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# A Comparative Study on the Compressive Strength of Fly Ash Replaced Concrete Mix using different Curing Methods

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**ABSTRACT:** Concrete has the composition of cement, aggregates and water. Several billion tons of normal water is being used to mix, cast and cure the concrete samples in the concrete industry for conducting various tests like compressive strength, split tensile and flexural strength using suitable machines. This research is focused on using sea water apart from normal water for curing the samples. Cement is partially replaced by Fly Ash (FA) by weight in 5% increments up to 25%. The properties of concrete ingredients are obtained and the mix proportion was arrived using ACI method for C30 grade concrete. Thirty six cube samples were cast out of which 18 cubes were cured in normal water and the remaining samples were cured in seawater for a duration of 28 days and their compressive strength was determined using appropriate tests. Results show that both normal and sea water samples attained maximum strength at 15% FA replacement in concrete mix. Sea water cured samples produce appreciable results when compared with normal water cured concrete specimens.

**KEYWORDS**: Compressive Strength, Fly Ash, Normal Water Curing, Sea Water Curing,Concrete Mix

## I. INDROUCTION

Concrete isa composite material which is used in the construction industry in large scale. Admixtures such as fly ash, silica fume, GGBS are either added or replaced partially in the concrete mix to improve the mechanical properties of concrete. Residential, commercial as well as infrastructure projects require lot of fresh water to mix, cast and cure the concrete specimens like cubes, cylinders, prism and beams hence there is a need to find alternate source for fresh water. About 71% of the total earth's surface is covered by water of which 95% constitutes sea water. Some research has been carried out using sea water to cure the concrete samples and their effects on the mechanical properties of concrete have been studied.

In this study thirty six cube samples were cast and 50 percent of the samples were cured in normal water and the rest of the samples were cured in sea water. Moreover fly ash replaced cement (5%, 10%, 15%, 20% and 25%) partially by weight in the concrete mix. Basic laboratory tests like specific gravity and sieve analysis were conducted to find the properties of raw materials used in concrete. The mix proportion for C30 grade of concrete was calculated using the physical properties of fine and coarse aggregates. Compression tests were conducted and their ultimate strength was recorded to find the compressive strength of concrete. The results of both normal water and sea water cured samples are tabulated and discussed in the sections below.

[1]. One of the earlier research work shows the effect of salt water and normal water cured samples on the compressive strength of concrete. Cubes were cast with two different sets of design mix of M20 and M30 grade concrete. The specimens are cured for 7, 14,28, 56 and 84 days in both normal and sea water. Test results reveal that the compressive strength of cubescured with sea water does not give much variation while comparing it with normal water cured samples. The compressive strength obtained from normal water curing after 84 days has a maximum value of 34.5N/mm$^2$.

[2]. Experimental investigations on the effect of sea water on the compressive strength of concrete was carried out in previous research work. Cubes of standard size were cast with fresh and sea water with a mix ratio of 1:2:4 with a water-cement ratio of 0.6. Curing was done for 7, 14, 21, 28 and 90 days and compressive strength test was performed on all the samples. The shows an increase in the compressive strength of concrete specimens mixed and cured with sea water. Compressive strength of concrete was also affected when the

concrete was cast with fresh water and cured with sea water.

[3]. The result and findings of an experimental research on the effect of salt water and fresh water on the compressive strength, flexural strength and split tensile strength of concrete is presented in this literature. A total specimen of 24 cubes, 24 beams and 24 cylinders were cast for both mixes and exposed to 7 days and 28 days period of curing. The rate of strength gain in fresh water cubes is slow when compared with salt water cured specimens. It was found that there was no reduction in strength when salt water was used to cast and cure the samples which can be used for region having more salty water.

[4]. The influence of mixing and curing of concrete with sea water on the compressive, tensile, flexural and bond strength showed that there was increase in the strength of concrete when mixed and cured in sea water at early ages and a decrease in strength for ages more than 28 days up to 90 days.

