COMPRESSIVE STRENGTH AND SORPTIVITY OF PLAIN AND BLENDED CONCRETE EXPOSED TO SALINE ENVIRONMENT

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ABSTRACT. This paper presents the strength and sorptivity study of concrete using fly ash (FA) and silpozz exposed to sea water. Conventional concrete made with 100% cement. First blended concrete series made with 0% FA and 10-30% replacement of silpozz with cement and second series made 10% FA and 10-30% silpozz replaced with cement. The studied parameters are compressive strength for 7, 28, 90, 180 and 365 days and flexural strength and split tensile strength for 7, 28 and 90 days of sew water curing (SWC) and normal water curing (NWC) samples. Modulus of elasticity and strength reduction factor (SRF) in bond strength along with slip of 28 days SWC samples are also studied. The chloride binding capacity, water absorption and sorptivity were observed as durability indicator. It reveals from the present investigation that incorporation of silpozz significantly improves the strength and reduces sorptivity of concrete against sea water.

Keywords: Blended concrete, Compressive strength, Deterioration, Fly ash, Silpozz.

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INTRODUCTION

The growth of concrete technology is completely based on its strength but not only that should be considered but the coarseness degree of various environmental circumstances to which concrete is being exposed for life long as should be considered and have given lot of importance. So, finally both compressive strength and its nature of durability are considered clearly at different design phase and its relationship also is taken into account. While estimating the conditions of present structures, concrete's durability is the most important consideration to be taken into account in designing new structures. Construction of concrete is gradually very cost effective as its durability has been higher so it's becoming one of the most complex things. When one understands the concrete's fundamental basic of durability, all starts finding new methods to increase its service life of all the new and upcoming structures. Concrete's long-time durability potential is the key to knowledge as it consists of uncommon materials such as recycled aggregate and high silica aggregates with mineral admixtures. Although concrete is probably to get damaged upto some extent, ensuring good durability of concrete and minimizing the rate of damage. Some of the researchers have reported the deterioration mechanism in marine exposure condition such as Sunil [1] studied the percentage decrease in compressive strength for the period of one year of exposure both in fresh water and sea water curing and concluded that the compressive strength decreases as the age of exposure increases. Menon et al. [2] investigated the effect of high strength concrete incorporated with fly ash (FA), silica fume (SF) and ground granulated blast furnace slag (GGBS) with super plasticizer under severe exposure sea water tidal zone without serious deterioration. Wegian [3] reported all forms of deterioration can be controlled by using higher cement content in sea water. Anwar and Roushdi [4] showed the improvement of mechanical properties of concrete containing OPC, FA and SF in artificial sea water and resist against environmental deterioration. Jena and Panda [5-7] studied the development of mechanical properties in blended concrete made with silpozz to improve the durability of marine structures and diffusion of chloride and carbonation is minimized due to replacement of FA and silpozz with ordinary Portland cement (OPC). Seyed et al. [8] investigated the compressive strength and water absorption with chloride ion penetration by using 5, 10, 15, 20 and 25% rice husk ash (RHA) incorporated with 10% micro silica (MS) and found 15% RHA with 10% MS gives optimized results. Kumar et al. [9] investigated the better strength and sorptivity of concrete by utilising the sugarcane bagasse ash and SF as a partial replacement of cement. Kartini et al. [10] studied the strength and sorptivity of blended concrete incorporating 20-30% rice husk ash (RHA) replaced with OPC.

The objective of this present work is to study the compressive strength as well as water absorption and sorptivity of blended concrete incorporated with FA and silpozz with proper doses of super plasticizer in marine environment and the utilization of eco-friendly materials in construction industry.

METHODOLOGY

Materials

In this study OPC 43 grade cement was used. The physical properties of OPC determined as per is 8112-1989 [11] such as initial setting time, final setting time, standard consistency, specific gravity and fineness are 165 min, 360 min, 34%, 3.15 and 333m^2 / kg respectively. Fineness modulus of coarse aggregates 7.0, specific gravity 2.86, impact value 24% and crushing value 23.3% was used. Specific gravity of fine aggregate 2.67 and fineness modulus 3.03 (zone-3) was used. Normal water having ph value 6-8, sea water of Bay of Bengal, puri beach and CERA HYPERPLAST XR-W40high end super plasticizer (sp) was used. The experimental value of coarse and fine aggregates is confirming to is 383-1970 [12]. Physical properties FA and silpozz supplied by the supplier is presented in Table 1 and chemical composition of cementitious materials is presented in Table 2.

