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RESEARCH ARTICLE

Compressive Strength of Concrete in Normal Water and Seawater using Fly Ash

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ABSTRACT

At present, the construction of concrete in marine areas has been facing durability issues. This research uses fly ash to determine the effect of seawater curing on strength and durability of different concrete structures. The chemical reaction of chlorides, sulphates and alkalies like sodium and potassium, and in some cases dissolved carbon dioxide affect the strength of concrete as well as durability vigorously. Normal and sea water are used as mixing water in making the test specimens. Different ingredients have been selected to determine the compressive strength i.e. 30% fly ash with 70% of cement concrete; 70% fly ash with 30% of cement concrete and only cement concrete. Finally, three specimens are cured in normal tap water and seawater for 7, 14 and 28 days, and the compressive strength is tested. The result indicates that the compressive strength of concrete is higher in normal water and lower in the seawater in different days of curing.

Keywords: Compressive strength, Normal water, Sea water, Fly ash, Green concrete, Acid attack.

1. INTRODUCTION

Concrete plays a vital role in several construction purposes [1]. Sulfuric acid affects the concrete and its reinforcement. This increases 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. Due to environmental problems, concrete structure experiences changes in physical and chemical properties and hence microstructural analysis are investigated [2]. Several industries in United States have replaced the use of cement with fly ash in making concrete structure due to better economic benefits and high performance [3]. Concrete is the second most used materials next to water that has resulted in deforestation and ecological imbalance [4]. Four major compounds tri calcium silicate, dicalcium silicate tricalcium aluminate, tetra calcium aluminoferrite tricalcium silicate and dicalcium silicate contribute to 70% of cement [5]. Due to the absence of adhesive property, dry or anhydrous cement cannot bind together to form concrete. Hydration of cement refers to the process of chemical reaction that takes place when cement is mixed with water. Since calcium hydroxide possesses lower surface area, it does not contribute much to the strength of concrete [6]. Portland cement has been replaced by fly ash or slag based concrete structure in several construction areas [7]. Fly ash increases the mechanical, economic, environmental and structural benefits of concrete structures and in addition acts as a corrosion resistant. Compressive strength, an important property of concrete is closely related to tensile strength, flexural strength, elasticity modulus etc. [8]. Increased concentration of fly ash in concrete decreases the water absorption capacity as well as the permeable voids [9]. The factor which affects the physical and chemical properties of fly ash are as follows: coal type, boiler type, operating conditions and post-combustion conditions [10]. Due to several advantages like

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low cost and good efficiency, sea water and sea sand are used for constructing several industrial purposes thus overcoming large consumption of river sand [11]. Sea water contains certain chemical constituents such as ions, chloride, magnesium, calcium and potassium. Lower concentration of fly ash increases the compressive strength of sea sand concrete [12]. M60 grade of concrete is adopted in this study with different proportions of fly ash based on IS-10262:2009 standard.