[5]. A marginal increase in the strength of concrete cubes was found in previous work which was cast and cured with salt water as compared with concrete cubes cast and cured with fresh water. The rate of strength gain in fresh water cubes is slow as compared with the salt water cubes.

[6]. The effect of sea water on compressive and flexural strength of concrete was studied. Two mixes were prepared first one potable water mixing and sea water curing and the second one was mixed and cured with sea water. A total of 54 cubes, 54 cylinders and 54 beams were cast and cured for 7, 28 and 90 days respectively. Researcher's observed that there is no considerable reduction in compressive strength due to mixing of sea water and also due to mixing and curing sea water with sea water compared to its target strength.

[7]. Researchers explored the effect of sea water concentration on the compressive strength of concrete. The compressive strength of cubes were determined after curing the samples for 7,14,21 and 28 days. Concrete cubes cast with fresh water and cured with sea water have their strength increased after 7, 14, 21 and 28 days of curing period.

[8]. A few authors examined the suitability of sea water for mixing and curing of concrete. Different mix ratios of concrete were prepared with different water cement ratios. Test specimens were cured under sea water of varying normality (1N,3N and 5N) as well as plain water up to 180 days. Authors concluded that concrete specimen made and cured with sea water exhibit compressive strength loss of about 10% compared to plain water mixed and cured concrete samples.

## II. MATERIALS USED

The materials used in this study is being discussed in this section.Concrete is a composite building material obtained by combining a chemically inert mineral aggregate (usually sand, gravel, or crushed stone), a binder (natural or synthetic cement), chemical additives, and water. The sub sections below give a brief description of the materials.

### 2.1: Ordinary Portland Cement:

Cement is a basic material for concrete used in the construction industry which represents about 30% of the components of a concrete structure.It is the adhesive which holds together the construction materials such as fine and coarse aggregates in the concrete mix [9]. In this research ordinary Portland cement of grade 53 is used along with other ingredients to prepare and mix the concrete.

### 2.2: Fine Aggregate (Sand):

It is the particles bound together with cement to produce concrete mix.Specific gravity is one of the physical properties of material which is obtained by conducting experiment in the laboratory. The specific gravity test for fine aggregates is carried out in the laboratory and found to be 2.6. Similarly the fineness modulus is found by performing sieve analysis test in the material laboratory. The fineness modulus of fine aggregate is 4.12.

### 2.3: Coarse aggregate:

Natural gravels of size (15-20mm)obtained from quarries were used as coarse aggregates. It occupies around 70% of the volume of concrete mix and it plays an important role on the strength and durability of concrete. Different properties of aggregate like its shape, texture and mineralogy have an effect on the properties and behavior of interfacial transition zone [10]. The specific gravity test for coarse aggregates is carried out in the laboratory and found to be 2.7. Similarly the fineness modulus is found by performing sieve analysis test in the material laboratory. The fineness modulus of fine aggregate is 5.3.

### 2.4 Water:

Water is an important ingredient of concrete. Part of mixing water is utilized in the hydration of cement and the balance water is required for imparting workability of concrete. The strength and durability of concrete is reduced due to the presence of chemical impurities in water [11].Two types of water (Normal and Sea) were

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used during the lab experiments. Normal water which was brought from the college had a ph of 7.2and sea water which was brought from Al–Seeb seahad a ph of 7.9.

**2.5 Fly ash:**

Fly ash has become a substitute for cement in the concrete industry. It is produced from the combustion of pulverized coal and transported by the flue gases of the boilers by pulverized coal [12]. The fly ash required for this study was procured from AL-Turkey Company, Ghala (Oman).

## III. METHODOLODY

The process of selecting suitable ingredients of concrete and determining their relative amounts with an objective of producing a concrete of required strength, durability and workability as economical as possible is termed as concrete mix design [13]. Based on the physical properties of materials the concrete mix design was obtained using ACI method and the mix proportion was arrived for cement, fine aggregate, coarse aggregate and water. The mix ratio was found to be 1:1.67:2.34 with a w/c ratio of 0.5 for C30 grade of concrete. In this work the ingredients of concrete were mixed according to the mix proportion in a standard mixer machine.36 cube moulds of standard size (150mm x 150mm x 150mm) were used to cast the concrete cubes.After casting,18 cube samples were cured in normal water and the remaining 18 samples were cured in sea water separately for a period of 28days and their compressive strength was determined through compression test using a UTM in the concrete laboratory. Table 3.1 shows the various mixes with fly ash replacement percentage along with the number of samples used to find the compressive stress.

