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A STUDY ON DURABILITY OF DREDGED MARINE SAND CONCRETE

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Abstract: **The durability of dredged marine sand concrete has been studied through testing different properties of concrete including acid resistance, chloride and sulphur attack, sorptivity and water absorption. Two types of concrete mix, i.e. M25 and M40 were used. The results showed that the dredged marine sand concrete has more resistivity to acid, sulphur and chloride attack. Also, it is less porous as compared to concrete containing natural river sand.**

Keywords: **dredged marine sand, sorptivity test, natural sand, concrete.**

1. INTRODUCTION

Concrete is the most basic material required for construction of any structure. Sand, which is used as fine aggregate in manufacturing of concrete is extracted from alluvial rivers or quarries. Due to the increasing construction, the requirement of concrete is increasing and so is the demand for sand. The sources which are used for extraction of sand are depleting. To counteract this problem, other sources have been searched for extraction of sand. One of such source is dredged marine sand.

In this study, three types of concrete mixes i.e. Mix-A which is made with 100% natural river sand, Mix-B which is made with 50% replacement of natural river sand with dredged marine sand and Mix-C which is made with 100% replacement of natural river sand with dredged marine sand. Two different concrete grades are considered i.e. M25 and M40. Two cement types are taken into account i.e. OPC and PPC.

Basic information related to dredged marine sand i.e. the equipment used for dredging the marine sand, specification of the dredger, practical applications, location of site from where marine sand has been extracted etc. was done. The aggregates used as a fine aggregate are river sand which is locally available and raw dredged marine sand. The coarse aggregates which are used in concrete manufacturing are of size 10mm and 20mm, respectively. Sieve analysis and specific gravity tests are performed for the aggregates. Concrete mix design is done for two concrete grades such as M25 and M40. Casting of plain concrete specimens and RC specimens is done.

Mechanical properties such as compressive strength of plain concrete specimens are measured after 7, 28 and 56 days of moist curing for all mixes. The durability properties i.e. acid resistance, sulfate resistance after exposure of 3 months, chloride resistance after exposure of 2 months, water absorption test, sorptivity test and accelerated corrosion test is performed for all concrete mixes. For acid exposure and sulfate exposure 5% H_2SO_4 and 5% Na_2SO_4 is used, respectively. For chloride exposure 3% NaCl is used during the test. The time required for initiation of cracks in concrete specimens is measured. Corrosion rate using half-cell potentiometer is measured and current measurement for individual specimens during the test is determined. UPV test is conducted for concrete specimens after various durability tests.

2. MATERIALS

2.1. Aggregates:

Cement which is used for the casting work is 53 grade OPC. The physical properties of cement are shown in Table 1. Aggregates are procured locally for the casting work of concrete specimens. The aggregates are tested for their properties in accordance with the IS standards. Locally available river sand is used as a fine aggregate for concrete. Also locally available coarse aggregates of two grades are used in the concrete i.e.10mm and 20 mm. The sieve analysis of the fine aggregate is performed as per IS 2386 (1963) part-1.[25]

Table 1: Physical properties of cement

Properties	Results achieved	Specification in IS 12269:1987 for 53 grade OPC
Fineness in m^2/kg	351	Min. 225
Soundness by Le chatelier method in mm	0.4	Max. 10
Initial setting time in minutes	35	Min. 30
Final setting time in minutes	240	Max. 600
3 days compressive strength in MPa	28.75	Min. 27
7 days compressive strength in MPa	39.85	Min. 37
28 days compressive strength in MPa	54.47	Min. 53

The sieve analysis results are shown in Table 2 for natural river sand. To determine fineness modulus and zone of the sand the tests are conducted.

Table 2: Sieve analysis results of natural river sand

Sieve Size	Mass retained (grams)	% mass retained	Cumulative % of mass retained	Cumulative % of passing
4.75 mm	40	4	4	96
2.36 mm	227	22.7	26.7	73.3
1.18 mm	35	3.5	30.2	69.8
600 µm	144	14.4	44.6	55.4
300 µm	308	30.8	75.4	24.6
150 µm	165	16.5	91.9	8.1
Below 150 µm	81	8.1	-	0
Total	1000	100	268.8	-

Test performed for determining the specific gravity for natural river sand. Results of these parameters for natural river sand are given in Table 3.

Table 3: Results for various parameters of natural river sand

Type of Sand	Parameter	Result
Natural river sand	Fineness modulus	2.68
Natural river sand	Zone	2
Natural river sand	Specific gravity	2.6

Sieve analysis results for coarse aggregate of 10mm and 20mm are presented in Table 4 and Table 5 respectively.

Table 4: Sieve analysis results for 10 mm aggregate

Sieve Size	Mass retained (grams)	% mass retained	Cumulative % of mass retained	Cumulative % of passing
80 mm	0.0	0.0	0.0	100.0
40 mm	0.0	0.0	0.0	100.0
20 mm	0.0	0.0	0.0	100.0
10 mm	46.0	4.6	4.6	95.4
4.75 mm	875.0	87.5	92.1	7.9
2.36 mm	39.0	3.9	100.0	0.0
1.18 mm	0.0	0.0	100.0	0.0
600 µm	0.0	0.0	100.0	0.0
300 µm	0.0	0.0	100.0	0.0
150 µm	0.0	0.0	100.0	0.0
Below 150 µm	0.0	0.0	-	0.0
Total	1000	100		
Fineness modulus = 596.7/100 = 5.967				

Table 5: Sieve analysis results for 20 mm aggregate

Sieve Size	Mass retained (grams)	% mass retained	Cumulative % of mass retained	Cumulative % of passing
80 mm	0.0	0.0	0.0	100.0
40 mm	0.0	0.0	0.0	100.0
20 mm	660.0	33.0	33.0	67.0
10 mm	1270.0	63.5	96.5	3.5
4.75 mm	70.0	3.5	100.0	0.0
2.36 mm	0.0	0.0	100.0	0.0
1.18 mm	0.0	0.0	100.0	0.0
600 µm	0.0	0.0	100.0	0.0
300 µm	0.0	0.0	100.0	0.0
150 µm	0.0	0.0	100.0	0.0
Below 150 µm	0.0	0.0	-	0.0
Total	2000	100	729.5	
Fineness modulus = 729.5/100 = 7.295				

2.2. Superplasticizer:

There are two different concrete grades which were considered in the experimental work i.e. M25 and M40. For M40 concrete grade, super plasticizer has been used for achieving required workability of the concrete. FosrocConplast SP 430 was used as an admixture to improve workability of the fresh concrete.

2.3. Marine sand

Physical properties:

The test is performed to determine the fineness modulus and zone of the dredged marine sand. Results are given in Table 6 and Table 7respectively.

Table 6: Sieve analysis results of the dredged marine sand

Sieve Size	Mass retained (grams)	% of mass retained	Cumulative % of mass retained	Cumulative % of passing
4.75 mm	0	0	0	100
2.36 mm	44	4.4	4.4	95.6
1.18 mm	121	12.1	16.5	83.5
600 µ	276	27.6	44.1	55.9
300µ	516	51.6	95.7	4.3
150µ	27	2.7	98.4	1.6
Below 150µ	16	1.6	-	0
Total	1000	100	259.1	-

Table 7: Results for various parameters for dredged marine sand

Type of Sand	Parameter	Result
Dredged marine sand	Fineness modulus	2.59
Dredged marine sand	Zone	2
Dredged marine sand	Specific gravity	2.56

Chemical properties:

The chemical properties of marine sand are investigated by two other laboratories and results are presented in Table 3.9 and 3.10 respectively. Sample taken for test=35kg, Moisture condition when received= Surface dry.

Table 8: Chemical analysis results provided by Geo Test house

Sr. no.	Test name	Test method	Test result	Specification requirement (IS 383-1970)
1	Organic content	IS 2386 : Part-2 Cl-6.0	Not detected	-
2	Chloride (%)	B.S. 812 : P-117	0.034	Max 0.04%
3	Sulfur as SO_3 (%)	B.S. 812 : P-118	0.794	Max 0.05%
4	Presence of deleterious material (%)	IS 2386 : P-2 Cl-2 & 3	6.847	Max 5%
5	Volatile solids	IS 3025 : P-18	0.084	-

Table 9: Results of chemical analysis related with Alkali aggregate reactivity pro- vided by K.C.T. Consultancy Services

No.	Alkali aggregate reactivity test	Fine aggregate
1	Reduction in alkalinity (milimol / l)	132.19
2	Silica dissolved from 300 μm size aggregate material (milimol / l)	1.78

Table 10: Results of chemical test for deleterious material of marine sand provided by K.C.T. Consultancy Services

No.	Test description	Results (%)	Requirement as per IS 383 (%)
1	Coal and Lignite	Nil	Max 1%
2	Clay lumps	Nil	Max 1%
3	Material finer than75 μ	1.5	Max 3%
4	Shale	6.60	Max 1%
5	Total % of all deleterious material	8.10	Max 5%

3. CONCRETE MIX DESIGN

The concrete mix proportioning using dredged marine sand is not different than the usual mix design of concrete using natural river sand. All the constituents are same for both the cases i.e. concrete using dredged marine sand and natural river sand. The mix design is done based on provisions of IS 10262 (2009).[19]

The w/c ratio is selected 0.5 for M25 grade concrete and 0.4 for M40 grade concrete. For the concrete grade M40, the superplasticizer is added forcasting of concrete. The amount of 0.8% of total mass of cement was taken as a superplasticizer for M40 grade concrete. No super plasticizer is used for M25 grade concrete. Table 11 presents concrete mix proportioning for both concrete grades and for all concrete mixes respectively.