2. LITERATURE REVIEW

Depending on the effect of activating solution and curing procedure, the compressive strength of fly ash based geopolymer concrete is investigated. The obtained results indicate that using type F fly ash and activating solution as silica fume increases the compressive strength of geopolymer concrete. However this does not investigate the effect of degradation mechanisms related to external heat curing [13]. Investigation of compressive strength of ordinary Portland cement using different curing methods such as immersion in air, polythene sheet membrane, immersion in water, immersion in air and water and different mixing techniques (manual and mechanical mixing) is performed. Mechanical mixing of cement and immersion in water curing produces high compressive strength [14]. The effect of different parameters due to inclusion of blast furnace slag and fly ash based geopolymer concrete activated with sodium hydroxide is reported, in which a nonlinear increase exists depending on curing methods, and also increase in amount of slag improves the compressive strength [15]. [16] mainly focuses on the compressive strength of high volume fly ash concrete based on water to binder ratio, in which the compressive strength of concrete with lower water to binder ratio produces better results when compared to high binder ratio. The resistant to chloride ion penetration increases for high volume fly ash concrete in marine environment. Hence fly ash concrete provides better corrosion protection, but it has lower threshold values [17]. Fiber reinforced polymer overcomes the durability problem of Sea sand Sea water Concrete (SSC) with respect to abundant chloride ions. When compared to ordinary concrete, the initial and final setting time of sea water is short, and offers better workability. SSC is used in combination with recycled coarse aggregate [18]. [19] investigates the compressive properties of ordinary Portland cement treated with different percentage of fly ash such as 0, 5, 10, 15, 20, 25, 30. After 28 days, the obtained results indicate that 15% replacement of fly ash concrete has high density and compressive strength, low water absorption rate and high closed porosity, thus improving the concrete resistance. The fracture toughness and compressive strength of green concrete incorporated with 10%, 20% and 30% of fly ash at a curing period of 3, 7, 28, 90, 180 and 365 are investigated in which 20% additive fly ash guarantees high toughness and compressive strength, and it is also indicated that properties of fly ash treated green concrete depends on the age of the concrete [20]. Comparison of properties of Potassium Magnesium Phosphate Cement (MKPC) paste in sea water and fresh water is done, where the sea water provides high fluidity, long initial setting time and lower compressive strength when compared to curing in fresh water. Introducing several mineral admixtures such as silica fume and limestone powders into sea water cured MKPC decreases the negative impact property of hardening the body [21]. Compressive strength of Portland concrete is improved by adding metakaolin and curing in sea water by 33% and 22% respectively. This combination of sea water and metakaolin improves the chloride resistance and compressive strength by forming Friedel's salt in concrete [22]. Recycled aggregates mixed with Portland cement and blast-furnace slag cement cured in fresh and sea water are analysed, where the results show that sea water and slag cement improve the performance of recycled aggregate whereas sea water offers improved mechanical properties and drying shrinkage and reduced setting time [23]. The main objective of the present study is to determine the compressive strength and properties of concrete in normal and sea water using fly ash. Fly ash has been collected from LC India Limited in Neyveli. Compressive strength of concrete is carried outin 7, 14 and 28 days accordingly, and curing has been done both in normal water and sea water.

3. EXPERIMENTAL DETAILS

Various materials such as cement, fine and coarse aggregates, water, nano silica and polycarboxylic ether are used to design the mix for M60 grade of concrete. Concrete specimens are prepared using 53 graded slag cement that conforms to IS: 8112. The fine aggregate sand collected from the river after sieve analysis conforms to IS: 383-1970. The coarse aggregate of size 20 mm to 4.7 mm is prepared by crushing the parent concrete using mini jaw crusher. Fly ash is generated during coal combustion. The performance of the ordinary Portland cement can be improved by the addition of fly ash. The chemical composition of class F fly ash (% in weight) in characteristics is shown in table 1.

Table 1.Chemical composition of class F fly ash

Fly ash ingredients	(% in weight) in characteristics
Silica	55-60%
Iron oxide	5-7%
Aluminium oxide	22-25%
Calcium oxide	5-7%
Magnesium oxide	< 1%
Titanium oxide	< 1%
Phosphorous	< 1%
Sulphate	0.1%
Alkali oxide	< 1%

The physical properties of fly ash such as specific gravity (2.51), initial and final setting time (120 and 280 min), fineness specific surface (320 m^2/kg min) and lime reactivity average compression strength (4 N/mm^2) are found out. It has been analyzed that seawater contains 78% sodium chloride (NaCl), 10.5% magnesium chloride (MgCl), 5% magnesium sulphate ($MgSO_4$), 3.9% calcium sulphate ($CaSO_4$), 2.3% potassium sulphate (K_2SO_4) and 0.3% potassium bromate (KBr). Seawater has considerably varying pH value. Fly ash with different proportions such as 30%, 60% is added to M60 grade concrete. It is cured in normal and sea water for 7, 14 and 28 days and is compared with concrete without adding fly ash ingredients, with the same curing procedures.

3.1. Preparation of test specimen

Concrete cube of sizes 150 x 150 x 150 mm are casted to conduct the compressive strength test. A rotary mixture is used for thorough mixing, and a vibrator is used for good compaction. After successful casting, the concrete specimens are de-moulded after 24 hours and immersed in water or 28 days at 27 $\pm$ 1°C.

3.1.1. Methodology-mix design

The mix design of M60 grade of concrete is described below in accordance with Indian Standard code (IS): 10262-2009.

3.1.2. Target strength for mix proportioning

Characteristic compressive strength at 28days:

$$f_{ck} = 60 \text{ Mpa}$$

Assumed standard deviation based on IS 10262:2009:

sd = 7.8 MPa

Target average compressive strength at 28 days:

$$f_{target} = f_{ck} + 1.65sd = 72.87 \text{ Mpa}$$

3.1.3. Selection of water - cement ratio

As per IS–456, maximum water cement ratio = 0.45. Based on experience, water cement ratio is adopted as 0.40.