**Table 3.1** Cube Samples of Various Concrete Mixeswith Fly Ash Replacement

| Concrete Mix | Replacement of Fly Ash (%) | Number of cube Samples | |
|---|---|---|---|
| | | Normal water curing (NWC) | Sea Water Curing (SWC) |
| M 1 | 0 | 3 | 3 |
| M 2 | 5 | 3 | 3 |
| M 3 | 10 | 3 | 3 |
| M 4 | 15 | 3 | 3 |
| M 5 | 20 | 3 | 3 |
| M 6 | 25 | 3 | 3 |
| | | 18 | 18 |

**3.1 Casting Process**

The ingredients of concrete are taken and weighed separately according to their mix proportions and the materials for each mix is dumped in to the concrete mixer. The mixer machine is switched on and water is added as per the requirement during this process to obtain a homogenous mix. The cube moulds which are in a dry condition were applied with oil on the sides and kept ready to fill it with the concrete mix. Concrete was filled in 3 layers and each layer was compacted 25times with a standard tamping rod. The top surfaces of the moulds were levelled using a trowel (Figure 3.1). The cube samples were labelled with detailssuch as date of casting and percentage replacement of fly ash for identification after the curing process. They are allowed to dry for 2 to 3 hours at room temperature(Figure 3.2).

Figure 3.1 Samples levelled using Trowel

Figure 3.2Cube Samples Labelled

### 3.2 Curing Process

Curing is a process that facilitates maximization of its potential strength. It ensures that concrete experience continued hydration leading to its continued strength gain. Continued hydration is achieved by maintaining satisfactory moisture content and temperature within the concrete for a sufficient period of time [14].Eighteen cube samples were immersed in normal water and another 18 cube specimens were immersed in sea water in separate tanks and kept for a duration of 28 daysas shown in Figure 3.3 and Figure 3.4 respectively.

Figure 3.3 Normal water curing

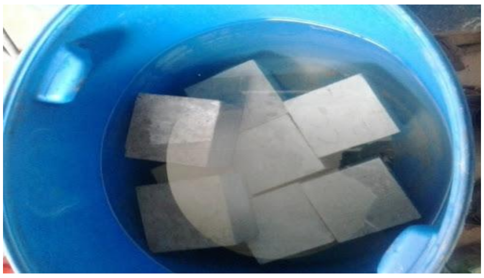

Figure 3.4 Sea Water Curing

### 3.3 Testing of Samples

Testing of hardened concrete plays an important role in controlling and confirming the quality of cement concrete. Compressive strength test is one of major strength tests conducted on concrete. As per Indian Standards 150mm cubes are used for determining the compressive strength of concrete. 100mm cubes are easier to handle and result in material saving, curing space, storage and labour. General specification provides acceptance criteria based on 150mm cube strength [15]. Compressive strength test was done using Universal Testing Machine (UTM) in concrete testing laboratory. The specimen is placed in the testing machine and the bearing surface of the testing machine shall be wiped clean and any loose sand or other material must be removed from the surface of the specimen.The load is applied continuously until the specimen breaks down and no greater load can be sustained. This procedure is repeated for cubes with various mix proportions of concrete replaced with silica fume and the corresponding readings are noted.

## IV. RESULTS AND DISCUSSION

The ultimate load values obtained through compressive strength test is used to calculate the compressive strength of conventional and fly ash replaced mix using relevant formula. The compressive strength value for each sample was obtained using relevant formula and the values are shown in Table 4.1 below.

