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Experimental investigation of Strength and Microstructure properties of Sea water sea sand concrete

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Abstract:
Background*:Concrete is a commonly used construction building material because it is characterized by its compressive strength, which ultimately gives durability and stability to the structure. Resources essential in the production of concrete cement, sand, aggregate, and water. Today's fast urbanization has increased the demand for construction materials, causing a shortage of these resources. Day-to-day infrastructure is leading to the demand for fresh water and river sand. To create replacements for these materials, research and development are still being done. On the other hand, sea sand and seawater are abundant in coastal areas. Recent research has shown that these substances can be used in place of fresh water and river sand. Furthermore, construction can be done without harming the ecosystem close to the coast. It is critical to know how concrete responds to sea sand and seawater in these circumstances. Numerous studies have looked at how seawater and sea sand affect concrete in comparison to freshwater. Previous studies have also demonstrated good outcomes when concrete is mixed with seawater and sea sand in its early ages and a slight reduction in lateral strength. This variation in strength causes because by the presence of chloride ions.*
Materials and Methods*: In thispresent study of Seawater sea sand concrete, Fly ash is used as supplementary cementitious material, Sea sand is used as a substitute for natural sand, and seawater is used as a replacement for Tap water. Sea water is used for mixing and curing purposes. In this paper Strength and microstructure properties are evaluated and presented.*
Results*: Results of compressive strength, Carbonation test, and microstructure study of saltwater sea sand concrete (SWSSC) with the addition of additional cementitious materials using scanning electron microscopy (SEM) are reported in this paper, along with that different patterns of SEM pictures of seawater sea sand concrete are presented.*
Conclusion:*This study concluded that for microstructure analysis of seawater sea sand concrete for 90 days' cracks and voids are observed and it causes a slight reduction in strength. This defect can be improved with the replacement of nanocomposite materials.*
Key Word*: Sea water sea sand concrete, Compressive strength, Carbonation, Scanning Electron Microscopy.*

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I. Introduction

Concrete is the most-used construction material worldwide whose production globally consumes over two billion tons of freshwater every year, this is approximately 9% of the global industrial water demand [1].The civil engineering world, especially in developed countries have been thinking about the next challenge will be lessening the potential for water / fresh water that can be used as an ingredient concrete mixing [2] Seawater is water gotten from sea, which is salty in taste. Sea water can be said to have a solution containing a great number of elements in different proportions. Primarily sea water contains some chemical constituent such ions of chloride, magnesium, calcium and potassium[3].The human population is concentrated near coastal areas, as about 60% of the world's population lives within 100 km of the coast. In the social-economic development of coastal areas, marine infrastructures play an important role, and reinforced concrete is the most widely used material in these infrastructures. One major challenge in the development of marine infrastructures is the shortage of freshwater and river/manufactured sand for making concrete on site, as the transportation of these materials is not only costly but also environmentally unfriendly, while desalination of seawater and sea-sand is also pricey [6]. The consumption of tremendous amounts of raw materials, particularly river sand and freshwater, in concrete production has raised serious environmental concerns. Extraction of river sand as fine aggregate impacts negatively on river ecosystems, navigation and flood control[4]. Massive river sand and gravel resources have been consumed for the construction of concrete structures in the past years, resulting in a huge amount of CO2 emissions [5]. More than 90% of the world's dredged sea sand has been used as a raw material in the construction industry, with over 45% of the dredged sea sand being used as fine aggregate for concrete [4]. People have recently turned their attention to the plentiful sea sand resources due to the growing size of engineering buildings and the growing scarcity of river sand resources. Ordinary concrete takes longer to reach its long-term strength than sea sand or saltwater, although both gain early strength faster than ordinary concrete. Due to their high chloride content, sea sand and seawater are likely to hasten the strength development of concrete during its early phases [7]. As river sand cannot keep up with the growing demand from the building industry, manufactured sand is becoming more and more in demand as fine aggregates for creating concrete. Due to its scarcity, Natural River sand's price has risen sharply. In this situation, using produced sand is no longer an option. Therefore, studying the differences between river and sea sand's qualities will help determine whether sea sand can be modified to replace river sand as an alternative that is becoming depleted in the coming years. Also, the addition of GGBS promotes strength gain when mixed up to 55% [8]. Both the environment and the construction industry's bottom line will gain from the substitution of fine aggregate in concrete with sea sand. In this way, it will help to lessen the shortage of fine aggregate. Sand is a major resource in the building sector. In today's construction business, concrete is employed extensively. Similarly, it is crucial to lower the embedded CO2 in concrete because cement contributes up to 10% of global CO2 emissions. It is vital to reduce CO2 emissions by looking into alternatives, such as using thermal power plant waste instead of cement, for example, GGBS, fly ash, and so on.

