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Durability and Corrosion Study of High Strength Concrete Admixed with Washed Silt

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ABSTRACT

In this paper durability andcorrosion study was done in High Strength Concrete (HSC), in which washed silt (Industrial Waste from Zirconium Complex) was used as a partial replacement for fine aggregate. In addition to that, 5% of microsilica as a partial replacement for weight of cement is used as an admixture to improve the homogeneity property of concrete. For this study, M_{80} grade concrete was selected and it was achieved with various trial and error proportions. The tests were conducted for various proportions of washed silt replacement with fine aggregate in the range of 0%, 25% and 50%. The parameters of investigation includedfresh concrete properties, water absorbtion test, sorpitivity test, chloride penetration test, alkalinity test, compressive strength, split tensile strength and flexural strength test. The obtained results were compared with the control specimen and it was discussed in detail below.

Keywords:High Strength Concrete, washed silt, micro silica, durability, corrosion

1. INTRODUCTION

Corrosion one of the inevitable word in hardened concrete at present stage and it needs special attention to minimize these problems. Corrosion in concrete leads to rebar corrosion, cracks, spalling, etc., in order to overcome these types of problem, the basic nature of concrete to be changed and this was done by adding special admixtures like silicafume, copper slag, flyash, ground granulated blast furnace slag, etc., and also by partial replacement of fine aggregate or coarse aggregate by e-waste, granite dust, glass powder, rubber tire waste, coconut shell, etc.,

Oguzhan Kelestemur[1]have made an experimental investigation to study the corrosion behavior of reinforced concrete specimen by replacing coarse aggregate by waste vehicle rubber tires in the range of 2%, 5%, 7% and 10% by volume of coarse aggregate. The author was observed that the replacement of coarse aggregate decrease the mechanical strength of concrete and it increases the corrosion rates of the reinforcing steels embedded in the concrete. Lakshmi.R *et al*.[2]&[7] have done an experimental study in concrete by replacing coarse aggregate with e-waste in the range of 0% to 30% in M20 grade concrete. The author concluded that 20% of e-waste can be acceptable for strength development without any long term detrimental effects. D.Brindha *et.al*. [3]have made an experimental study on corrosion and durability test on concrete containing copper slag as partial replacement of sand and cement. The author concluded that copper slag can be used as an alternate to fine aggregate and it can be used as raw material for making blended cements.

Blessen Skariah Thomas*et.al*.[4]have investigated the behavior of concrete by partially replacing fine aggregate and coarse aggregate with copper slag and discarded tyre rubber in M30 concrete mix with 0.4 water cement ratio. Finally the author concluded that 50% of copper slag with 15% of rubber tyre shows good durability and it can use in all types of construction works. Prashant O Modani *et.al*. [5]have done their experimental study in concrete by replacing bagasse ash in the ratio of 0%, 10%, 20%, 30% and 40% by volume of fine aggregate in concrete. Based on their experimental result the author was concluded that concrete with 10% to 20% of bagasse ash will be a suitable replacement to fine aggregate. Hebe Gurdian *et.al*. [6]concluded that 50% replacement of recycled aggregate with natural coarse aggregate shows reduced strength in concrete compared to conventional concrete. K.Shyam Prakash *et.al*. [8] have investigated the compressive strength behavior of concrete, in which quarry dust was replacedas a fine aggregate up to 50%. The author was concluded that 40% replacement of sand by the quarry dust induced higher compressive strength and the workability of concrete decreases as replacement of quarry dust increases. The main objective of this paper is to study the durability characteristics of concrete as well as corrosion resistance by replacing industrial waste from zirconium complex, in place of fine aggregate and it was discussed in detail below.

2. MATERIALS USED

The cement used in this study was 53 grade OPC. The properties of cement are given in Table 1. Locally available river sand and granite was used in this study. Physical features of fine and coarse aggregate are presented in Table 2. Additionally washed silt from zirconium complex was composited as a partial replacement for fine aggregate to control corrosion. After several chemical processes the zirconium is separated from sea sand for making nuclear reactor fuel container, and the remaining sand waste produced in this process was washed silt and this was used in this study. Physical properties of washed silt are presented in Table 3 and chemical compositions of washed silt are shown in Table 4. To improve the durability characteristics of concrete, microsilicao was used as partial replacement for cement up to 5% by weight of cement. Properties of microsilica are given in Table 5.

