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# EFFECT OF SEA WATER ON THE COMPRESSION STRENGTH OF CONCRETE

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## ABSTRACT

Now-a-days, construction of concrete in coastal areas has long been facing the challenge of keeping the concrete as durable concrete structures in a saltwater environment. The main aim of this research is to find the effect of seawater curing of strength and durability of different concrete structures. Chloride concentration is initially higher in seawater. To design a concrete, which can withstand the attack of sea water, a coal combustion byproduct bottom ash, a fly-ash was used in this study to determine the strength and durability of the concrete against seawater effect. The chemical reaction of chlorides, sulphates and alaklies like sodium and potassium and in some cases dissolved carbon dioxide will affect the strength of concrete as well as durability vigorously. As a part of durability study, this paper describes the effect of sea water on compressive strength of concrete when used as mixing and concrete specimens were cast from four different mixes and plain water as well as sea water was used as mixing water in making the test specimens. This green concrete containing bottom ash for fine aggregate replacements (30%) and again 30% bottom ash and 30% fly-ash is used in another mix, 30% fly-ash alone is used in another mix for fine aggregate replacements. These concrete specimens are cured in normal tap water as well as seawater. The specimens were tested cured and tested for compressive strength. Test results indicate that the loss of concrete strength in normal water curing and the seawater curing.

**KEYWORDS:** Green Concrete, Bottom Ash, Fly Ash, Acid Attack, Compressive Strength, Sea Water.

## INTRODUCTION:

The deterioration of concrete on the attack of sulphuric acid not only affects the concrete but also the reinforcement inside. On the other hand, increasing in the population increased the demand of infra structural development and also the electric power generation from thermal power stations in the country. This increased the utilization of natural raw materials for construction and production of coal combustion products that are dumped into the land causing land, air and water pollution. Concrete is the second most used materials next to water has resulted afforestation and ecological imbalance (Hale M, et al., (2009). This resulted increase in the price of raw materials such as cement, fine and coarse aggregates. To create a sustainable solution by designing a concrete resistance to sulphuric acid and to utilize bottom ash fine aggregate in concrete this study investigates strength and durability in terms of sulphuric acid attack on concrete.

Cement can be described as a crystalline compound of calcium silicates and other calcium compounds having hydraulic properties. The four major compounds that constitute cement are Tri Calcium Silicate, abbreviated as $C_3S$, Dicalcium Silicate ($C_2S$), Tricalcium aluminate ($C_3A$), Tetra calcium aluminoferrite ($C_4AF$) where C stands for CaO, S stands for $SiO_2$, A stands for $Al_2O_3$ and F for $Fe_2O_3$. Tricalcium silicate and Dicalcium silicate are the major contributors to the strength of cement, together constituting about 70% of cement (Alvin Harison, et al., 2014). Dry or anhydrous cement does not have adhesive property and hence cannot bind the raw materials together to form concrete. When mixed with water chemical reaction takes place and is referred to as 'Hydration of cement'. The products of this exothermic reaction are C-S-H gel and $Ca(OH)_2$. Calcium hydroxide has a lower surface area and hence does not contribute much to the strength of concrete. On hydration of cement aluminates a product is formed known as ettringite, which has a needle like morphology and contributes to some early strength of concrete. C-S-H gel refers to calcium silicate hydrates, making up 60% of the volume of solids in the complete hydrated cement (Djerbi A, et al., 2008).

The main objectives of the present study are to study the effect of fly Ash on the compressive strength of concrete and to explain the change in properties of concrete. The present study incorporates mix design based on the guidelines as per Indian Standard code IS 10262-2009. The Fly Ash used is imported from Neyveli (NLC INDIA limited). Compressive strength measurements are carried out in 7days, 14 days and 28 days and curing has been done both in normal water and sea water.

## MATERIALS AND METHODS:

The materials used to design the mix for M60 grade of concrete are cement, sand, coarse aggregate, water, Nano silica and polycarboxylic ether. The properties of these materials are presented below.

Ordinary slag cement of 53 grade conforming to IS: 8112 is used for preparing concrete specimens as shown in Table 1. Sand as fine aggregates are collected from the locally available river and the sieve analysis of the samples are done. It is found that the sand collected is conforming to IS: 383-1970. For coarse aggregate, the parent concrete is crushed though mini jaw crusher. During the crushing process is to produce the maximum size of aggregate in between 20mm to 4.7mm. The coarse aggregate particle size distribution curve.