3.1.4. Selection of water content

For 20 mm and 12 mm aggregates, 180 liters of water is used based on 25 to 50 mm slump range. Estimated water content for 50 mm = 180 + 6/100 x 180 = 190.8 litres. As super plasticizer is used, the water content can be reduced up to 30%. Based on trials with super plasticizer, water reduction of 29% has been achieved. Hence, the arrived water content = 190.8 x 0.71 = 135.46 litres.

3.2. Calculations of cement and fly ash content

Water - cement ratio = 0.40.

Material (cement + fly ash) content

=136/0.40

=340 kg/m^3

From IS–456, minimum cement content for sever exposure condition = 320 kg/m^3

350 kg/m^3 > 320 kg/m^3,

Now, to proportion a mix containing nano silica, the following steps are suggested. Cementitious material content = 340 x 1.10 = 374 kg/m^3

Water content = 140 kg/m^3

So, water – cement ratio = 140/374

= 0.363

Cement (OPC) @30% = 371.25 – 111.375

= 259.875 kg/m^3

@70% = 371.25 – 259.875
= 111.375 kg/m^3
= 359.04 kg/m^3

3.3. Proportion of water coarse and fine aggregates

Volume of coarse aggregate corresponding to 20 mm and 12 mm size aggregate and fine aggregate (zone 1) for water – cement ratio of 0.50 = 0.60.

Therefore, volume of coarse aggregate
= 0.62 x 0.9 = 0.56.

Volume of fine aggregate content
= 1 – 0.56 = 0.44

3.4. Mix calculation

Mix calculation per unit volume of concrete shall be as follows:

a) Volume of concrete = 1 m^3

Volume of specimen is calculated as,

$$\text{Volume of specimen} = \frac{\text{mass of specimen}}{\text{specific gravity of cement}} \times \frac{1}{1000}$$

b) Volume of cement

$$= \frac{340}{3.15} \times \frac{1}{1000} = 0.107 \text{ m}^3$$

c) Volume of flyash @30%

$$= \frac{259.875}{2.2} \times \frac{1}{1000} = 0.1181 \text{ m}^3$$

Fly ash at 70%

$$= \frac{359.04}{2.2} \times \frac{1}{1000} = 0.1632 \text{ m}^3$$

d) Volume of water

$$= \frac{\text{mass of water}}{\text{specific gravity of water}} \times \frac{1}{1000}$$

$$= \frac{136}{1} \times \frac{1}{1000} = 0.136 \text{ m}^3$$

e) Volume of chemical admixture (Superplasticizer) at 4% by mass of cementitious material

$$= \frac{7}{1.10} \times \frac{1}{1000} = 0.006 \text{ m}^3$$

f) Volume of all aggregates
= [a – (b + c + d + e)]
= [1 – (0.0825 + 0.1 + 0.136 + 0.006]
= 1 – 0.3245
= 0.675 m^3

g) Mass of coarse aggregate
= f x volume of coarse aggregate x specific gravity of coarse aggregate x 1000
= 0.675 x 0.56 x 2.74 x 1000
= 1035.70 kg

h) Mass of fine aggregate
= f x volume of fine aggregate x specific gravity of fine aggregate x 1000
= 0.675 x 0.44 x 2.74 x 1000
= 813.78 kg

The mix proportion for trail number is given below, The calculation according to single cube, (per cube)

Cement = 340 x 0.00375 = 1.275 kg
Fly ash at 30% = 259.875 x 0.00375
= 0.974 kg
at 70% = 359.04 x 0.00375
= 1.346 kg
Fine aggregate = 813.8 x 0.00375
= 3.051 kg
Coarse aggregate = 1036 x 0.00375
= 3.8 kg
Chemical admixture = 6.4 x 0.00375
= 20 ml
Water – cement ratio = 0.363 x 0.00375
= 1.2 l

3.5. Compressive strength test

The compressive strength of specimens is determined after 7, 14 and 28 days of curing with the surface dried condition as per IS: 516-1959. Three specimens of typical category are tested and the mean compressive strength of three specimens is considered as the compressive strength of the specified category.

3.6. pH test

Sea water sample is taken from Bay of Bengal (Mahabalipuram Beach) in Chennai (Tamil Nadu). The sea water sample is tested in a laboratory using pH meter and the value is noted as 8.20 pH.