Table 1. Properties of Cement

Sl. No.	Properties	OPC 53 (G)
1	Specific gravity	3.15
2	Fineness	4.0 %
3	Soundness	0.5 cm
4	Normal consistency	33.0 %
5	Initial setting time	60 min.
6	Final setting time	380 min

Table 2. Physical Features of Aggregates

Sl. No.	Parameters	Fine Aggregate	Coarse Aggregate
1	Specific gravity	2.60	2.82
2	Fineness Modulus	2.97	6.68

Table 3. Physical Properties of Washed Silt

Sl. No.	Properties	Test Results
1	Particle shape	Irregular
2	Appearance	White & Silty
3	Specific gravity& Fineness modulus	2.681& 2.102

Table 4. Chemical Composition of Washed Silt

Sl. No.	Properties	Content
1	ZrO_2	16.2
2	SiO_2	47.5
3	Loss of ignition	27.8
4	MgO	0.4
5	Fe_2O_3	0.07
6	Hf	0.21
7	Al	0.03
8	Na_2O	0.7

Table 5. Properties of Microsilica

Sl. No.	Properties	Content
1	SiO_2 (%)	94.21
2	Al_2O_3 (%)	0.64
3	Fe_2O_3 (%)	1.56
4	CaO (%)	0.41
5	S + C + MgO + Na_2O + K_2O + SO_3 + LOI (%)	3.18

3. EXPERIMENTAL PROGRAMME

Initially, M_{80} grade concrete was achieved by trial and error method according to ACI 211.4r [8]. Totally 3 concrete mixes were used in this experimental study and the details of mix proportion are shown in Table 6. First, fine aggregate with cement and microsilica was poured into the pan and mixed thoroughly for 2 minutes after that coarse aggregate was poured into that and mixing process was done for another 2 minutes. Secondly, 70% of water mixed with superplasticizer was added to the dry mix and the mixing process continues for 3 minutes, thirdly remaining water was poured into the mix and it continues for the next 2 minutes and finally it was poured into the mould. Demoulding of dry concrete was done after 24 hours of placing the concrete in the mould which is then transferred and placed in the curing tank for 28 days and it was shown in Figure 1. The chloride resistance of the high strength concrete was studied through chemical attack by immersing concrete specimen in 2 molarconcentration Nacl solution and it was shown in Figure 2. The solution was replaced by every 7 days to maintain constant concentration throughout the test period. The corrosion and durability test was performed at 28 days.

Table 6 Mix Proportions

Material	Control Specimen (CS) Weight (kg/m^3)	25% replacement of washed silt (Z_{25}) Weight (kg/m^3)	50% replacement of washed silt (Z_{50}) Weight (kg/m^3)
Cement	691.15	691.15	691.15
Microsilica	36.38	36.38	36.38
Fine aggregate	657.64	493.23	328.82
Washed Silt	0	164.41	328.82
Coarse aggregate	900	900	900
Water	189	189	189
Superplasticizers	10.9	10.9	10.9

Fig 1: Curing of Specimen in Water

Fig 2: Curing of Specimen in Nacl Solution

4. RESULTS AND DISCUSSIONS

A) GENERAL

The specimens were tested after 28 days of curing. The test was conducted in a well established laboratory and test results are discussed below.

B) FRESH CONCRETE PROPERTIES The potential strength and durability of concrete of a given mix proportion was dependent on consistency and workability test. Following test were performed for all the three mixes, they are slump test, flow test, compaction factor test and vebe consistometer test. Table 7 shows the test results of fresh concrete properties. From the test result, it was concluded that all the three mixes were stiff and dry, and it needs vibration while placing the concrete in mould.

Table 7.Results of Fresh Concrete Properties

Mix Designation	Slump Test (mm)	Flow Test (%)	Compaction Test	Vebe consistometer Test (Sec)
CS	18	23	0.85	10
Z_{25}	15	18	0.79	14
Z_{50}	10	12	0.78	16

C) WATER ABSORPTION TEST

The water absorption test was conducted in 150mm diameter x 50 mm height cylindrical specimens, andit was immersed both in water and Nacl solution for 28 days. The specimens were oven dried for 24 hours at the temperature 100°C until the mass became constant and again weighed and it was shown in Figure 3. This weightwas noted as the dry weight (W_1) of the cylinder.After that the specimen was kept in hot water at 85°C for 210 minutes and it was shown in Figure 4. Then this weight was noted as the wet weight (W_2) of the cylinder. Percentage of water absorption was calculated by the formula,

Percentage of water absorption = $[(W_2 – W_1) / W_1]$ x 100

Where, W1 = oven dry weight of the cylinder in grams.