The physical properties of both fine aggregate and recycled coarse aggregate are evaluated as per IS: 2386 (Part 3)-1963 as shown in Table 1. The properties are assumed to be same as that of normal water. Fly Ash is a by- product of coal-fired electric generating plants. Fly Ash is one of the residues generated in combustion and comprises the fine particles that rise with the flue gases. Fly Ash can be used in Ordinary Portland cement concrete to enhance the performance of the concrete. Dry Fly ash conforming to IS 3812-2003 obtained from Neyveli (NLC INDIA limited) of Tamilnadu from southern part of India was made use of in the casting of the specimens.

The chemical composition and physical properties of fly Ash used in this experimental investigation. It has been analyzed that seawater contains a percentage by weight of major salt compounds: 78% NaCl, 10.5% MgCl, 5% $MgSO_4$, 3.9% $CaSO_4$, 2.3% $K_2SO_4$, 0.3% KBr as shown in Table 2. It can be seen from the above that sodium chloride is being the predominant salt component of sea water. Different sources of sweater have different concentrations, but the relative and plays a major function in any electrolyte action between dissimilar metals and between salt concentration and steel (Arunakanthi E, et al., 2013). Seawater has considerably varying pH value. The predominant mineral phases in Portland cements, in approximate descending order of mass, are tricalcium silicate ($3CaO.SiO_2$ $C_3S$), dicalcium silicate ($2CaO.SiO_2$ or $C_2S$ tricalcium aluminate ($3CaO.Al_2O_3$ or $C_3A$), Tetracalciumaluminoferrate ($4CaO.AlO_3.Fe_2O_3$), Calcium Sulphate hemi and dihyrdate ($CaSO_4.5H_2O$, $CaSO_4.2H_2O$), periclase (MgO) and calcium oxide (CaO) (Diao B, et al., 2011). Approximately 3 - 6% gypsum is typically added to control the hydration rate of the most reactive phase, $C_3A$.

The earliest phases formed when Portland cement hydrates are calcium hydroxide (from the residual CaO in the clinker) and ettringite . For a less than stoichiometric amount of sulphate is added for reaction with $C_3A$, a second phase, mono sulfate ($C_3A.CaS0_4.12.H_2O$ starts to form after several days, followed by a concomitant decline in ettringite content. The rate of these reactions depends on the amount of sulphate and the reactivity of the $C_3A$; the cubic form of $C_3A$ is more reactive than the orthorhombic (Fareed Ahmed Menon, et al., 2010), $C_3A$ and $C_2O$ reacts with water to form calcium silicate hydrate (C-S-H), which is amorphous and of variable composition; $C_3O$ is significantly more reactive than $C_2S$ and generates a by product, calcium hydroxide, which at later ages may comprise between 20 to 30% of the mass of the hydrated Portland cement paste. All of the aforementioned reactions and hydrates have implications for the durability of hydrated Portland cement in seawater. AI-Amount (2002a) and Cohen & Bentur (1988) describe the sequence of attack by magnesium sulphate in seawater as follows (the equations are simplified, and therefore non stoichiometric).

The products of magnesium sulphate attack are gypsum, brucite and a magnesium silicate hydrate. The latter hydrate has no binding properties. Brucite is considerable soluble than portlandite and a saturated solution has a pH of 10.5 compared to 12.4 for portlandite. The lower pH is not conducive to the tarnation of expansive ettringite which requires a pH greater than 10.5. The lower pH causes C-S-H to release the lime in order to maintain equilibrium with the pore solution, the result of which leads to a progressive decalcification of the paste. Furthermore, magnesium and calcium are both divalent and have similar atomic radii

and it is relatively easy for magnesium to substitute for calcium in C-S-H. With time the concentration of gypsum and brucite increases in sea water, but in contrast to sulphate attack by sodium sulphate solution, the gypsum formed does not lead to the formation of expansive 'secondary' ettringite. If the water/cement ratio of the paste is high (e.g., >0.45), there is the potential for the chemical attack to continue until all the C-S-H has been decalcified; if the w/c is low (e.g., <0.45), the chemical attack is surficial and brucite forms an impermeable layer. Calcium chloro aluminate hydrate ($3CaO.AlO_3.CaCb.l0H_2O$), also known as Friedel's salt, is an important phase formed during the exposure of concrete to Seawater (Swaroop A.H.L, et al., (2013). It appears to be formed predominately by the reaction of chloride ion with mono sulfate, which typically appears only after several days of hydration. Ettringite has the lowest solubility product and therefore it is formed preferentially relative to Friedel's salt, but mono sulfate is not stable in the presence of chloride. Chloride binding will occur when mono sulfate is present and therefore cements which generate large amounts of mono sulfate at later ages (i.e., cements that have C3A contents greater than 8% (Aman Jatale, et al., 2013) will have a greater chloride binding capacity. Although ettringite and gypsum have been found in concrete exposed to seawater (Arivazhagan K et al. 2011), the excessive expansion and cracking typically associated with sulphate attack is not observed. Achintya, et al., 2003, has proposed that the presence of chloride in the pore water suppresses the expansion of concrete because etringite requires an alkaline environment to swell.