Table 11: Concrete mix proportion for all concrete mixes

Grade of concrete	w/c ratio	Water content (kg/m^3)	Cement Content (kg/m^3)	Fine Aggregate (kg/m^3)	20 mm aggregate (kg/m^3)	10 mm aggregate (kg/m^3)
M25	0.5	191.8	383.16	630.47	733.15	488.78
M40	0.4	143.8	359.22	599.88	761.67	507.78

4. TESTING

4.1. Acid resistance test:

The plain concrete specimens are exposed in the acid tank for required ages in months. After completion of exposure, the specimens are taken out of the acid tank. The required exposure ages considered for plain concrete specimens are 3 months, 6months and 12 months respectively.

The acid which is used for the test is Sulfuric acid (H_2SO_4) solution having 5% concentration by volume of water. [22] The solution is stirred every week and pH value of solution is measured after every 15 days. Modification in the pH is done by adding acid or water in the tank if pH value differs from 1. Fig.1 and 2 show acid tank with concrete specimens for acid exposure and digital pH measuring device respectively.

Figure 1: Tank of acid solution with concrete specimen

Figure 2: Digital pH measuring device

All the specimens are weighed before keeping them into the acid tank. After removing from the tank of acid solution after completion of exposure, respective specimens are wiped clean and weighed. This weight is considered as a final weight of concrete specimens in kg. Change in mass of concrete specimens after completion of exposure of corresponding age is evaluated. For evaluating the change in compression strength of concrete specimen after completion of exposure age in acid, the specimens are kept in saturated surface dry (SSD) condition.

Details of acid exposure test parameters are given in Table 12. The concrete specimen size is 150mmX150mmX150mm for this test.

Table 12: Details of acid resistance test

Parameters to study	Unit	Acid solution concentration	Exposure age in months	Total no. of concrete cubes
Change in compressive strength	MPa	5%	3, 6 and 12	108
Change in mass	kg	5%	3,6 and 12	

4.2. Sulphate Resistance test:

All the plain concrete specimens are exposed to the sulfate attack for required time duration. After completion of exposure at designated ages, the concrete specimens are taken out of the tank of sulfate solution. The time duration for sulfate exposure, selected for plain concrete specimens is 3 months, 6 months and 12 months respectively.

Sodium sulfate (Na2SO4) is used to prepare sulfate solution having 5% concentration by total mass of water. [21] The sodium sulfate powder of required quantity is added to water to make the sulfate solution. The sulfate solution is stirred every week and pH value of is measured after interval of 15 days and modification in the pH is done by adding sodium sulfate powder or water in the tank if pH value differs from1.

The concrete specimens are weighed prior to keeping them in the sulfate solution. After removing them out from the tank after completion of exposure, respective specimens are wiped clean and weighed. This is considered as a final weight of concrete specimens in kg. Change in mass of specimens after completion of respective exposure is determined. For evaluating the change in compressive strength of concrete specimens after completion of designated duration in sulfate solution, the specimens are considered saturated surface dry (SSD) condition. Details of sulfate exposure test parameters are given in Table 13. The concrete specimen size is 150 mm X 150mmX 150 mm for this test. They are studied and comparison between all concrete mixes is to be evaluated after completion of exposure in sulfate solution at corresponding time duration.

Table 13: Details of sulfate resistance test

Parameters to study	Unit	Sulfate solution concentration	Exposure ages in months	Total no. of concrete cubes
Change in compressive strength	MPa	5%	3, 6 and 12	108
Change in mass	kg	5%	3,6 and 12	
Pulse velocity by UPV test	m/s	5%	3,6 and 12	

4.3. Chloride resistance test:

All the plain concrete specimens are exposed to the chloride attack for required time duration. After completion of the exposure at designated age, the concrete specimens are taken out of the tank of chloride solution. The time duration for chloride exposure selected for plain concrete specimens is 2months.

Sodium chloride (NaCl) is used to prepare chloride solution having 3% concentration by total mass of water. The sodium chloride powder of required quantity is added to water to make chloride solution. The solution is stirred every week and pH value is measured after interval of 15 days and modification in the pH is done by adding sodium chloride powder or water in the tank if pH value differs from 1.

Details of chloride exposure test parameters are given in Table 14. The concrete specimen size which was decided is 150mmX150mmX150mm for this test. They are studied and comparison between all concrete mixes is to be evaluated after completion of exposure in chloride solution at corresponding time duration.

Table 14: Details of chloride resistance test

Parameters to study	Unit	Chloride solution concentration	Exposure ages in months	Total no. of concrete cubes
Change in compressive strength	MPa	3%	2	36
Change in mass	kg	3%	2	
Pulse velocity by UPV test	m/s	3%	2	

4.4. Sorptivity test:

Sorptivity is defined as a measure of the capacity of the medium to absorb or desorbs liquid by capillarity. Hall (1989) [23] had given the definition of sorptivity that sorptivity is a quantity that measures the unsaturated flow of fluids in to the concrete. In simple words sorptivity is defined as the cumulative water absorption per unit area of inflow surface per square root of elapsed time.

For performing this test first of all concrete specimens are cured for 28 days. The concrete specimens are put into the oven for 7 days at 50C temperature. The specimens are taken out of the oven and weighed. This phenomenon is considered as weight of oven dried cubes in kg. The concrete specimens are sealed using electrician's tape or any appropriate sealing material such as mixture of wax and resin with appropriate proportion. The mixture of wax and resin is taken as a sealing material. The proportion of wax and resin is considered as 60% resin and 40% wax. Both the materials are available in solid form. It is essential to convert them in liquid form.

All four sides of concrete specimens are sealed using this mixture up to the height of 15mm to 20mm as height of immersion in water for performing the test is 15-20mm. The initial weight of concrete specimens is measured and is considered as weight of sealed cubes at time equal to 0 seconds. The time intervals considered for the test are 1, 2, 3, 4, 5, 9, 12, 16, 20 and 25 minutes, respectively. A bunch of filter papers of approximate thickness of 7 mm to 10 mm is put on to the shallow tray and water is poured up to a height such that after keeping the cube on it, 5-10mm concrete surface comes in the contact to water.

4.5. Water absorption test:

This test is done to know the relative porosity or permeability characteristics of the concrete. The test is carried out after 28 days of moist curing. The concrete specimens used for this test are 150 mm X 150 mm X 150 mm size cubes. The percentage absorption [6] is calculated using Eq. below.

$$\text{Absorption } (\%) = (w2 - w1)/w1 * 100$$

Where, w1=weight of concrete specimen after complete drying at 105C

w2= final weight of surface dry concrete specimen after immersion in water at least 24 hours

The concrete specimens are first dried for 24 hours at 105C in oven. The concrete specimens are removed from the oven and weighed which is considered as initial weight w1. They are immersed in water again for 24 hours.

Table 15: Details of water absorption test

Parameters to study	Unit	Period in oven for complete dry	Duration of immersion in water tank	No. of concrete cubes
Change in mass	kg	24 hours	24 hours	36

4.6. Accelerated corrosion test:

This experiment is related with the RC specimens. Impressed current technique (ICT) is used for conducting the accelerated corrosion test.[7] For the test RC specimens are cast using one HYSD bar of 8 mm diameter to serve as anode. One stainless steel bar of same diameter is inserted in the concrete at the time of casting to serve as cathode for proper circuitry. Specimens are of 150 mm diameter and 300 mm height. Fig 3 shows such type of specimens. Average result of three specimens is to be taken as a final result.

Figure 3: Specimens for accelerated corrosion test

To protect any structure from adverse effects of corrosion, study of initiation of corrosion in structure is very essential. It is obvious that corrosion is a natural process and takes years to occur in RC structures. Therefore, investigation related to corrosion in limited time duration is conducted to fulfill following objectives.

To induce corrosion in reinforcement of concrete cylinders

To evaluate rate of corrosion with the help of half-cell potentiometer and compare results for all concrete mixes

To observe time period for initiation of crack in concrete

Fig4. Shows the test set up for accelerated corrosion test. In the test HYSD bar is connected with positive terminal which serves as an anode and stainless steel bar is to be connected with negative terminal which serves as a cathode.

For the test, concrete specimens are to be immersed in the water having 5% NaCl concentration. The water level is adjusted in such a way that approximately 2/3 of height of the specimens come in contact with water. Fig 5 and 6 shows the concrete specimen kept for ACT in tank of NaCl solution and rectifier which is used for DC power supply, respectively. 9 concrete specimens are put in parallel connection for the test. The voltage is set constant throughout the test i.e. 30V. Current is measured every day separately for all the specimens in ampere. 12 concrete specimens can also be put in parallel connection for this test at 30 V.