W_2 = after210 minutes wetweightof the cylinder in grams.

Figure 5 shows the test result of water absorption. From the test results, normal curing of concrete shows water absorption percentage in the range of 2%, 1.21% &2.1% of CS, Z_{25}& Z_{50}. Z_{25} concrete mix shows lower water absorption percentage when compared with other mix,and this was due to the presence of washed silt, which reduced the pores present in the concrete. But when thespecimen was subjectedto Nacl curing, all the concrete mix shows more water absorption capacity,when it was compared with normal curing. The reason behind the result makes clear that, after Nacl curing, the concrete matrix was disturbed with the solution and it leads to some material loss in concrete. In addition to that, the test result clearly explains that concrete with 25% replacement of washed silt with fine aggregate shows good result compared to the other concrete mix under Nacl curing. The reason behind the poor performance of Z_{50} concrete mix was due to very dry and stiff concrete matrix and it needs vibration while compacting the concrete. During compaction some point inside the concrete was not well compacted and it leads to the formation of honeycombs in the concrete and this will leads to the more water absorption capacity of concrete.

Fig 3: Specimens kept in Hot Air Oven

Fig 4:Specimens kept in Hot Water

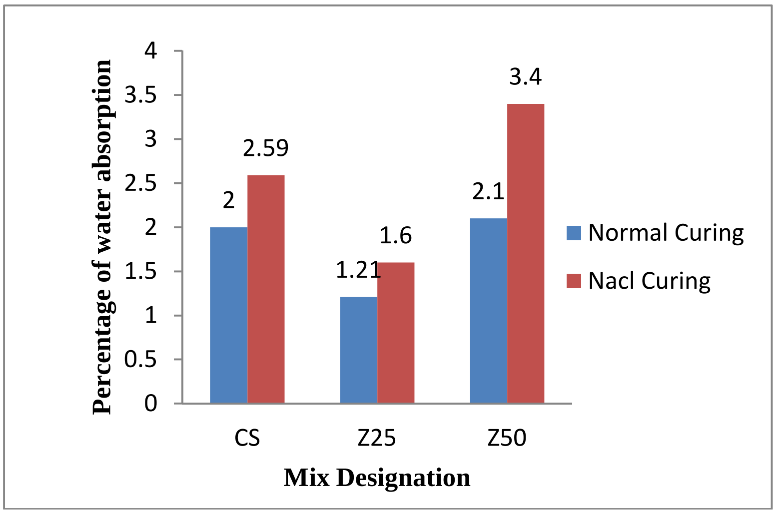

Fig 5: Test Results of Water Absorption

D) SORPTIVITY TEST

The sorptivity test was determined in cylindrical specimen of size 150mm diameter x 50mm height. Specimens were kept in water and Nacl solution for 90 days curing. After that specimens were dried in oven at a temperature of 100°C for 24 hours. The top surface of the specimen was sealed by a transparent polythene cover to avoid the peripheral surface flow of water, and the sealed specimen was immersed in water level not more than 5mm above the base of the specimen and it was shown in Figure 6. According to Vimal N.Patel[9], the specimens were weighed in machine after 30 minutes of curing in water. Sorptivity (S) was calculated by the formula,

Sorptivity (S) = $\{\Delta w/Ad\} / t^{1/2}$

Where; S= sorptivity in mm.

t = elapsed time in minutes.

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Δw= change in weight = W_2-W_1.

W_1 = oven dry weight of cylinder in grams.

W_2 = weight of cylinder after30 minutes capillary suction of water in grams.

A= surface area of the specimen through which water penetrated.

d = density of water.

Figure 7 shows the result of sorpitivity test. From the test result, it was clearly observed that water absorption in normal curing was relatively low, when compared with Nacl curing. But in Z_{25} concrete mix the water absorption value remains constant in both types of curing. Therefore, 25% replacement of washed silt instead of fine aggregate shows good resistance to water absorption when compared with other concrete mixes and this was may be due to the above mentioned reason in the water absorption test.

