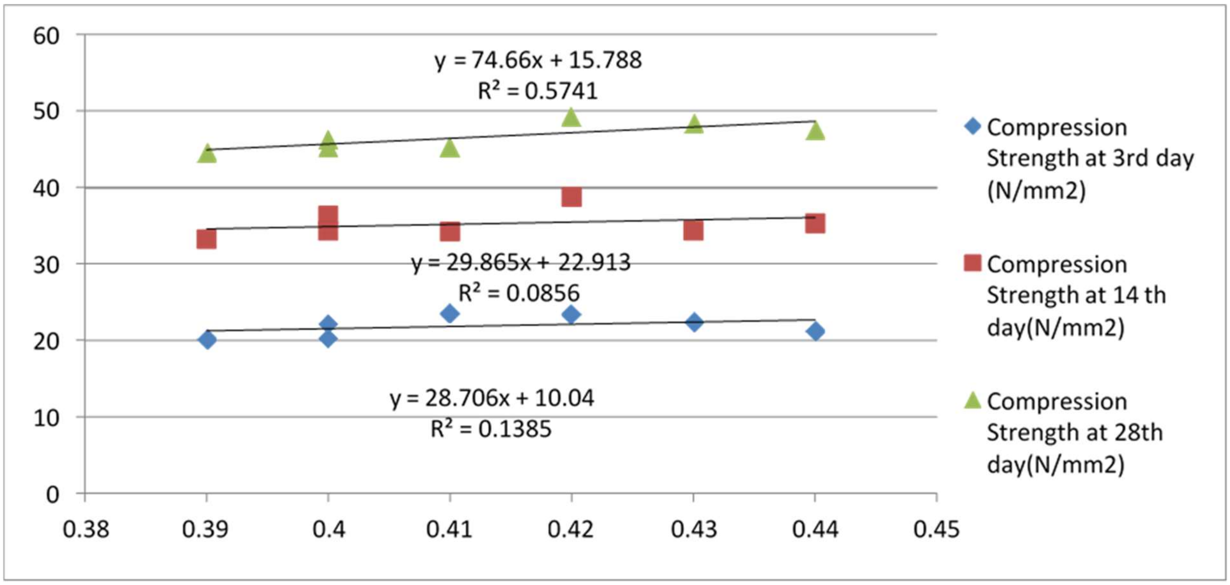


Figure 2: Correlations of Compression Strength with water binder ratio



2.11 Rapid Chloride permeability test

In this test method a charge is passed through concrete specimen using Rapid Chloride permeability test apparatus according to AASHTO T 277 or ASTM C 1202. ASTM C 1202 is a standard test method for electrical indication of concrete ability to resist chloride ion penetration. The instrument is supplied complete with 4 sets of cells, connecting cables, temperature sensors, desiccator, vacuum pump and software. In this RCPT apparatus, 4 concrete samples are test at a time by applying electrical potential across the specimens. When we are start RCPT test, the 60-volt DC is automatically selected by the instrument. If the concrete is more permeable, the result of this test is higher in value of coulombs.

Table 2.17 : RCPT Test Results

S. No	Mix	RCPT Value (Coulombs)	Chloride Ion Penetrability Remarks
1	M-1	1026	Low
2	M-2	1009	Low
3	M-3	993	Very Low
4	M-4	1002	Low
5	M-5	985	Very Low
6	M-6	976	Very Low
7	M-7	961	Very Low