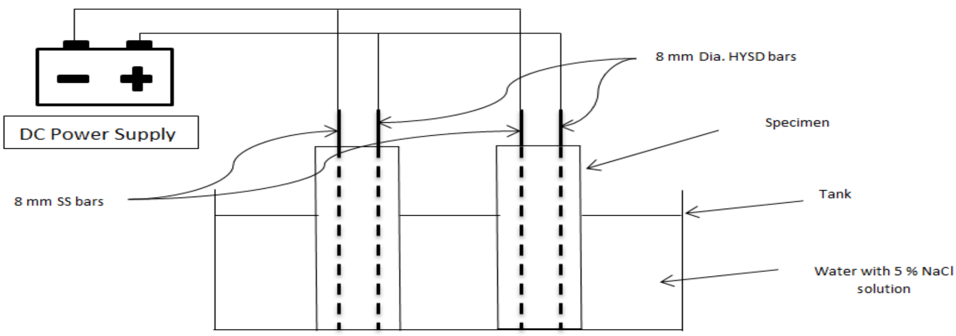

Figure 4: ACT test setup

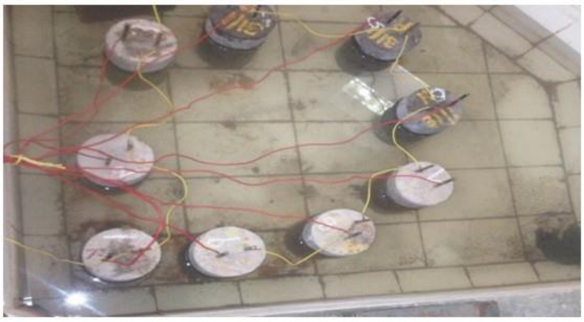

Figure 5: Specimens in tank of NaCl solution for ACT before starting of test

Figure 6: Rectifier for DC power supply

On observation basis the corrosion in the reinforcement is detected after completion of 1 to 2 weeks.UPV test is used as non-destructive test. Corrosion rate in the reinforcement is measured using half-cell potentiometer before starting of test and after completion of the test in mV.

5. RESULTS

5.1. Acid exposure:

The plain concrete specimens are exposed in the tank with acid solution for designated age in terms of months. After completion of the exposure, the concrete specimens are taken out of the tank. The pH value of the acid solution is measured which is maintained having value between 0.80 and 0.87.

The specimens are taken out of the tank after 3 months of exposure. The evaluation of change in mass and change in compressive strength is conducted for all concrete mixes. The results of change in compressive strength are presented in Table 16. Graphical representation of results is shown in Fig 7. The results of change in mass of the concrete specimens are shown in Table 17. The graphical representation related to the same is shown in Fig 8.

Table 16: Acid resistance test for concrete mixes

Grade of concrete	Cement type	Mix	Compressive strength after 28 days curing (MPa)	Compressive strength after 3 months exposure (MPa)	Reduction in compressive strength (%)
M25	OPC	Mix A	35.4	25.33	39.75
		Mix B	41.3	34.67	19.12
		Mix C	43.26	38.96	11.03
M25	PPC	Mix A	32.9	26.44	24.43
		Mix B	32.9	29.33	12.17
		Mix C	33.19	29.48	12.58
M40	OPC	Mix A	48.74	36.22	34.56
		Mix B	54.07	45.33	19.28
		Mix C	54.52	46.52	17.19
M40	PPC	Mix A	42.96	38.22	12.40
		Mix B	43.11	40.15	7.372
		Mix C	47.4	42.82	10.69

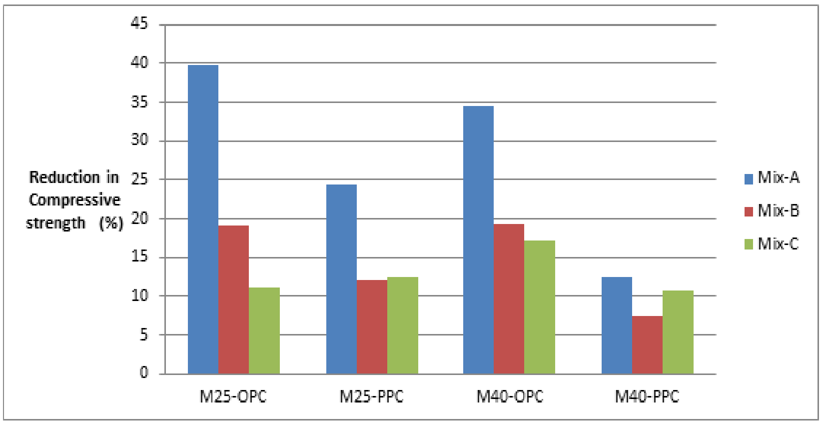

Figure 7: % change in compressive strength of concrete mixes for acid exposureof3months

The results indicate that the compressive strength of M25 grade concrete with OPC for Mix-C has less percent age reduction as compared to that for Mix-A and Mix-B, respectively. 40% reduction in compressive strength is observed for concrete Mix-A. On the other hand 19% and 12% reduction in compressive strength is observed in Mix-B and Mix-C, respectively. 24% reduction in compressive strength is observed for concrete Mix-A, whereas 12% reduction in compressive strength is observed for Mix-B and Mix-C, respectively for M25 grade PPC based concrete.

For M40 grade concrete with OPC for Mix-A indicate higher percentage of reduction in compressive strength of 35%. 15% of strength reduction in compressive strength is observed in concrete Mix-B and Mix-C after 3 months of exposure in acid solution. The concrete made with PPC of M40 grade show 13% reduction in compressive strength for concrete Mix-A. In case of Mix-C and Mix-B, 10% and 7% reduction in compressive strength is observed respectively.

The compressive strength of concrete specimens for all mixes after 28 days is compared with corresponding compressive strength for the mixes after completion of 3 months acid exposure.

Table 17: Change in weight of concrete mixes for acid resistance test

Grade of concrete	Cement type	Mix	Initial weight (kg)	Final Weight (kg)	Reduction in weight (%)
M25	OPC	Mix A	8.56	8.17	4.70
		Mix B	8.72	8.39	4.01
		Mix C	8.87	8.55	3.74
M25	PPC	Mix A	8.53	8.16	4.57
		Mix B	8.75	8.43	3.79
		Mix C	8.80	8.50	3.48
M40	OPC	Mix A	8.52	8.16	4.40
		Mix B	8.82	8.49	3.96
		Mix C	8.88	8.55	3.89
M40	PPC	Mix A	8.74	8.39	4.08
		Mix B	8.69	8.37	3.82
		Mix C	8.94	8.62	3.71

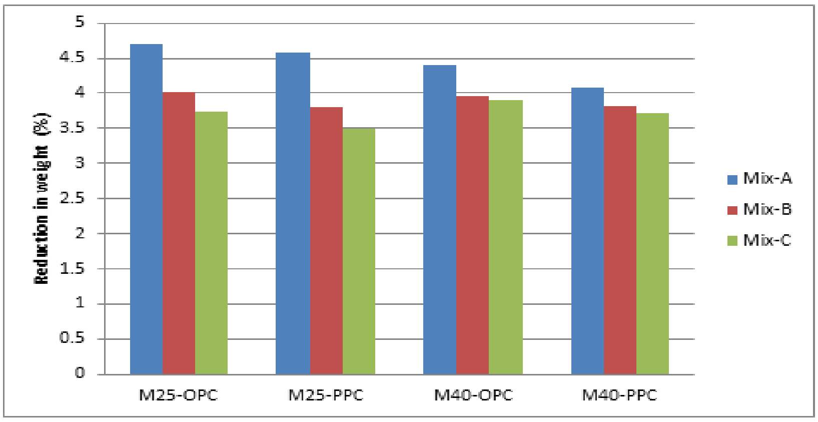

Figure 8: Reduction in weight of concrete specimens after acid exposure of 3 months

The results of reduction in weight after completion of acid exposure of 3 months duration are shown in Fig 8. The results show that the percentage reduction in concrete Mix-C and Mix-B is less as compared to that of Mix-A.

The test results for acid exposure show that concrete Mix-C is superior against acid attack as compared to Mix-A and Mix-B, respectively.

5.2. Sulphate exposure:

The plain concrete specimens are exposed in the tank with sulfate solution for designated age in terms of months. After completion of the exposure, the concrete specimens are taken out of the tank. The pH value of the sulfate solution is measured which is maintained having value between 8 and 9.

The specimens are taken out of the tank after 3 months of exposure. The evaluation of change in mass and change in compressive strength is conducted for all concrete mixes. The results of change in compressive strength are presented in Table 18. Graphical representation of results is shown in Fig9. The results of change in mass of concrete specimens are shown in Table 19. The graphical representation related to the same is shown in Fig 10. For exploring the quality of specimens UPV test was performed for all specimens before and after completion of exposure of 3 months. The results are presented in Table 20.