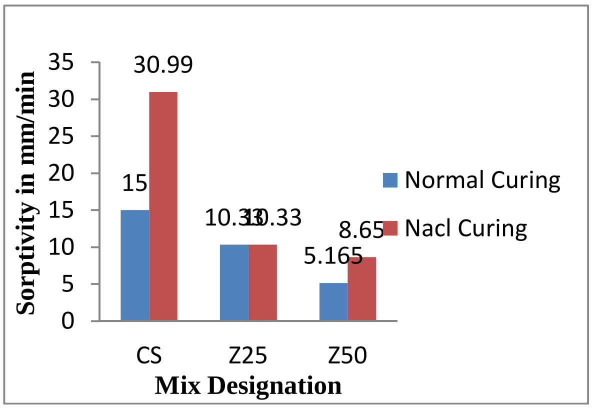

Fig 7: Test Results of Sorptivity

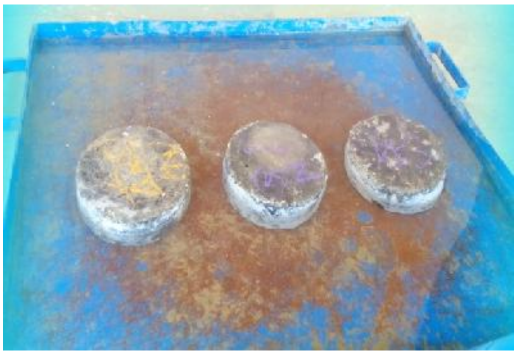

Fig 6: Specimens kept in Water for curing

E) CHLORIDE PENETRATION TEST

The chloride penetration test of concrete was done according to RILEM TC 178-TMC[10]. After 28 days, the specimen which was cured in Nacl solution was crushed and converted into powder sample. The sample must pass through 0.315mm sieve, and nearly 5 grams of powder sample (M_{pe}) with exact mass at $\pm$ 0.001gram was taken to the test. After that, the sample was transferred to 250ml beaker. Add 50ml of distilled water to the sample, and place the beaker in magnetic agitating plate for 3 minutes and it was shown in Figure 8. Filter the solution with filter paper and add 2 ml of concentrated nitric acid and complement the filtered solution up to 250 ml (V_f) in graduate flask. Take 10 ml of solution (V_p) and pour it into a conical flask and titrate against with silver nitrate solution (C_{AgNO3}). 2 to 3 drops of potassium chromate (K_2CrO_4) is added as an in indicator. The volume of silver nitrate solution (V_e) required to colour change from yellow to reddish brown. Percentage of chloride penetration was calculated by the formula,

Percentage of chloride penetration = { 3.545x C_{AgNO3} xV_e xV_f } / { M_{pe} x V_p }

Where, V_e = volume of silver nitrate solution.

V_f = volume of filter solution + 2 ml of concentrated nitric acid

V_p = volume of pipette solution.

M_{pe} = 5 gram of powder sample.

C_{AgNO3} = {C_{HCl} x V_{HCl}} / V_t

Figure 9 shows the results of chloride penetration. From the test result, it was concluded that the percentage of chloride penetration was more in Z_{50} concrete mix compared to the other concrete mix. Control specimen with normal curing shows 0.25% of chloride penetration in concrete and this indicates that the tap water which was used for curing has consist some amount of chloride content. Z_{25} concrete mix shows 1.17% of chloride penetration value which was relatively lower when it was compared with control specimen with Nacl curing value of 1.45%. . Therefore, 25% replacement of washed silt to fine aggregate shows good resistance to chloride penetration when compared with other concrete mixes.