Table 1 Physical properties of FA and Silpozz

PHYSICAL PROPERTIES	FA	SILPOZZ
Specific gravity	2.12	2.3
Bulk Density (gm/cc)	1.2	0.23
Specific surface, m^2/g	33	17
Particle size (Micron)	34	25
Color	Gray	Gray black
Physical state	-	Solid Non-hazardous

Table 2 Chemical composition of cementitious materials

OXIDES (%)	CEMENT (OPC)	SILPOZZ	FA
SiO_2	20.99	88.18	58.13
Al_2O_3	6.05	1.61	31.00
Fe_2O_3	6.01	0.56	4.10
Carbon	-	2.67	-
CaO	62.74	1.59	0.60
MgO	1.33	1.63	0.10
K_2O	0.40	1.67	0.90
Na_2O	0.04	-	0.05
SO_3	1.82	-	0.12
TiO_2	.025	-	1.63
Others	-	2.09	0.011
Moisture content (%)	-	0.79	3.0
Loss on ignition (%)	1.14	0.04	0.29

Mix Design and Identity

The mix design is targeted for M30 as it is the marine exposure condition as per IS 10262-2009 [13]. The obtained material ratio was (1:1.44:2.91), water to binder ratio 0.43. The controlled specimen is prepared with 100% OPC without SP and there is no change of quantity of materials. As SP is used in blended concrete mixes, the amount of water was reduced by 20% based upon the several trial mixes in order to maintain the slump in between 25-50 mm. The strength properties and durability observations were studied and their percentage decrease in strength was evaluated. The mix identity MC100F0S0 means OPC

100%, FA 0% and silpozz 0% without SP. Similarly the mix M1C90F0S10 means OPC 90%, FA 0% and silpozz 10% with SP 0.2% and so on. The details of mix identity along with their percentage of cementitius materials with SP are presented in Table 3 and details of concrete mix quantities in kg/m3 along with slump value and compaction factor are shown in Table 4.

Table 3 Details of cementitius materials with SP

MIX IDENTITY	OPC (%)	FA (%)	SILPOZZ (%)	SP(%)
MC100F0S0	100	0	0	-
M1C90F0S10	90	0	10	0.20
M1C80F0S20	80	0	20	0.29
M1C70F0S30	70	0	30	0.40
M1C80F10S10	80	10	10	0.22
M1C70F10S20	70	10	20	0.33
M1C60F10S30	60	10	30	0.47

Table 4 Details of mix quantity

MIX IDENTITY	CEMENT (kg/m^3)	FINE AGGREG-ATE (kg/m^3)	COARSE AGGREG-ATE (kg/m^3)	FA (kg/m^3)	SILPOZZ (kg/m^3)	WATER	SP (kg/m^3)
MC100F0S0	434.32	624.77	1264.97	0	0	186.76	-
M1C90F0S10	390.88	624.77	1264.97	0	43.44	149.40	0.781
M1C80F0S20	347.45	624.77	1264.97	0	86.86	149.40	1.005
M1C70F0S30	304.00	624.77	1264.97	0	130.33	149.40	1.229
M1C80F10S10	347.45	624.77	1264.97	43.44	43.44	149.40	0.781
M1C70F10S20	304.00	624.77	1264.97	43.44	86.86	149.40	1.005
M1C60F10S30	260.60	624.77	1264.97	43.43	130.33	149.40	1.229

RESULTS AND DISCUSSIONS

Properties of Fresh Concrete

Properties of fresh concrete were measured by slump value and compaction factor to know the workability. The dose of SP was added only to maintain the slump in between 25-50 mm and the experimented slump ranged from 34 to 42 mm was observed. The compaction factor ranges from 86.20 to 96.20% which shows moderate workable concrete at all levels.