Table 18: Sulfate resistance test for concrete mixes

Grade of concrete	Cement type	Mix	Compressive strength after 28 days curing (MPa)	Compressive strength after 3 months exposure (MPa)	Reduction in compressive strength (%)
M25	OPC	Mix A	35.4	34.22	3.44
		Mix B	41.3	40.3	2.48
		Mix C	43.26	42.22	2.46
M25	PPC	Mix A	32.9	31.25	5.28
		Mix B	32.9	31.8	3.45
		Mix C	33.19	32.89	0.91
M40	OPC	Mix A	48.74	46.22	5.45
		Mix B	54.07	53	2.01
		Mix C	54.52	53.48	1.94
M40	PPC	Mix A	42.96	40.74	5.44
		Mix B	43.11	42.22	2.10
		Mix C	47.4	47.26	0.29

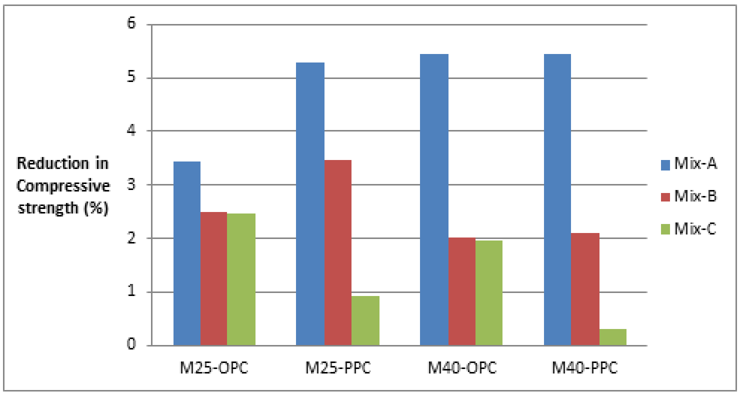

Figure 9: % change in compressive strength of concrete mixes for sulfate exposure of 3months

Table 19: Change in weight of all concrete mixes for sulfate resistance test

Grade of concrete	Cement type	Mix	Initial weight (kg)	Final Weight (kg)	Increase in weight (%)
M25	OPC	Mix A	8.53	8.67	1.60
		Mix B	8.51	8.54	0.27
		Mix C	8.77	8.79	0.22
M25	PPC	Mix A	8.43	8.54	1.33
		Mix B	8.74	8.77	0.34
		Mix C	8.76	8.77	0.11
M40	OPC	Mix A	8.50	8.54	0.50
		Mix B	8.81	8.83	0.17
		Mix C	8.59	8.62	0.34
M40	PPC	Mix A	8.53	8.67	1.64
		Mix B	8.75	8.77	0.26
		Mix C	8.85	8.87	0.22

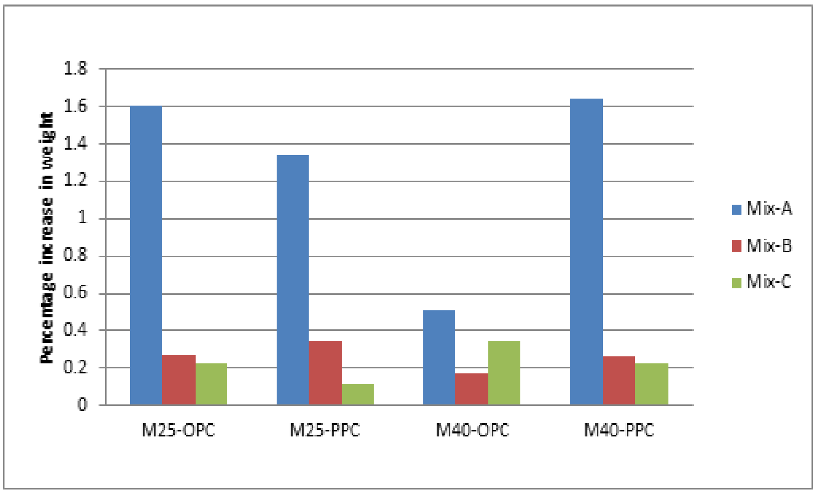

Figure 10: Increase in weight of specimens after 3 months of sulfate exposure

Table 20: Average UPV results for sulfate exposure for all concrete mixes

Grade of concrete	Cement type	Mix	Initial reading (m/s)	Final reading (m/s)
M25	OPC	Mix A	4770	4746
		Mix B	4663	4646
		Mix C	4860	4843
M25	PPC	Mix A	4666	4646
		Mix B	4783	4766
		Mix C	4776	4760
M40	OPC	Mix A	4793	4776
		Mix B	4810	4793
		Mix C	4990	4973
M40	PPC	Mix A	4863	4846
		Mix B	4730	4713
		Mix C	4843	4826

The reduction in compressive strength in percentage is from 1% to 5% for all concrete mixes. For M25 grade of concrete with OPC show almost same values of compressive strength reduction for all three concrete mixes. In case of M25 grade concrete with PPC, % reduction in compressive strength is less in Mix-C as compared to that of Mix-B and Mix-A.

For M40 grade concrete made with OPC and PPC both for Mix-A and Mix-B show more reduction in strength as compared to Mix-C.

The compressive strength of concrete specimens for all mixes after 28 days is compared with corresponding compressive strength for the mixes after completion of 3 months sulfate exposure.

The chemical consequences of sulfate attack on concrete components are the formation of ettringite (calcium aluminate trisulfate 32 hydrate, CaOAl2O33CaSO432H2O) and gypsum (calcium sulfate dihydrate, CaSO42H2O). The formation of ettringite can result in an increase in solid volume, leading to expansion and cracking. The formation of gypsum can lead to softening and loss of concrete strength. [16] Both increase in weight and loss in compressive strength of concrete are observed from previous results shown in Table 18 and 19, respectively.

The test results for sulfate exposure show that Mix-C performs better as compared to that of Mix-B and Mix-A.

5.3. Chloride exposure:

The plain concrete specimens are exposed in the tank with chloride solution for designated age in terms of months. After completion of the exposure, the concrete specimens are taken out of the tank. The pH value of the chloride solution is measured which is maintained having value between 9 and 9.8.

The specimens are taken out of the tank after 2 months of exposure. The evaluation of change in mass and change in compressive strength is conducted for all concrete mixes. The results of change in compressive strength are presented in

Table 21. Graphical representation of results is presented in Fig 11. The results of change in mass of the concrete specimens are shown in Table 22. The graphical representation related to the same is shown in Fig12. For exploring the quality of specimens UPV test was performed for all specimens before and after exposure. The results are shown in Table 23.

Table 21: Chloride resistance test for concrete mixes

Grade of concrete	Cement type	Mix	Compressive strength after 28 days curing (MPa)	Compressive strength after 3 months exposure (MPa)	Reduction in compressive strength (%)
M25	OPC	Mix A	35.4	35.11	0.82
		Mix B	41.3	38.81	6.41
		Mix C	43.26	38.455	12.49
M25	PPC	Mix A	32.9	32.89	0.03
		Mix B	32.9	31.26	5.24
		Mix C	33.19	29	14.44
M40	OPC	Mix A	48.74	48.29	0.93
		Mix B	54.07	48	12.64
		Mix C	54.52	42.6	27.98
M40	PPC	Mix A	42.96	42.37	1.39
		Mix B	43.11	41.19	4.66
		Mix C	47.4	38.9	21.85

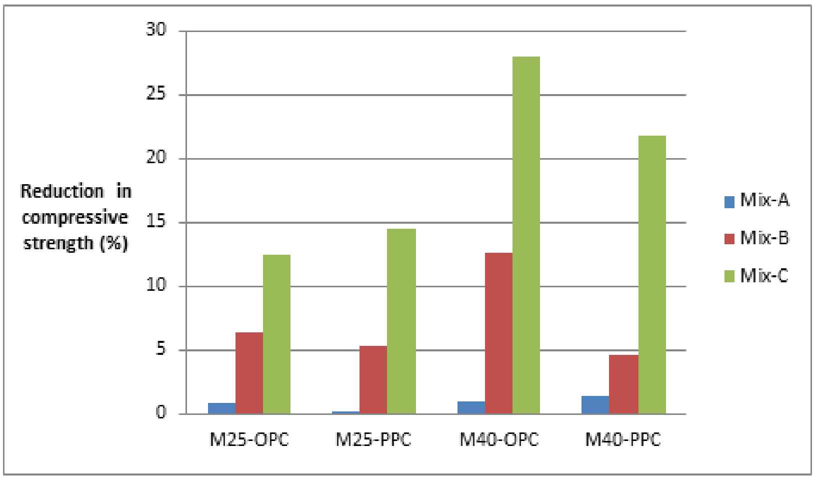

Figure 11: % change in compressive strength of concrete mixes for chloride exposure of 2months

M25 grade with OPC for Mix-C shows more reduction in strength of 13% as compared to Mix-A. For PPC Mix-C, the results show 12% of reduction in compressive strength which is more as compared to Mix-B and Mix-A. For PPC, the reduction in compressive strength is 14% in case of Mix-C which is more as compared to Mix-A.

For M40 grade concrete made with OPC and PPC both for Mix-C show more reduction in compressive strength as compared to Mix-A. The percentage reduction in compressive strength is 21.85% for Mix-C with OPC and 28% for Mix-C with PPC respectively. The percentage reduction in compressive strength is 12.64% for Mix-B with OPC and 4.66% for Mix-B with PPC respectively.

The compressive strength of concrete specimens for all mixes after 28 days is compared with corresponding compressive strength for the mixes after completion of 2 months chloride exposure.

The results of compressive strength of concrete specimens made with DMS indicate that the concrete have less resistance against the chloride attack for the exposure age of 2 months. Therefore, further investigation is required to be made with respect to chloride resistance test for concrete made with DMS.