Aim

To examine the impact of sea water sea sand concrete with supplementary cementitious material on strength and microstructure properties.

Objectives

1. To examine early and later compressive strength of sea water sea sand concrete.
2. To determine the optimum mix design of sea water sea sand concrete.
3. To investigate the effect of salts on sea water sea sand concrete using carbonation test.
4. To compare microstructure characteristics of conventional and sea water sea sand concrete using Scanning Electron Microscope.

II. Material and Method

This research work has been carried out at B G Shirke Construction Pvt Ltd Pune, all casting part has been carried out at their site, strength tests has been carried out at Constrologix Puneand SEM analysis has been carried out at NCL Laboratory Pune.

Materials used

For this study, the Ordinary Portland Cement (OPC) of 43-Grade in accordance with the IS code: 8112:1989 is used. Concrete is the common raw material used in the construction industry. According to the Bureau of Indian Standards (BIS), a concrete's assessment number indicates the minimum compressive quality that the concrete must achieve within 28 days. The minimum compressive quality achieved by the concrete at the end of the 28th day should not be less than 43 Mpa or 430 kg/sq.cm 43-grade OPC cement.

Aggregates

Coarse aggregate of 10 mm conforming to table 2 IS 383 was used. The basic constituents of concrete are coarse aggregates, which account for about 70-75 % of the volume in concrete compositions. A gross total size of 10 mm is used, which is graded according to IS 383:1970. Particulates larger than 4.75mm are considered coarse totals. The largest coarse totals used in the construction of concrete will be 20 mm. Aggregates have a significant impact on a structure's load transfer capability since they contribute compressive strength and bulk to concrete.

Fly Ash

Fly ash (Class C) is the most widely used supplementary cementitious material Using fly ash as a concrete additive significantly not only adds specialized properties to concrete but can also help in the reduction of pollution. Because of the substantial commitment to environmental contamination and the high usage of resources such as limestone. The fly ash was obtained from the Ready-mix concrete plant. For homogeneous blending with cement is achieved, fly ash complying with IS 3812 can be used as a partial replacement for OPC.

GGBS

GGBS will be acquired by squeezing the molten iron slag from the blasting furnace and drying it to a fine powder. The substance left over after extracting iron ore from iron ore is known as GGBS. It is one of the raw elements used to make a cement less binder, with cementitious and pozzolanic qualities. If homogeneous blending with cement is achieved, GGBS adhering to IS: 12089 can be used as a partial substitution for OPC.

Sea Sand

This sand comes from ocean beaches or seaward digging. Ocean sand is similar to stream sand in appearance, with finely adjusted grains and a mild darker tint. Sea sand from Zone II conforming to IS 383 is used and is 1.18mm. For this experiment work, readily available material was cement, crushed sand, aggregates, fly ash, GGBS, and fresh water. Coastal Sand and Seawater was collected from Varsoli Beach located in Alibaug. Sea Sand was collected.

Table no 1 Index Properties of materials

Properties	**Value**
Cement	
Initial setting time	64 Min
Final setting time	121 Min
Specific surface area	3907 cm2/gm
28 days compressive strength	31.5 MPa
Coarse Aggregate	
Density	1830 kg/m3
Fineness Modulus	7.53
Specific Gravity	2.78
Water absorption	1.60 %
Surface moisture	Nil
Crushed M Sand	
Specific Gravity	2.87
Water Absorption	2.72 %
Bulk Density	
a Loose	1.88 kg/L
b Rodded	2.02kg/L
Sea Sand	
Specific gravity	2.68
Water Absorption	1.98 %
Fineness Modulus	1.89
Fly Ash	
Specific gravity	2.1-3.0
Shrinkage Limit	Higher
Plasticity	Lower or non-plastic
Porosity	30-65 %
Surface Area	500-5000 m2/kg
GGBS	
Specific gravity	2.9
Bulk density	
a Loose	1000 – 1100 kg/m3
b Vibrated	1200 -1300 kg/m3
Fineness	>350 m2/kg

Methodology

Mix Design

Mix design of concrete used in the experimental program was as per Indian Standard Specifications given in BIS 10262:2019. Grade of the concrete selected was M30 and water cement ratio is 0.38. Exposure conditions were selected as per the specifications of BIS 456:2000.