4. RESULTS AND DISCUSSION

The results of the experiments are carried out towards the objective of the project. It includes results from compressive strength test. The experiment is carried out using M60 grade concrete, but the results show that the compressive strength of concrete is around 20 N/mm^2, since normal water causes environmental change in the curing process. During 7 days curing using 30% fly ash, the compressive strength of the mixture using normal and sea water is 19.43 N/mm^2 and 20.44 N/mm^2 respectively. At 70% fly ash, the compressive strength is almost the same, and without the addition of flyash, concrete strength is reduced in sea water. Figure 1 shows the compressive strength in normal water and sea water for 7, 14 and 28 days.

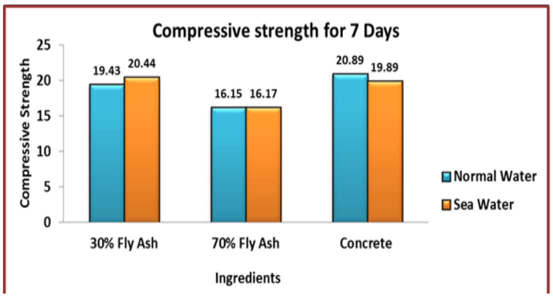

Figure 1.Compressive strength of various ingredients using normal and sea water for 7 days curing

During the 14 and 28 days curing process, the compressive strength is reduced while using 30% and 70% fly ash concrete mixture and also using concrete alone as shown in figures 2 and 3 respectively. The mean values of compressive strength in 7, 14 and 28 days using normal and sea water is shown in table 2, which states that the compressive strength in normal water using salt water is lower in all cases.

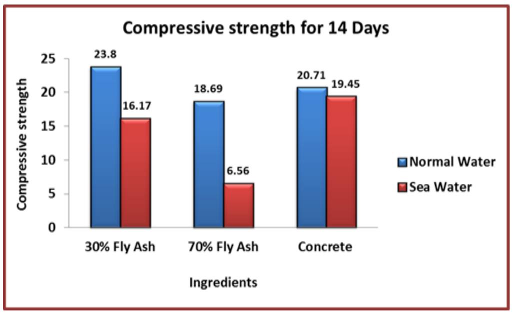

Figure 2.Compressive strength of various ingredients using normal and sea water for 14 days curing

This research suggests that 28 days compressive strength seems to be lower than 7 days compressive strength due to lower quality of sea water. 70% fly ash in concrete results in lower values at different days due to poor condition in the curing process mainly using sea water. Table A1 shows the cumulative results of compression strength of different ingredients used in the discussion.

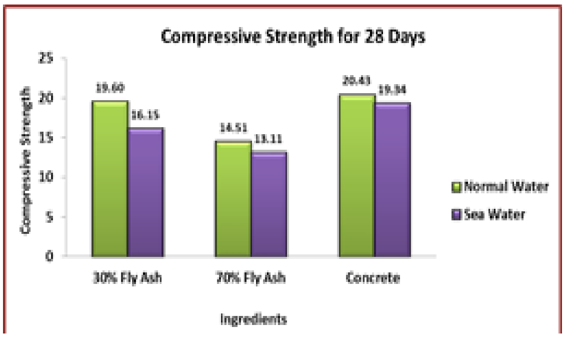

Figure 3.Compressive strength of various ingredients using normal and sea water for 28 days curing

Table 2.Values of compressive strength for 7, 14 and 28 days in normal and sea water

No. of days	Mean values of compressive strength in normal water (n/mm^2)	Mean values of compressive strength in sea water (n/mm^2)
7	21.160	20.830
14	21.060	15.210
28	18.840	16.200

5. CONCLUSIONS

Fly ash concrete is the most important building material for the sustainable construction. This paper has an overview of fly ash concrete in sea water curing that leads to the formation of pores and voids. Due to environmental changes or longer curing period or usage of higher fly ash concentration in the specimen, internal reaction in the casting ingredients takes place. Finally, the results indicate that the mix design procedure for fly ash concrete by less than 30% could achieve the required strength at 28 days. It focuses on economical and durable fly ash concrete, with higher days of curing are required.

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APPENDIX

Table A1.Compressive strength in normal water and sea water for 7, 14 and 28 days

Ingredients	Compressive strength (N/mm2) – 7 days		Compressive strength (N/mm^2) – 14 days		Compressive strength (N/mm^2) – 28 days	
	Normal water	Sea water	Normal water	Sea water	Normal water	Sea water
30% fly ash	19.43	20.44	23.8	16.17	19.60	16.15
70% fly ash	16.15	16.174	18.69	6.56	14.51	13.11
Concrete	20.89	19.894	20.71	19.45	20.43	19.34