Table 22: Change in weight of all concrete mixes for chloride resistance test

Grade of concrete	Cement type	Mix	Initial weight (kg)	Final Weight (kg)	Increase in weight (%)
M25	OPC	Mix A	8.67	8.78	1.22
		Mix B	8.64	8.69	0.54
		Mix C	8.63	8.67	0.50
M25	PPC	Mix A	8.48	8.59	1.29
		Mix B	8.71	8.81	1.14
		Mix C	8.76	8.82	0.68
M40	OPC	Mix A	8.66	8.73	0.42
		Mix B	8.74	8.79	0.49
		Mix C	8.73	8.80	0.80
M40	PPC	Mix A	8.46	8.61	1.76
		Mix B	8.55	8.60	0.58
		Mix C	8.83	8.88	0.60

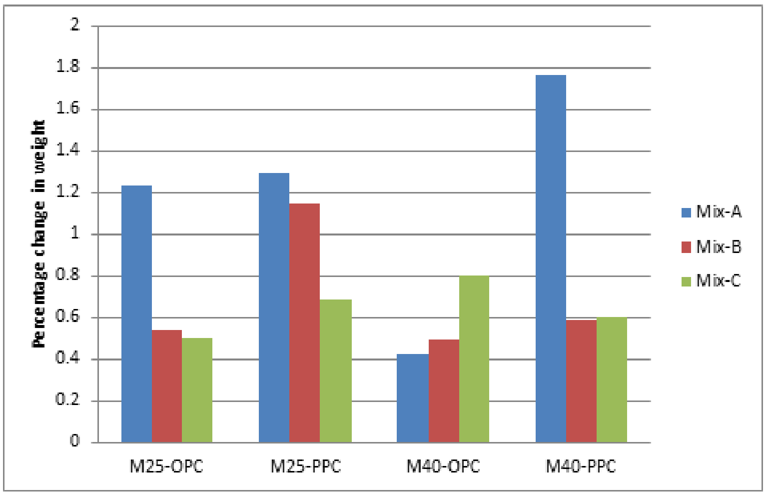

Figure 12: Increase in weight of specimens after 2 months of exposure in NaCl solution

Where concrete structures are placed on reclaimed coastal areas with foundations below saline ground water level, capillary suction and evaporation may cause super-saturation and crystallization in the concrete above ground. This can result in chemical sulfate attack, physical salt attack, or both. In addition, aggravated corrosion of embedded steel can be induced by the chloride in sea water. [16] This phenomena may be applied in chloride attack, which would increase the weight of concrete after completion of exposure duration.

The results of the UPV test for all concrete mixes show that pulse velocity is not decreased with higher percentage after completion of 2 months chloride exposure.

Table 23: UPV results for chloride exposure for all concrete mixes

Grade of concrete	Cement type	Mix	Initial reading (m/s)	Final reading (m/s)
M25	OPC	Mix A	4723.3	4680
		Mix B	4856.7	4830
		Mix C	4860	4840
M25	PPC	Mix A	4640	4600
		Mix B	5180	5143.3
		Mix C	4950	4920
M40	OPC	Mix A	4866.7	4813.3
		Mix B	4810	4770
		Mix C	4926.7	4903.3
M40	PPC	Mix A	4646.7	4586.7
		Mix B	4956.7	4916.7
		Mix C	4843.3	4826.7

5.4. Accelerated corrosion test:

It is observed that within 10-15 hours of starting the power supply, the initiation of corrosion starts in the reinforcement bars for the concrete cylinder. Water with NaCl in tank also starts exhibiting the change in color due to rust formation.

Current readings for the RC specimens are taken on regular basis and variation in current is observed throughout the test. The graphical representation of the current readings for all specimens of Mix-A, Mix-B and Mix-C is shown in Fig13, 14 and 15, respectively.

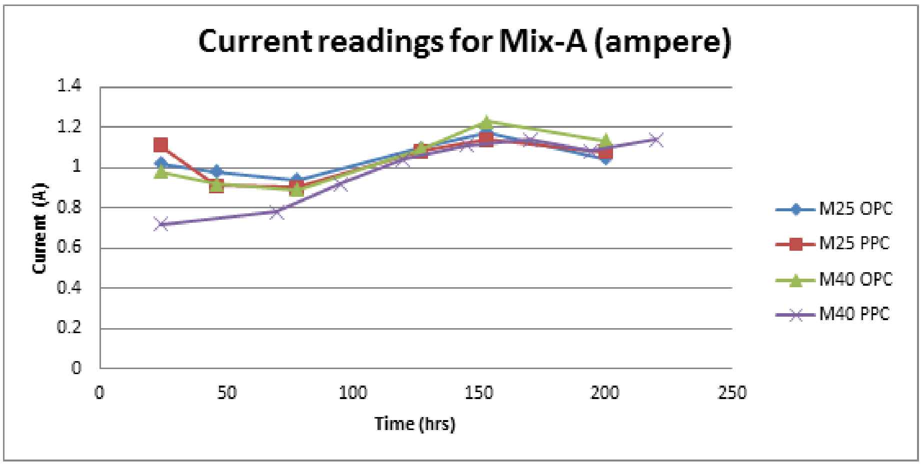

Figure13: Current measurement of concrete Mix-A

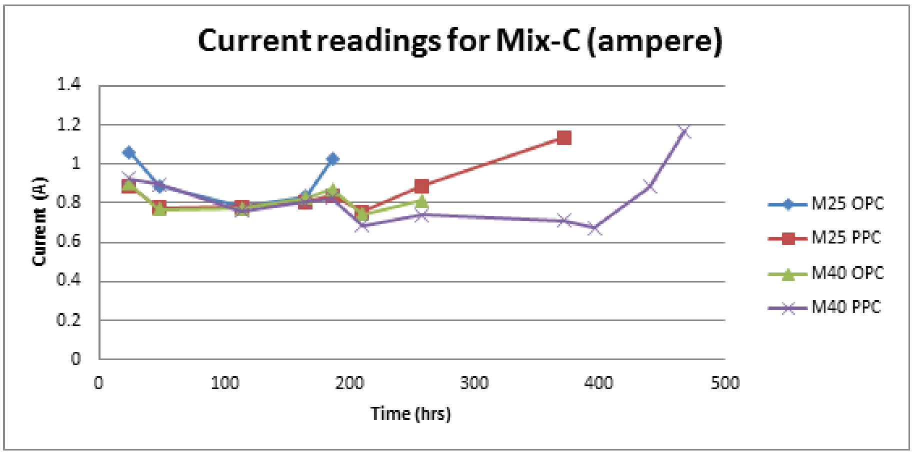

Figure 14: Current measurement of concrete Mix-B

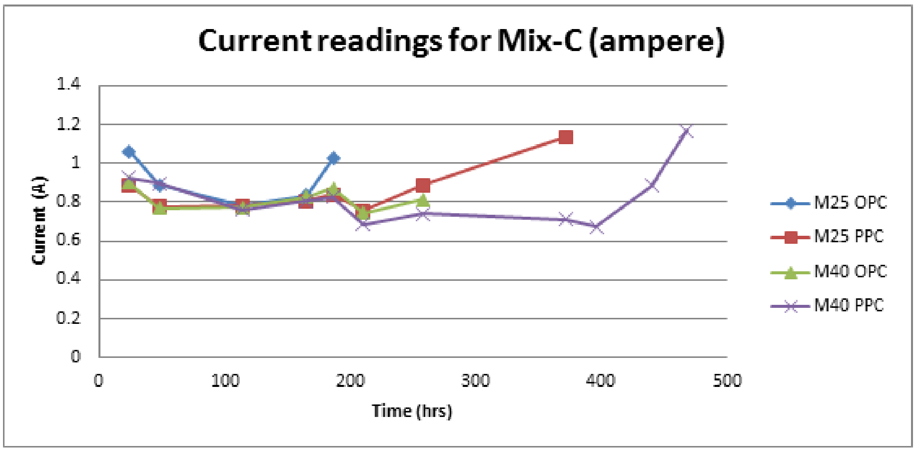

Figure 15: Current measurement of concrete Mix-C

The results of current measured for the ACT for all mixes indicate that at the beginning of the test the current goes down after that again it starts increasing. When the volume of the reinforcement starts increasing and cracks are initiated, the current starts increasing again and indicate further widening of cracks in to the concrete specimen on the side where HYSD bar in embedded.

Half-cell potentiometer test is also performed to check and measure the rate of corrosion in the embedded reinforcements for all concrete mixes. Fig 16, 17 and 18 show the results of Half-cell potentiometer test on specimens before and after the ACT for Mix-A, Mix-B and Mix-C, respectively.