Mix Types

Mix 1: Cement +Fly Ash
Mix 2: Cement +Fly Ash +50% Sea Sand
Mix 3: Cement +Fly Ash + 100% Sea Sand
Mix 4: Cement +Fly Ash +GGBS+ 50% Sea Sand

Slump Cone Test (IS 1199-1959)

Concrete consistency is assessed using the slump test, which can be performed in a lab or on-site. The results of a slump test reveal if concrete in various batches is uniform. Concrete slumps' shapes reveal details about the material's quality and use. Making a few tamping or blows by tapping a rod on the base plate is used to assess the qualities of concrete about its inclination to segregate.

Compression Test (IS:516-1959)

In this test technique, cylinders are subjected to a compressive axial load that is applied at a rate that is within the permitted range until failure. By dividing the maximum load recorded during the test by the specimen's cross-sectional area, the compressive strength of the specimen is determined. This strength can be described as a concrete's inherent strength, measured 28 days after mixing.

Carbonation Test [IS-516(Part 5/Sec 3):2021]

In the process of carbonation, carbon dioxide from the environment permeates the concrete's porous layer, lowering its pH to 8 or 9. A very common technique for assessing the chemical composition of concrete is the pH indicator method. To identify the area impacted by the carbonation, a 0.2% solution of phenolphthalein chemical is sprayed on the concrete's surface. The pH level change in the concrete is indicated by the phenolphthalein solution. The concrete is in good condition if it becomes pink from its original grey color. Concrete that has not changed in color indicates that carbonation has harmed the region.

Scanning Electron Microscopy [ISO 16700:2016]

A scanning electron microscope (SEM) is a type of electron microscope that produces images of a sample by scanning the surface with a focused beam of electrons. The electrons interact with atoms in the sample, producing various signals that contain information about the surface topography and composition of the sample. The electron beam is scanned in a raster scan pattern, and the position of the beam is combined with the intensity of the detected signal to produce an image. In the most common SEM mode, secondary electrons emitted by atoms excited by the electron beam are detected using a secondary electron detector (Everhart–Thornley detector). The number of secondary electrons that can be detected, and thus the signal intensity, depends, among other things, on specimen topography. Some SEMs can achieve resolutions better than 1 nanometer.

Sample Preparation

First the cube is broken under compression testing machine and the material from core is collected. Only fine particles along with some fine crystals is collected and tested under SEM. Following image shows the specimen that were collected.

Fig 4 SEM Sample

Fig 5 SEM Testing Machine

III. Result and Discussion

Fresh Concrete Properties

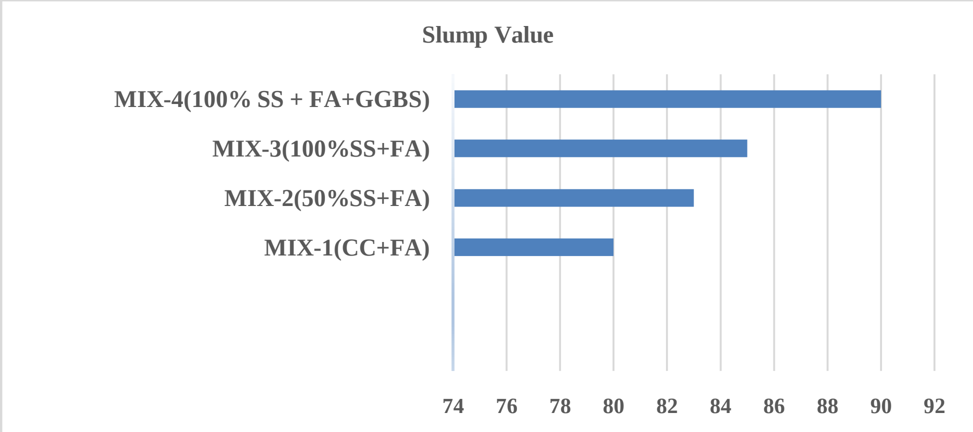


Fig 3.1 Fresh Concrete Properties

Compression Test (IS:516-1959)