**Table 1:** Properties of Ordinary Slag Cement, Coarse aggregate and Fine aggregate

| Properties of ordinary slag cement | | |
|---|---|---|
| **Specific Gravity** | **Fineness by sieve analysis** | **Normal consistency** |
| 3.15 | 2.20% | 40% |
| **Properties of coarse aggregate and fine aggregate** | | |
| **Property** | **Coarse Aggregate** | **Fine Aggregate** |
| Specific Gravity | 2.74 | 2.74 |
| Bulk Density (kg/L) | 1.408 | - |
| Loose Bulk Density (kg/L) | 1.25 | - |
| Water Absorption (%) | 0.5 | 1.0 |
| Impact Value | - | - |
| Crushing Value | 28.5 | - |
| Fineness Modulus | 3.7 | 2.36 |

**Table 2:** Chemical composition and Physical properties of Fly Ash

| Chemical composition of fly ash | |
|---|---|
| **Characteristic** | **Class F Fly Ash (%wt)** |
| Silica | 55-65 |
| Iron –oxide | 5-7 |
| Aluminum oxide | 22-25 |
| Calcium oxide | 5-7 |
| Magnesium oxide | <1 |
| Titanium oxide | <1 |
| Phosphorous | <1 |
| Sulphate | 0.1 |
| Alkali oxide | <1 |
| **Physical properties of Fly Ash** | |
| **Physical properties** | **Properties of Fly Ash used class F** |
| Specific gravity | 2.51 |
| Initial setting time | 120 min |
| Final setting time | 280 min |
| Fineness specific surface m2/kg min | 320 |
| Lime reactivity Average compression strength | 4 |

## RESULTS AND DISCUSION:

The results of the experiments were carried out towards objective of the project. It includes results from compressive strength test as shown in Table 3 to 5.

**Table 3:** Compressive strength specimen in normal water and sea water for 7 days

| Compressive strength of specimen in normal water (7 Days) | | | |
|---|---|---|---|
| **Sample No.** | **Weight (kg)** | **Load (KN)** | **Compressive strength (N/mm$^2$)** |
| 30% Fly Ash | 7.89 | 430.720 | 19.430 |
| 70% Fly Ash | 7.50 | 363.440 | 16.153 |
| Concrete | 8.14 | 527.680 | 20.897 |
| Mean | | | 21.160 |
| **Compressive strength of specimen in sea water (7 Days)** | | | |
| **Sample No.** | **Weight (kg)** | **Load (KN)** | **Compressive strength (N/mm$^2$)** |
| 30% Fly Ash | 7.45 | 363.97 | 20.436 |
| 70% Fly Ash | 6.5 | 414.76 | 16.176 |
| Concrete | 8.38 | 527.680 | 19.897 |
| Mean | | | 20.830 |

**Table 4:** Compressive strength specimen in normal water and sea water for 14 days

| Compressive strength of specimen in normal water (14-Days) | | | |
|---|---|---|---|
| **Sample No.** | **Weight (kg)** | **Load (KN)** | **Compressive strength (N/mm$^2$)** |
| 30% Fly Ash | 7.89 | 535.56 | 23.80 |
| 70% Fly Ash | 7.50 | 195.720 | 18.69 |
| Concrete | 8.14 | 691.90 | 20.71 |
| Mean | | | 21.06 |
| **Compressive strength of specimen in sea water (14-Days)** | | | |
| **Sample No.** | **Weight (kg)** | **Load (KN)** | **Compressive strength (N/mm$^2$)** |
| 30% Fly Ash | 7.90 | 363.970 | 16.176 |
| 70% Fly Ash | 7.45 | 325 | 6.560 |
| Concrete | 8.20 | 432.43 | 19.450 |
| Mean | | | 29.210 |