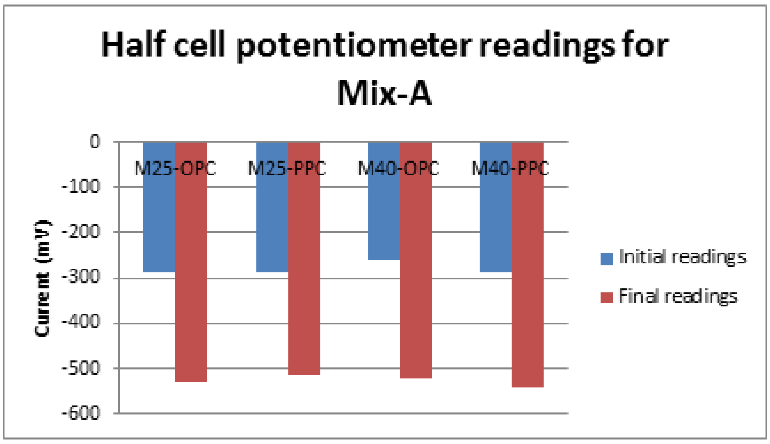

Figure 16: Results of half-cell potentiometer for concrete Mix-A

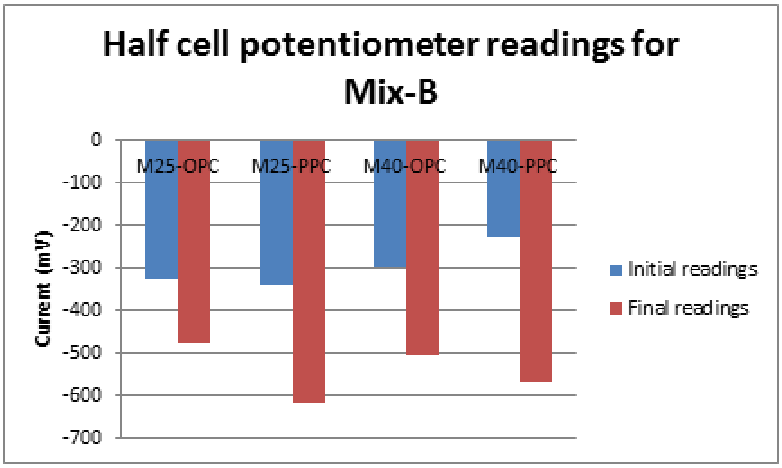

Figure 17: Results of half-cell potentiometer for concrete Mix-B

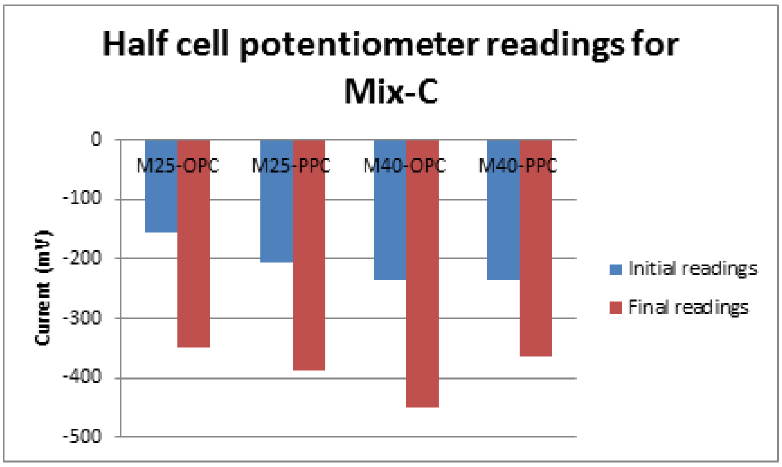

Figure 18: Results of half-cell potentiometer for concrete Mix-C

Readings of the half-cell potentiometer are negative and in mV unit. The higher the reading on negative side, the possibility of corrosion in the embedded bars is more. The reading more negative-350mV indicated more possibility of active corrosion in the embedded bars.[26]

The results of half-cell potentiometer test show that values for the RC specimens before starting the test, are not beyond negative-350mV which indicate less possibility of corrosion in reinforcement bar in concrete specimen. After completion of test due to development of crack in specimen the reading of half-cell potentiometer less than negative-350mV For concrete Mix-C and Mix-B, it is observed that the percentage difference of half-cell potential reading is less as compared to that of Mix-A. This shows that the concrete Mix-C and Mix-B have more resistance against the corrosion as compared to that of Mix-A.

The time taken for initiating the cracks in the RC specimens is to be measured. Fig19, 20 and 21 show the time period required for initiation of cracks in the specimens for Mix-A, Mix-B and Mix-C respectively

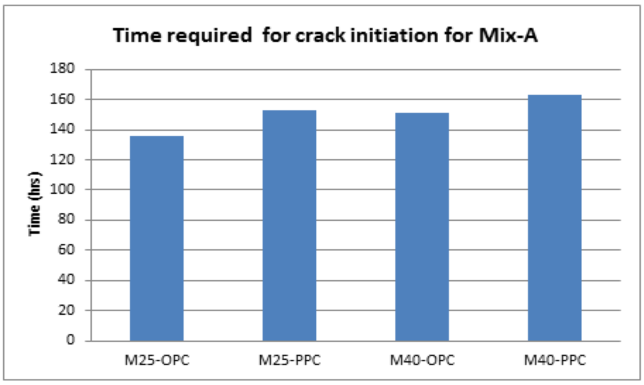

Figure 19: Time required for crack initiation for Mix-A

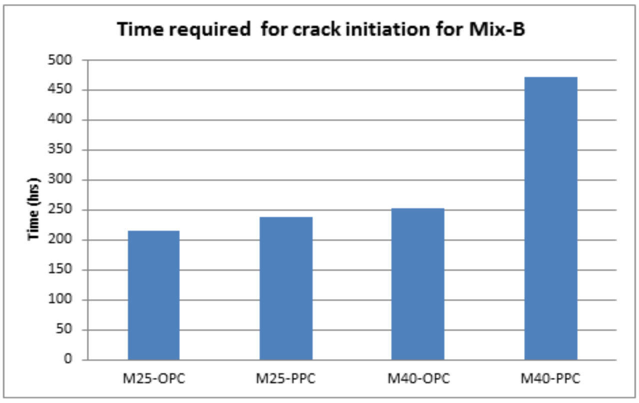

Figure 20: Time required for crack initiation forMix-B

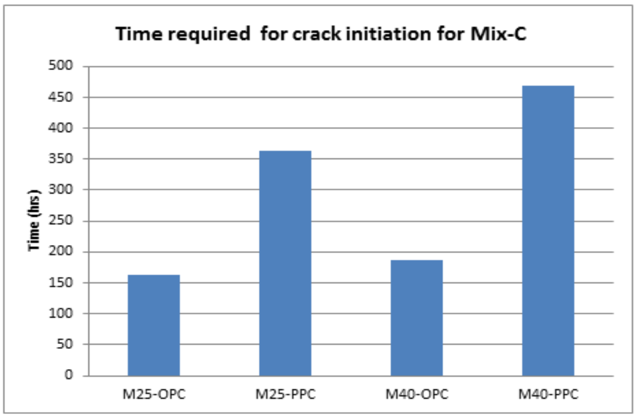

Figure 21: Time required for crack initiation forMix-C

The results have clearly demonstrated that concrete Mix-C consumes more time for crack development as compared to that of concrete Mix-B and Mix-A, respectively for all concrete mixes.

UPV test is done on all the cylinders before commencing of the test and after completion of test. Fig 22 and 23 indicate the results of UPV test on RC specimens for ACT for concrete of both grades.

Results of UPV test shows that quality of the specimens after completion of test is decreased as expected and as cracks are developing in the concrete due to increase in volume of embedded bar within the specimens. Higher percentage decrease is found in case of Mix-A as compared to Mix-B and Mix-C. The percentage reduction in velocity is found nearly 18% to 23% in Mix-A.

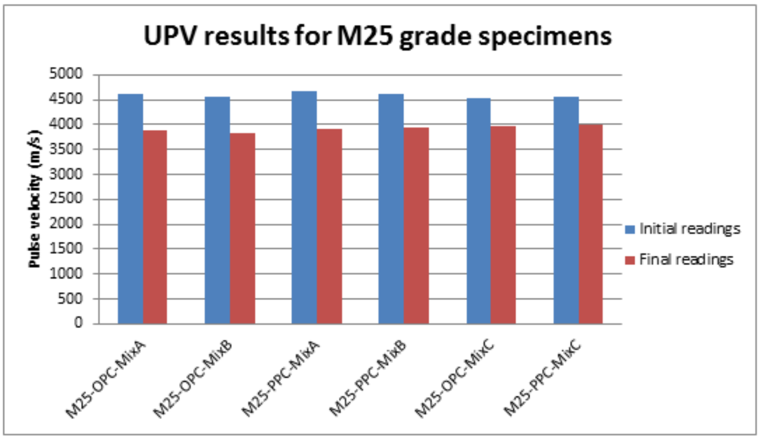

Figure 22: UPV results for M25 grade RC specimens

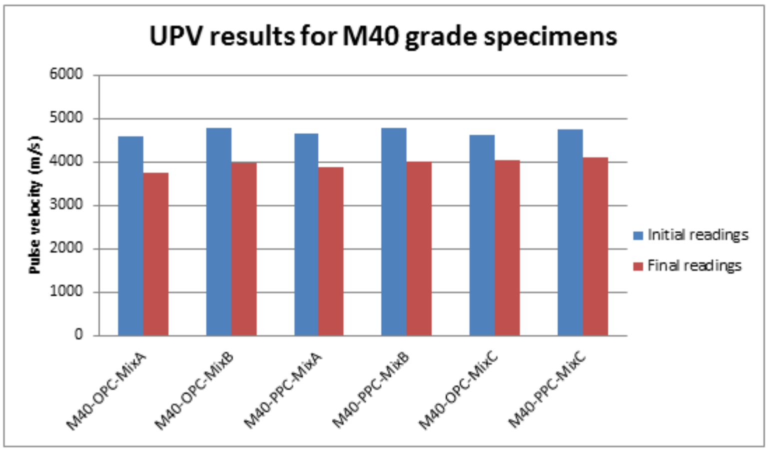

Figure 23: UPV results for M40 grade RC specimens

5.5. Sorptivity test:

Table 24: Sorptivity test for concrete mixes

Concrete mix	Grade of concrete	Cement type	Sorptivity (S) ($mm/min^{0.5}$)
Mix-A	M25	OPC	0.086
	M25	PPC	0.108
	M40	OPC	0.076
	M40	PPC	0.087
Mix-B	M25	OPC	0.072
	M25	PPC	0.091
	M40	OPC	0.074
	M40	PPC	0.082
Mix-C	M25	OPC	0.068
	M25	PPC	0.078
	M40	OPC	0.074
	M40	PPC	0.080

Figs24, 25 and Fig 26 show graphical representation of sorptivity test results for concrete mixes Mix-A, Mix-B and Mix-C, respectively. The orange line in graphs shows actual behavior and black line indicates best fit curve i.e. linear graph for corresponding concrete mixes, respectively.