Hardened Concrete Property

The hardened concrete property was determined as per IS 516-1959 [14]. The property of hardened concrete is evaluated by their compressive strength upto 365 days curing period. The decrease in strength depends upon the time of exposure, quality of materials, concentration of CO_2, diffusion rate of chloride into concrete samples and other harmful constituents present in the sea water.

Compressive strength

Figures 1 and 2 show compressive strength versus curing time in days for both NWC and SWC samples respectively. The percentage decrease in compressive strength is limited to 8%

for 12 months study but the sample having 10% FA and 20% silpozz replaced with OPC gives minimum 4.2%.

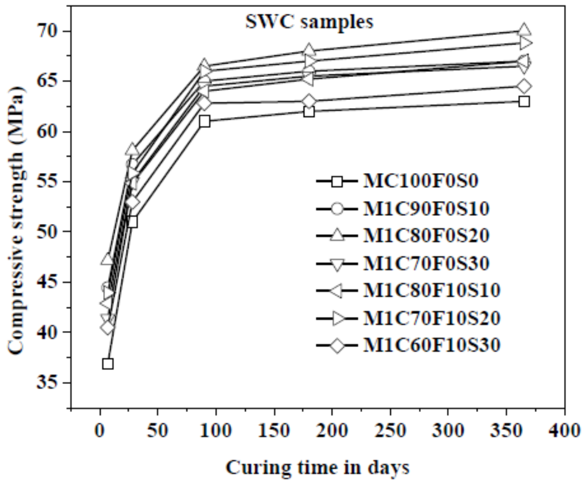

Figure 1 Compressive strength vs. curing time in days (SWC samples)

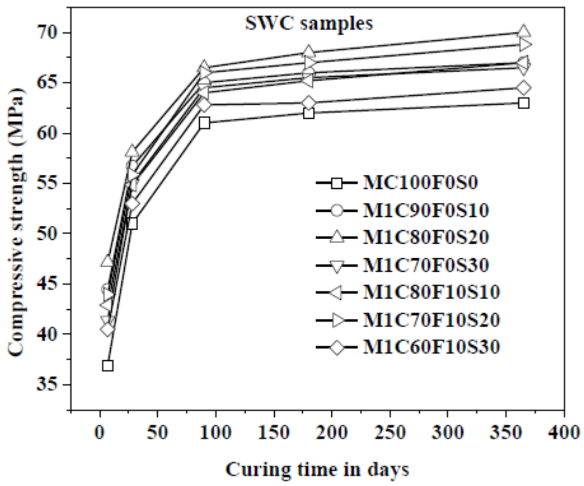

Figure 2 Compressive strength vs. curing time in days (SWC samples)

It is observed from Figure 2 that the normal mix shows higher percentage decrease in compressive strength at all ages of curing. The sodium chloride and some amount of CO_2 present in sea water reacts with $Ca(OH)_2$ and the formation of hydrochloric acid and $CaCO_3$ may reduce the strength gain in sea water. But FA and silpozz with proper doses of SP restricted the intrusion of chloride and CO_2, thus decrease in strength is minimizing. The percentage decrease in compressive strength of sample having 0% FA and 20% silpozz replaced with OPC is 2% after 3 months of exposure and 4.8% after 12 months as compared to conventional concrete. From the above study, concrete works better in sea water with FA and silpozz having proper doses of SP. The percentage decrease in compressive strength for conventional concrete is 7% at 365 days of SWC curing compared with NWC samples. It is observed that the rate of deterioration is more in between 28 to 90 days and slowly reduces to 2% from 90 to 365 days. The silpozz based concrete without FA performed better in normal water at all ages but the blended sample containing 10% FA and 20% silpozz performed better in sea water in long-term basis at least for a period of one year which is experimented from this study. The percentage reduction in strength is seems to be very small for one year but the costal structures are vulnerable for long-term exposure conditions. Therefore, it may be recommended that the resistance against concrete deterioration in marine environment is significantly enhanced by using FA and micro silica present in silpozz with proper doses of high-end SP.

Durability Properties

Deterioration of structural components in marine climate is generally associated with the chlorides penetration into concrete causing damage. The WSC known as free chloride and ASC known as total chloride are determined as per IS 14959 – 2001 (Part-1I) [15]. Water absorption and sorptivity are done confirming to ASTM C 1585 – 04 [16]. The samples are tested for water absorption and sorptivity after curing 28 days in normal water and SWC precast samples. The test procedures are described below for both water absorption and sorptivity test.