Fig 8: Sample placed in magnetic stirrer and filtration of solution

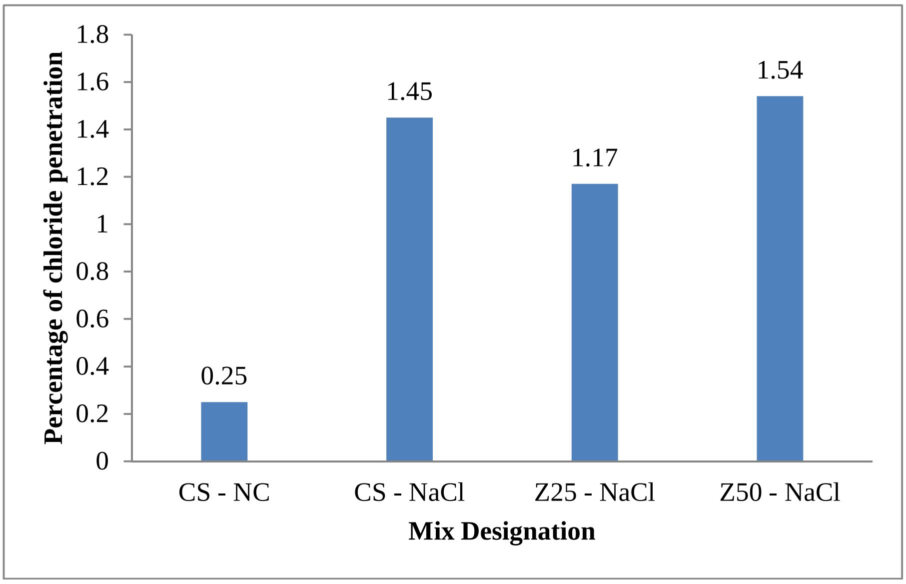

Fig 9: Test Results of Chloride Penetration

F) ALKALINITY TEST

After 28 days curing, the concrete specimens are taken out from the curing tank. Specimens are dried in oven at105°C for 24 hours. The dry specimens cool to room temperature. After that, dry specimens are broken out and separate the mortar from the concrete. Then the mortar is grinded into powder form. The powdered mortar was sieved in 150µ. 10 gm of mortar is taken and it is diluted in 50ml distilled water and completely stirred it. Then the pH meter immerse into the solution and pH value of the solution was noted. The general pH value of the solution and the level of inducing corrosion in the concrete were noted and it was shown in Table 8. From the test results, it was confirmed that the pH value of Z_{25}& Z_{50} concrete mix was more compared to control and normal water curing specimen. The pH value observed for the alkalinity test showed that the specimen with washed silt shows more resistance towards corrosion.

Table 8.Results of Alkalinity Test

Mix Designation	pH value for Normal Curing	pH value for Nacl Curing
CS	11.4	11.2
Z_{25}	11.8	12.5
Z_{50}	11.5	12.3

G) HARDENED PROPERTIES

The basic hardened properties of concrete were discussed in detail below. After 28 days of curing, the following test was conducted in the concrete specimen, and they are compressive strength test, split tensile strength test & flexural strength test, and the test results was given in Table 9.

Table 9. Results of Hardened Concrete

Mix Designation	Compressive Strength (N/mm^2)			Split Tensile Strength (N/mm^2)			Flexural Strength (N/mm^2)		
	Normal Curing	Nacl Curing	% decrease in strength	Normal Curing	Nacl Curing	% decrease in strength	Normal Curing	Nacl Curing	% decrease in strength
CS	80.24	68.55	14.57	5.71	4	29.95	5.8	5.3	8.62
Z_{25}	66.93	58.88	12.03	3.618	3.488	3.59	5.6	5.2	7.14
Z_{50}	52.8	43.11	18.35	3.004	1.56	48.07	4	2.96	26.00

One of the basic tests on hardened properties of concrete was compressive strength. In this test, the specimens cured in Nacl solution show reduction in strength, when it was compared with normal water curing. The percentage of decrease in strength was in the range of 14.57%, 12.03% & 18.35% of CS, Z_{25}& Z_{50}. Similarly, split tensile strength and flexural strength test result also indicate a reduction of strength. Split tensile strength shows reduction in strength in the percentage of 29.95%, 3.59% &48.07% and for flexural strength the percentage of decrease in strength was in the range of 8.62%, 7.14% & 26.00%.

Regarding the test results, it was concluded that the concrete mix with 25% replacement of fine aggregate with washed silt shows high resistance to chloride attack and shows minimum percentage of loss in strength when compared with other mix.

5. CONCLUSIONS

Based on the experimental results washed silt can be used as an alternate for fine aggregate up to a partial replacement of 25%. Z_{25} specimens cured in Nacl solution show lower water absorption and sorptivity value than the specimens cured in normal water. In the chloride penetration test, the percentage of chloride penetration in concrete was minimum for Z_{25} specimen, this shows that 25% replacement of washed silt to fine aggregate shows good resistance to chloride attack when compared with other concrete mixes.The pH value observed for the alkalinity test showed that the specimen with washed silt shows more resistance towards corrosion. Regarding the hardened properties

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result, it was concluded that the concrete mix with 25% replacement of fine aggregate with washed silt shows the minimum percentage of loss in strength when compared with other mix. The reason behind the poor performance of Z_{50} concrete mix was due to very dry and stiff concrete matrix and it needs vibration while compacting the concrete, and this leads to the formation of honeycombs in the concrete and it results in more water absorption capacity of concrete and reduce the strength of concrete.

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