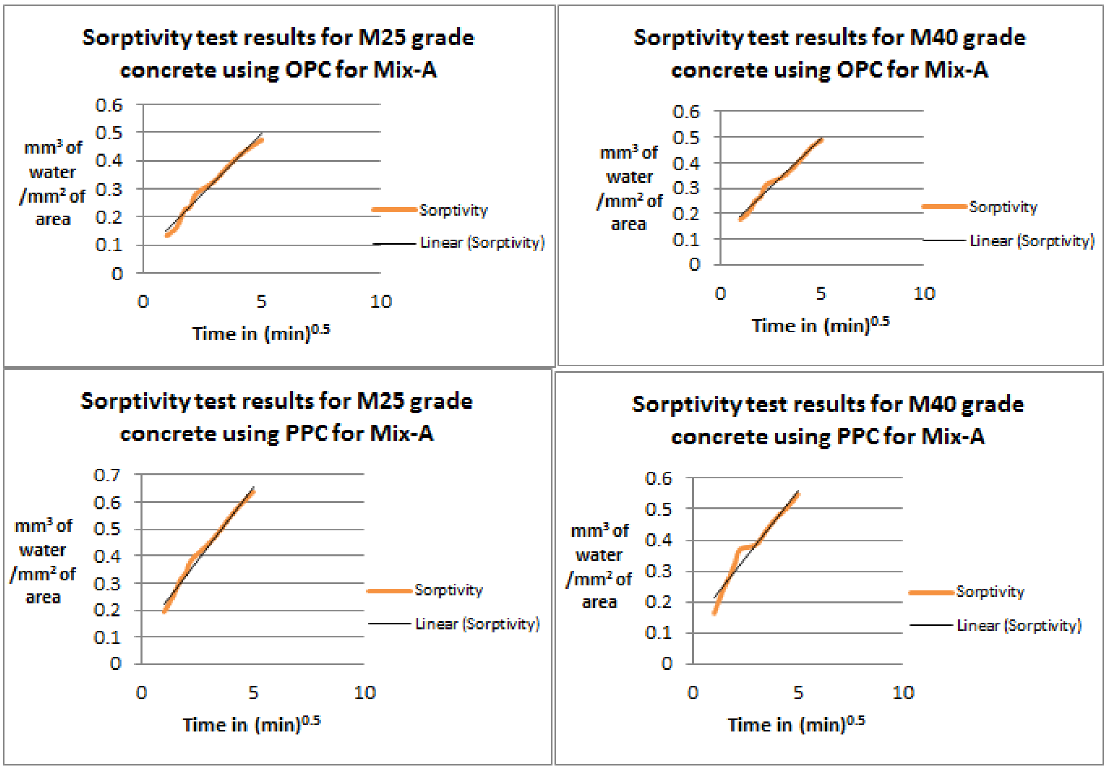

Figure 24: Sorptivity test result for Mix-A

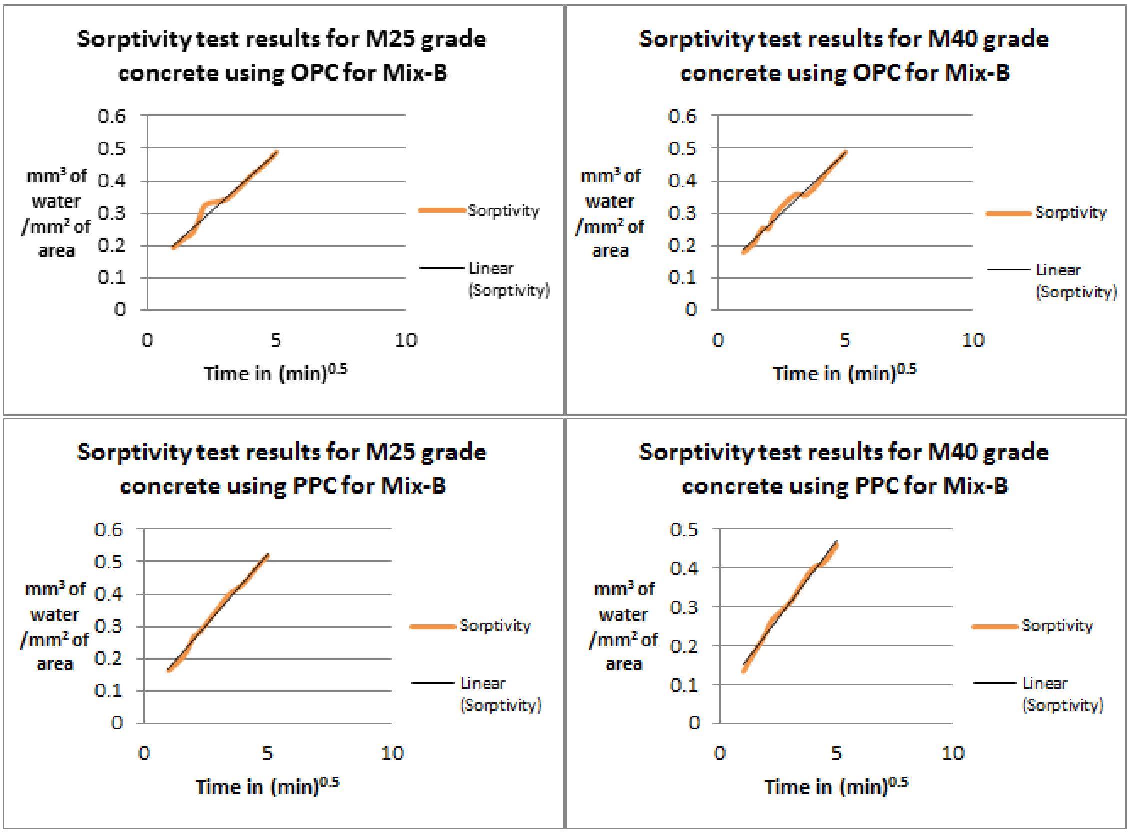

Figure 25: Sorptivity test result for Mix-B

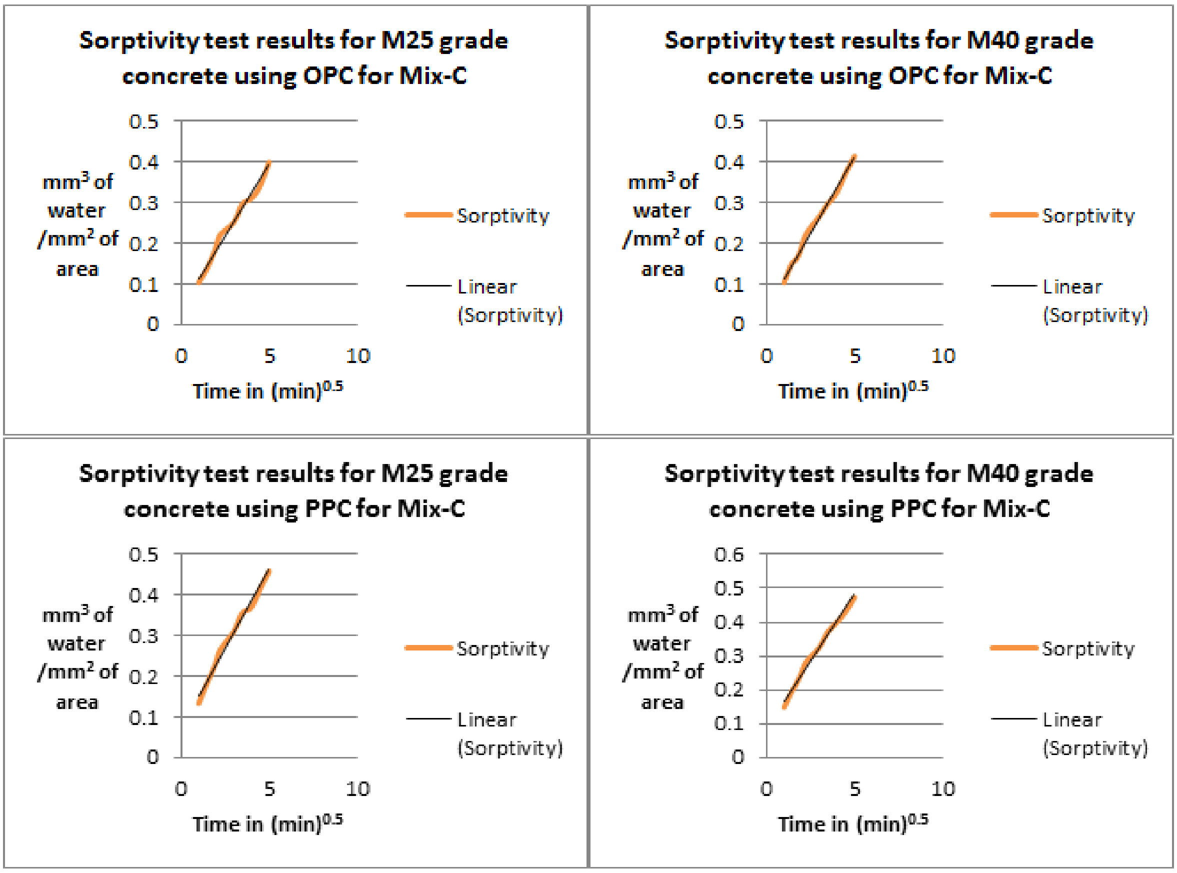

Figure 26: Sorptivity test result for Mix-C

After studying the behavior of all mixes related with sorptivity of the concrete, concrete made with 100% dredged marine sand i.e. Mix-C shows better results as compared to other two mixes i.e. Mix-A and Mix-B, respectively. Concrete Mix-C shows less water absorption due to capillary action as compared to that of Mix-A and Mix-B. This is due to the fine particles available in DMS and which makes the concrete less porous as compared to the control concrete.