Table 2 Compressive Strength

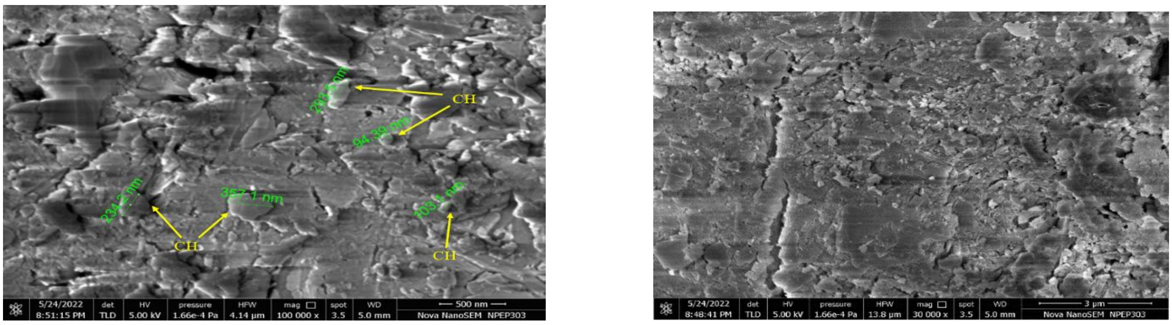
Mix Type	Compressive Strength(N/mm^2)		
	7 Days	**28 Days**	**90 Days**
MIX-1(CC+FA)	18.20	38.25	44.44
MIX-2(50%SS+FA)	22.45	40.20	40.15
MIX-3(100%SS+FA)	24.88	44.00	40.00
MIX-4(100% SS + FA+GGBS)	27.77	46.22	44.60

Carbonation Test [IS-516(Part 5/Sec 3):2021]

Table 3CarbonationDepth

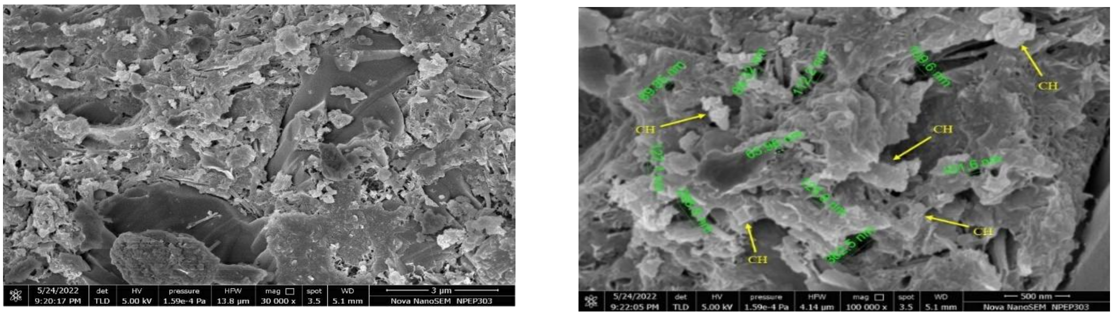
Mix No	Carbonation depth
Mix 1	21.13
Mix 2	11.81
Mix 3	16.38
Mix 4	18.43

Scanning Electron Microscopy [ISO 16700:2016]