Chloride Binding Capacity

The chloride binding capacity (P_{cb}) can easily be evaluated as per the following relation.

$P_{cb} = [(C_t - C_f) / C_t] *100$ whereas C_t = Total chloride, C_f = Free chloride. Figure 3 shows chloride binding capacity (%) versus concrete mix.

It is observed that the chloride binding capacity in percentage is 24.44%, 23.91%, 23.95% and 24.15% for 28, 90, 180 and 365 days of SWC control samples respectively. At instance chloride binding capacity is more upto the age of 28 days but subsequently the value obtained is less. This is due to the physical chloride binding in concrete observed by Cheewaket et al. [17]. Due to pozzolanic reaction, C–A–H, ettringite, C–S–H, and monosulfate produced which are responsible for physical chloride absorption. Physical adsorption and chemical reactions are two main reasons for chloride binding capacity of concrete Rui et al. [18]. In this study FA contains aluminium oxide (Al_2O_3) at 31%, whereas OPC contains Al_2O_3 only 6.05%. After replacing FA in concrete, the amount of Al_2O_3 increases, as a result of which chloride binding capacity increases. It is also observed that when percentage of silpozz increases the chloride binding capacity (%) is increased.

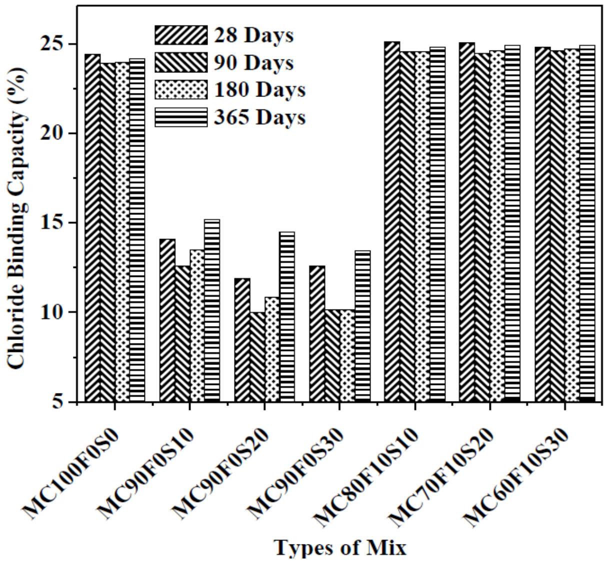

Figure 3 Chloride binding capacity (%) vs. Types of mix

Water Absorption

The graphical plot between water absorption and concrete mixes is shown in Figure 4. It is observed from Figure 4 that the water absorption capacity for conventional concrete is 2.6% and 2.08% both in NWC and SWC pre-cast samples respectively.