5.6. Water absorption test:

Table 25: Water absorption test results for all concrete mixes

Concrete mix	Grade of concrete	Cement type	Initial wt. w_1 (kg)	Final wt. w_2 (kg)	Water absorption (%)
Mix-A	M25	OPC	8.607	8.725	1.67
	M25	PPC	8.305	8.469	1.97
	M40	OPC	8.685	8.794	1.25
	M40	PPC	8.514	8.624	1.29
Mix-B	M25	OPC	8.537	8.673	1.6
	M25	PPC	8.502	8.624	1.41
	M40	OPC	8.650	8.720	0.81
	M40	PPC	8.627	8.716	1.02
Mix-C	M25	OPC	8.509	8.627	1.24
	M25	PPC	8.345	8.486	1.35
	M40	OPC	8.649	8.730	0.72
	M40	PPC	8.515	8.599	0.98

Fig 27 shows the graphical representation of water absorption test of all concrete mixes. The results indicate that concrete Mix-C shows less water absorption as compared to that of Mix-A and Mix-B, respectively for both concrete grade M25 and M40 made using OPC and PPC both.

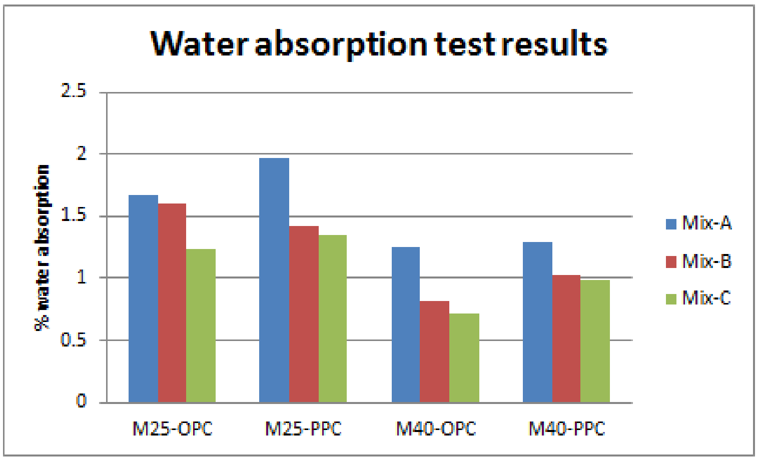

Figure 27: Water absorption test results for all concrete mixes

The concrete made with DMS showing slightly less percentage of water absorption as compared to that with river sand because of the presence of finer particles in DMS, which makes concrete less permeable which reduces the porosity of the concrete.

6. CONCLUSION

Reduction in compressive strength and weight after completion of acid and sulfate exposure for Mix-B and Mix-C are less as compared to that of concrete Mix-A for 3 months of exposure, which indicates that concrete made using DMS performed satisfactorily as compared to that with natural river sand.

Reduction in compressive strength is observed higher in case of concrete Mix-B and Mix-C as compared to that of concrete Mix-A for chloride exposure of 2 months, which indicates that concrete made with DMS has less resistance against chlorides. Further investigation are required to be made for the chloride resistance of concrete with DMS.

Corrosion rate determination using half-cell potentiometer is observed in embedded reinforcement for concrete Mix-C and Mix-B, which is less as compared to that of Mix-A after completion of accelerated corrosion test.

Time required for crack initiation in specimens of Mix-A is less as compared to specimens of Mix-B and Mix-C which indicate better resistance against corrosion for concrete made using dredged marine sand.

The sorptivity for the specimens of Mix-C found less as compared to concrete Mix-B and Mix-A.

Water absorption is found less in case of concrete specimens of Mix-C as compared to concrete Mix-B and Mix-A.

For the tests and duration attempted in present investigation, it allows the successful use of dredged marine sand in concrete construction activities.

REFERENCES

[1] Limeira,J., Etxeberria,M., Agullo,L., Molina,D., Mechanical and durability prop-erties of concrete made with dredged marine sand, Construction andBuildingMaterials, 19 April 2011,Pp. 4165-4174.

[2] Limeira,J.,Etxeberria,M.,Agullo,L.,Dredgedmarinesandinconcrete:Anex-perimentalsection of a harbor pavement, Construction and Building Materials,3 December 2009,Pp. 863-870.

[3] Dias,W.P.S., Seneviratne,G.A.P.S.N., Nanayakkara,S.M.A., Offshore sand for re-inforcedconcrete, 8 June 2007,Pp.1377-1384.

[4] AdamA.,StrengthandDurabilityPropertiesofAlkaliActivatedSlagandFlyAsh-Based GeopolymerConcrete,School of Civil, Environmental andChemicalEngineering, RMIT University Melbourne, Australia, August 2009,Pp. 30-35.

[5] Shetty,M.S., Concrete Technology (Theory and Practice),Revised edition2005,Pp. 489-500.

[6] Sathia,R., Ganesh Babu,K., Santhanam,M., Durability Study Of Low CalciumFlyAshGeopolymerConcrete,The3rd ACFInternationalConference-ACF/VCA2008,Pp.1153-1159.

[7] Barot.U.N., Experimental Investigation on Flexural and Shear Behaviour ofRe-inforcedConcrete Beams using GFRP Reinforcement, Major project(2009),NirmaUniverisity, Ahmedabad, Gujarat.

[8] Basack,S., Purkayastha,R. D., Engineering properties of marine clays fromtheeastern coast of India, Journal of Engineering and Technology ResearchVol.1 (6), Pp.109-114, September,2009.

[9] Stanish,K.D., Hooton,R.D., Thomas,M.D.A., Testing the ChloridePenetrationResistance of Concrete: A Literature Review, Department of CivilEngineeringUniversity of Toronto, Toronto, Ontario, Canada.

[10] Austin,S.A., Lyons,R., Ing,M.J., The Electrochemical behaviour of SteelRein-forced Concrete During Accelerated Corrosion Testing,Centre for InnovativeCon-struction Engineering, LoughboroughUniversity,Leicestershire, LE11 3TU, UK.

[11] Sangoju,B., Gettu,R., Neelamegam,M., Chloride-Induced Corrosion of Steel inCracked OPC and PPC Concretes: Experimental Study, American SocietyofCivil Engineers.

[12] Hafiz,M.S., Investigation of Abundant Treated Sea Sand With DifferentPercent-agesinConcreteBrickRatioof1:3, AfinalyearprojectreportsubmittedforthedegreeofBachelorofCivilEngineering,FacultyofCivilandEnvironmentalEngineering University Malaysia Pahang, December2010.

[13] Wang,H.Y., Durability of self-consolidating lightweight aggregate concreteusingdredgedsilt,Construction and Building Materials,4 November 2008,Pp. 2332-2337.

[14] Rodica,R.,Lupinca,I.,UsePossibilitiesforRiverSandinFoundry,AnaleleUni-versittii"EFTIMIE MURGU" Resita Anul XIX, NR. 1, 2010, ISSN 1453 - 7394

[15] EngineeringUseofMarineSandinCoastalProjects,TheAmericanandGlobalExperience, EMSAGG Seminar at Turkish Chamber of Shipping, Bob DeanUni-versity of Florida, May13,2011

[16] Guide to Durable Concrete,ACI 201.2R-08, American Concrete Institute,June2008.

[17] Marine sands in mortar, British Marine Aggregate Producers Association.

[18] Study of Environmental Aspects for the Use of Marine Sand Deposits, BEACHMEDproject,Phase-C

[19] IS 10262-2009 Concrete mix proportioning - guidelines, Bureau of IndianStan-dards, New Delhi, 2009.

[20] IS516-1959Methodsfortestsforstrengthofconcrete, BureauofIndianStan-dards, New Delhi, 1959.

[21] Vora,P.,Strengthanddurabilitystudyofflyashbasedgeopolymerconcrete,Majorproject(2012),NirmaUniversity, Ahmedabad, Gujarat.

[22] Rao,P.S.,Sravana,Rahim,Z.A.,Sekhar,T.S.,DurabilityDurabilityStudiesonSteelFibreReinforcedMetakaolinBlendedConcrete,CivilEngineeringDepart-ment, Jawaharlal Nehru Technological University College of Engineering,Hyder-abad.

[23] Hall,C.,Watersorptivityofmortarsandconcretes:areview,Magazineofcon-crete research, vol. 41, no. 147, Pp. 51-61, 1989

[24] George,V.,Zandbergen,J.,AGreenfieldProjectinIndia,AdaniReport.

[25] IS 2386 (Part I)-1963 Methods of test for aggregates for concrete, BureauofIndian Standards, New Delhi,1997.

[26] Malhotra,V.M.andCarino,N.JHandbookonNondestructive TestingofConcrete,Second Edition, Pp.241-245.