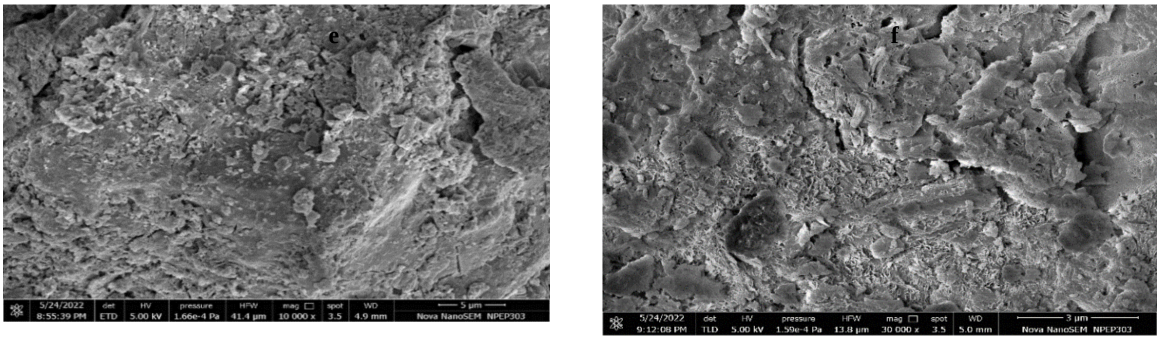
a **b**

Fig 3.2 Mix 1



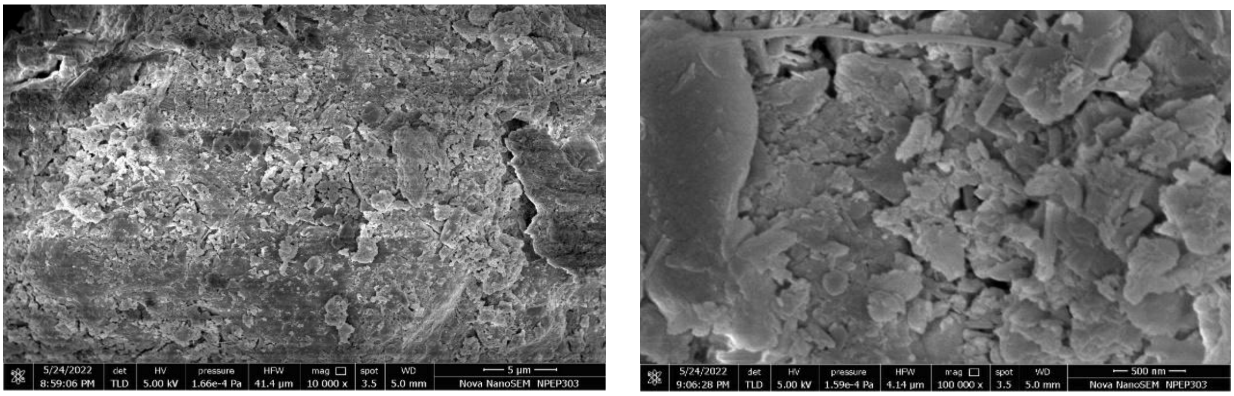
c **d**

Fig 3.2 Mix 2



e **f**

Fig 3.3 Mix 3



g **h**

Fig 3.4 Mix 4

Compressive strength and Carbonation strength of seawater sea sand concrete is feasible as compared with conventional concrete

Fig 3.1 represents SEM for Mix 1 of conventional concrete with fly ash. Calcium Hydrate formulation is identified. CH which is nothing but a product formed as a result of hydration can be seen at a magnia fiction of 500 nanometers. These compounds are seen to be ranging from 100nm to 400nm in size and have formed a structure with micro cracks.

Fig 3.2 represents SEM for Mix 2 i.e. concrete with the addition of 50% sea sand and 50% M-sand. In this image, it is clearly evident that the morphology is not even and the layers of hydration with no proper interlocking are observed. Also, the number of voids present is greater than the conventional concrete, ranging from 50nm to 400nm. These voids tend to initiate cracking in the structure thereby reducing its durability of it.

Fig 3.3 represents SEM for mix 3 i.e. concrete with the addition of 100% sea sand. In this CSH gel formulation occurs also dense concrete can be observed. The ettringite phase is observed here.

Fig 3.4 represents The above image represents SEM for mix 4 i.e. concrete with the addition of GGBS. In this trial the addition of GGBS has promoted the development of ettringite-shaped fibers which has helped in the bonding of material and thereby greater compaction and less porous structure. The addition of GGBS has led to the development of greater compressive strength in the early stage and is greater than that of conventional concrete but fails to achieve the same in the later stage.

IV. Conclusion

Based on the obtained results, the following are the conclusions drawn from the experimental work

1. The desired target strength for all the mixes was achieved.
2. Maximum strength achieved is observed for 50% Sea Sand replacement.
3. Carbonation depth achieved for all samples is less than 50mm which implies no carbonation in concrete.
4. SEM analysis helps in understanding the microstructural morphology of the concrete thereby providing support to the mechanical behavior of the seawater sea sand concrete.
5. With the addition of GGBS and Fly ash strength and microstructure properties could improve.
6. SEM analysis further confirmed that sea sand and seawater have a remarkable effect on the surface morphology and the significant contrast from ordinary concrete.
7. SEM analysis helps in understanding the microstructural morphology of the concrete thereby providing support to the mechanical behaviour of the concrete.

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