**Table 5:** Compressive strength specimen in normal water and sea water for 28 days

| Compressive strength of specimen in normal water (28 Days) | | | |
|---|---|---|---|
| **Sample No.** | **Weight (kg)** | **Load (KN)** | **Compressive strength (N/mm$^2$)** |
| 30% Fly Ash | 7.89 | 418.410 | 19.596 |
| 70% Fly Ash | 6.50 | 319.820 | 14.512 |
| Concrete | 8.20 | 510.000 | 20.430 |
| Mean | | | 18.846 |
| **Compressive strength of control specimen in sea water (28 Days)** | | | |
| **Sample No.** | **Weight (kg)** | **Load (KN)** | **Compressive strength (N/mm$^2$)** |
| 30% Fly Ash | 7.50 | 363.440 | 16.153 |
| 70% Fly Ash | 6.97 | 294.94 | 13.108 |
| Concrete | 8.40 | 456.23 | 19.340 |
| Mean | | | 16.200 |

**Comparison of compressive strength results:**

The change in compressive strength for the blended sample in % for 7, 14 and 28 days as shown in Table 6 and Fig. 1.

**Table 6:** Comparison of compressive strength for 7, 14 and 28 days

| Comparison of compressive strength for 7 days | | |
|---|---|---|
| **7-DAYS RESULT** | **Strength (N/mm$^2$)** | **Increase in strength (%)** |
| Normal water | 21.16 | 1.16 |
| Sea water | 20.83 | 0.73 |
| **Comparison of compressive strength for14 days** | | |
| **14-DAYS RESULT** | **Strength (N/mm$^2$)** | **Increase in strength (%)** |
| Normal water | 21.06 | 1.09 |
| Sea water | 15.21 | 0.56 |
| **Comparison of compressive strength for 28 days** | | |
| **28-DAYS RESULT** | **Strength (N/mm$^2$)** | **Increase in strength (%)** |
| Normal water | 18.84 | 0.98 |
| Sea water | 16.20 | 0.43 |

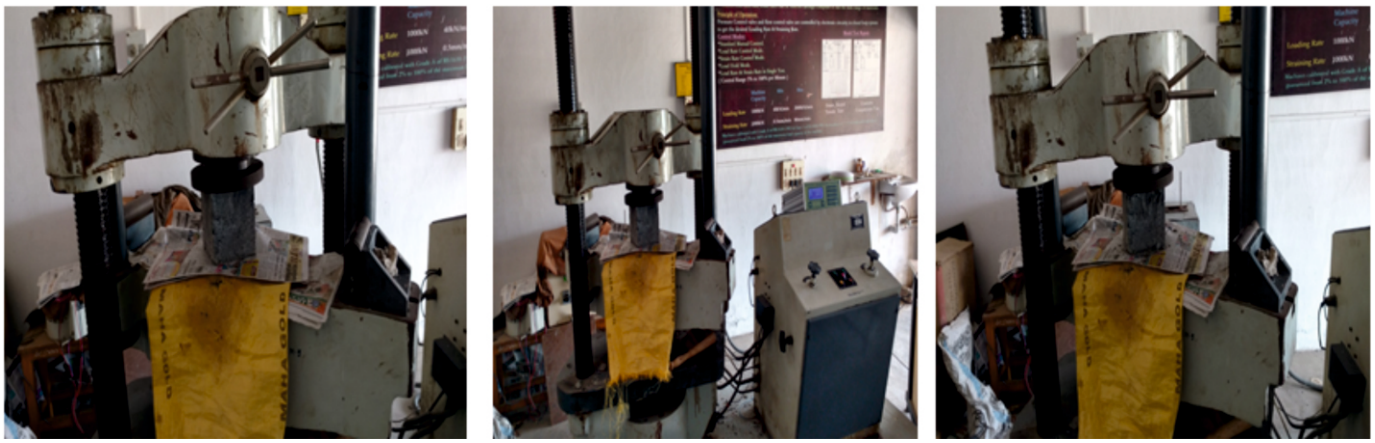

**Fig. 1:** Comparison of strength for 7, 14 and 28 Days

## CONCLUSION:

Fly ash concrete is the most important building material for the sustainable construction and consumption of large volumes of fly ash. Literature discussed in the present paper has given an overview of that fly ash concrete in sea water curing leads to the formation of pores due replacing of cement and increasing voids. The literature surveyed has also listed the slower strength gain at early ages as a major problem in making fly ash concrete very popular in the Indian construction industry which is only focused on short term strength gain. A detailed mix design procedure along with the conformation of results for designing fly ash concrete of less than 30% to achieve the required strength at 28 days and more may be possible. It is must shift contractors focus on economical and durable fly ash concrete, even if higher days of curing are required.

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