Figure 3: RCPT (Coulombs) Test Results

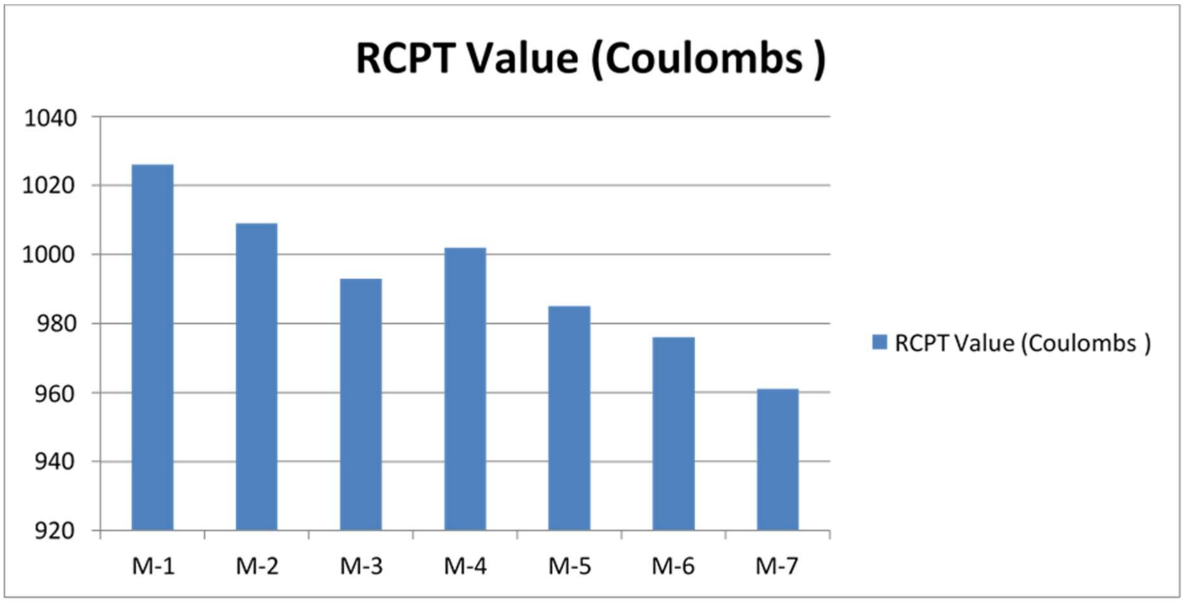
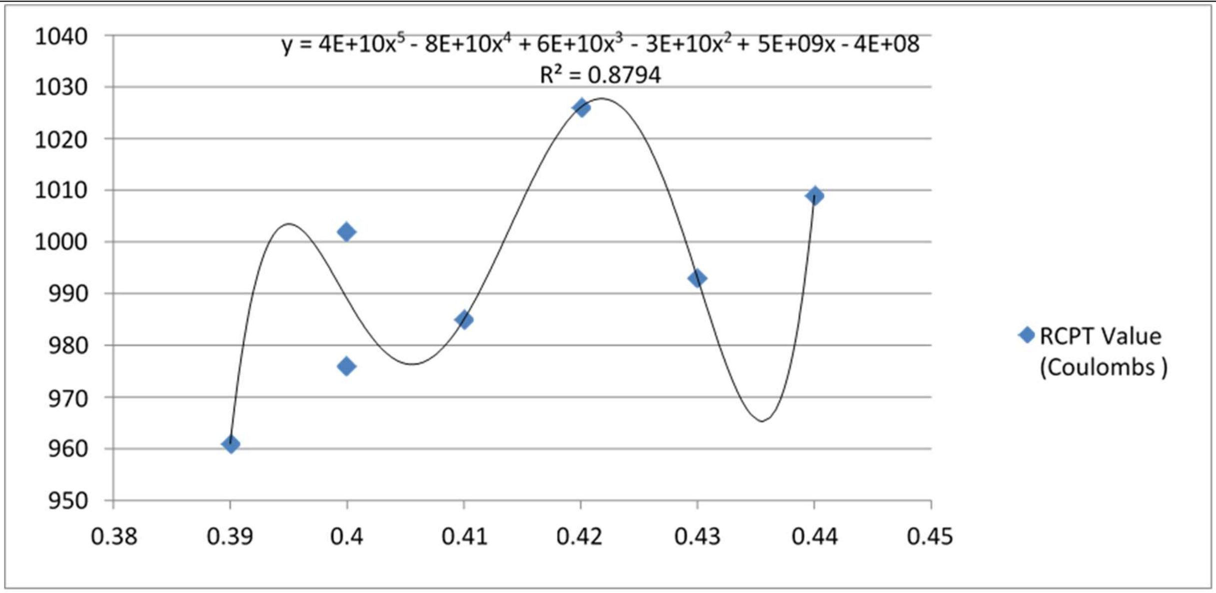


Figure 4 : Correlations of RCPT (Coulombs) with water binder ratio



3 CONCLUSIONS

We can say that the use of SCM produce more workable, higher performance and durable with compare to conventional concrete. The use of mineral admixture (GGBS and Fly Ash) as replacement in optimum quantity with cement in concrete gives batter strength and durability in conventional concrete. The utilization of mineral admixture in concrete gives the best way to disposal of byproduct of industrial west which is environmental friendly and economical The use of supplementary cementitious materials like GGBS and fly ash as partial replacement of cement (in optimum quantity) in conventional concrete shows that there is increase in strength and decrease in porosity of concrete. This occurs because in concrete mixes, the mineral admixtures play the role of filler material and reduce the pore size of the concrete mix. A reduction in porosity decreases chloride penetration in conventional concrete. The influence of water/Binder ratio is very much significant on the strength and porosity of the concrete since the strength and porosity of the concrete depends on water/Binder ratio. If water and binder ratio increases, the strength decreases and porosity in concrete increases. Due to an increase in porosity of concrete, the chloride penetration increases. Because of this phenomenon, the durability of concrete changes as according there is an increase or decrease in the value of water and binder ratio.

Declaration of competing interest: The authors proclaim that they have no conflict of interest

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