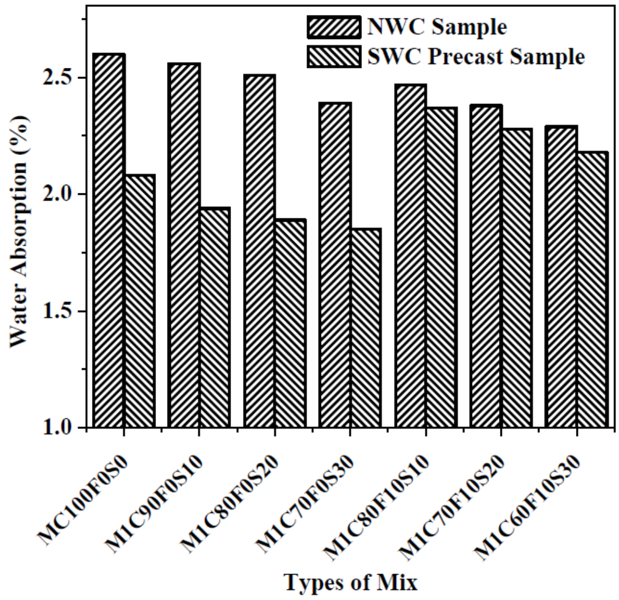

Figure 4 Water absorption (%) vs. Types of mix

It is also observed that SWC pre-cast blended concrete samples have less absorption capacity as compared to NWC samples. It is clear from the observations that the pre-cast samples have already cured in normal water for 28 days and then they have been cured in sea water for next 28 days. Therefore, absorption capacity decreases for hardened matured stage. When the replacement percentage of silpozz increases, the absorption capacity decreases. When FA is replaced, again absorption capacity increases and after replacing silpozz, it counteracts the absorption capacity and reduces the rate of absorption. After replacing FA, the absorption capacity increases for both in NWC and SWC pre-cast samples. Silpozz based samples have higher resistivity then the composite samples having FA and silpozz. The absorption capacity depends on the porosity of concrete, particle size of FA and silpozz and their inner structural mechanism of concrete. The dense and compact structured concrete may give less absorption capacity.

Sorptivity

The comparison results of the sorptivity test between NWC and SWC pre-cast samples have shown in Figure 5. It is observed from Figure 5 that the conventional concrete has the highest sorptivity value among all mixes both in NWC and SWC pre-cast samples.

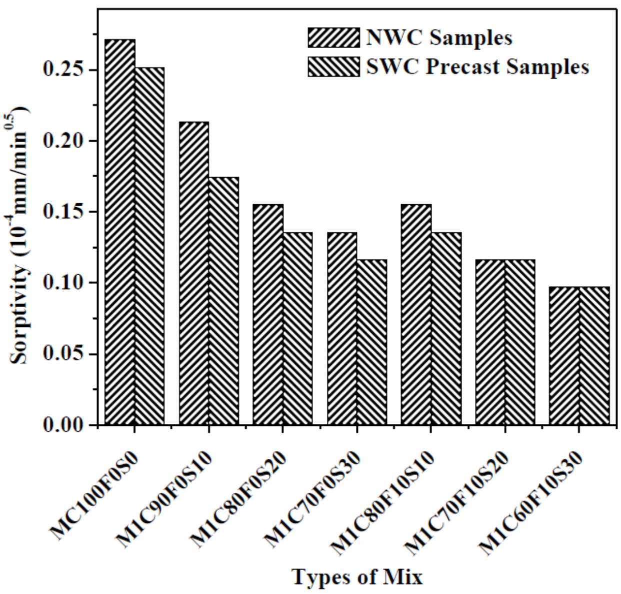

Figure 5 Sorptivity vs. Types of mix

The samples M1C70F10S20 and M1C60F10S30 have same sorptivity value for both in NWC and SWC. The value of sorptivity decreases by the partial replacement of silpozz and the value increases after partial replacement of FA. The result obtained from the silpozz based SWC samples is less than the NWC composite samples partially replaced with FA and silpozz. In normal water curing, a significant amount of calcium hydroxide migrates from specimens pores into surrounding water resulted less dense matrix hence sorptivity is more but in pre-cast samples which have already cured in normal water for 28 days and become hardened stage provides dense matrix. Then after the pre-cast samples were cured in sea water for 28 days and taken for testing which gives less sorptivity. In case of higher water-cement ratio with 20% silpozz replacement, upon evaporation leaves voids spaces in concrete specimen leads to higher absorption but in lower water-cement ratio, doses of SP enhances the liquidity of silpozz concrete mixes and optimize the compaction results high impermeable concrete and less absorption capacity.

CONCLUSIONS

The following concluding remarks may be drawn from the present study:

- From the study it reveals that the concrete deterioration is not significantly changed. The SRF is found to be less than 3% and 8% for 10% FA upto 20% silpozz replaced with cement at 90 and 365 days of exposure respectively.
- The SWC pre-cast samples have better performance against water absorption. When the replacement percentage of silpozz increases, the absorption capacity decreases. After replacing FA the absorption capacity increases for both in NWC and SWC pre-cast samples.
- The SWC pre-cast samples are showing lower sorptivity value than the NWC samples after 28 days of curing. The conventional concrete has the highest sorptivity value among all mixes both in NWC and SWC pre-cast samples. The samples M1C70F10S20 and M1C60F10S30 have same sorptivity value for both in NWC and SWC pre-cast samples.

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