**Table 4.1** Test Resultsof Normal Water Cured Samples

| S.No | Silica Fume Replacement (%) | Ultimate Load (KN) | Average Compressive Strength (N/mm$^2$) |
|---|---|---|---|
| 1 | 0 | 769.5 | 34.2 |
| 2 | 5 | 855 | 38 |
| 3 | 10 | 931.5 | 41.4 |
| 4 | 15 | 992.2 | 44.1 |
| 5 | 20 | 859.5 | 38.2 |
| 6 | 25 | 794.2 | 35.3 |

$$\text{Compressive strength} = \frac{\text{Ultimate load applied}}{\text{Cross sectional area}} = \frac{769.5 \times 10^3}{150 \times 150} = 34.2\ \text{N/mm}^2$$

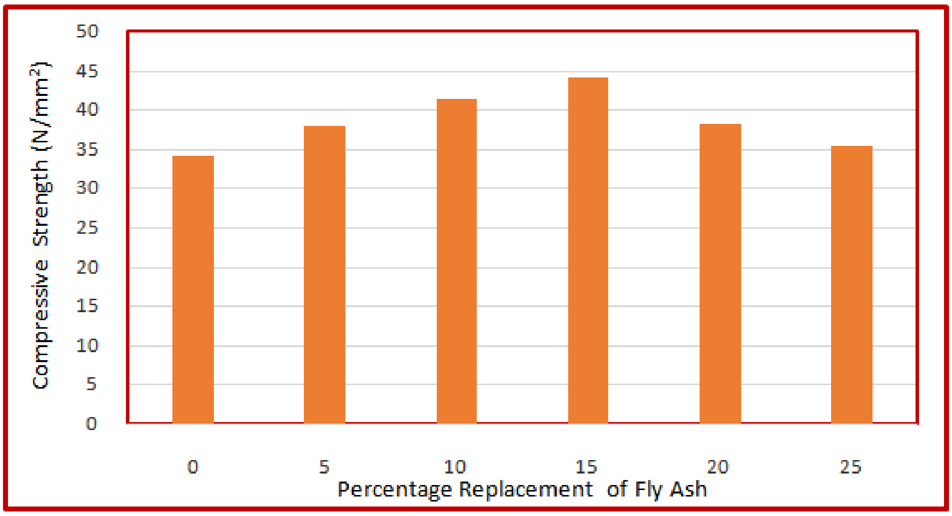


**Figure 4.1 –** Compressive Strength ofNWCSamples

Based on the above results a bar chart is drawn and the results are discussed below. From Figure 4.1 it is seen that a maximum strength of 44.1N/mm$^2$ is achieved at 15 percent replacement of cement with fly ash hence it is considered as optimum replacement level of fly ash in concrete mix. Ten percent increase in strength is found at 5 and 20 percent FA replacement when compared with normal mix. A substantial increase in strength is observed while comparing the optimum replacement strength value with that of conventional mix value. A further increase in FA content decreases the strength as the puzzalonic action slows down. A minimum strength of 35.3 N/mm$^2$ is obtained when 25% of cement in concrete is replaced with fly ash which is close to the control mix result. The observations and results of sea water cured concrete samples are shown in Table 4.2 below.

**Table 4.2** Test Results of Sea Water Cured Samples

| S.No | Silica Fume Replacement (%) | Ultimate Load (KN) | Average Compressive Strength (N/mm$^2$) |
|---|---|---|---|
| 1 | 0 | 769.5 | 33.5 |
| 2 | 5 | 855 | 35.7 |
| 3 | 10 | 931.5 | 37.4 |
| 4 | 15 | 992.2 | 38.6 |
| 5 | 20 | 859.5 | 34.6 |
| 6 | 25 | 794.2 | 32.2 |

Depending on compressive strengthvalues a bar chart is drawn and the results are analysed. From Figure 4.2 it is evident that maximum strength of 38.6N/mm$^2$ is achieved at 15 percent replacement of cement with fly ash hence it is considered as optimum replacement level of fly ash in concrete mix. Six percent increase in strength is found at 5 and 20 percent FA replacement when compared with normal mix. A significant increase in strength is observed while comparing the strength at optimum replacement with conventional mix value.

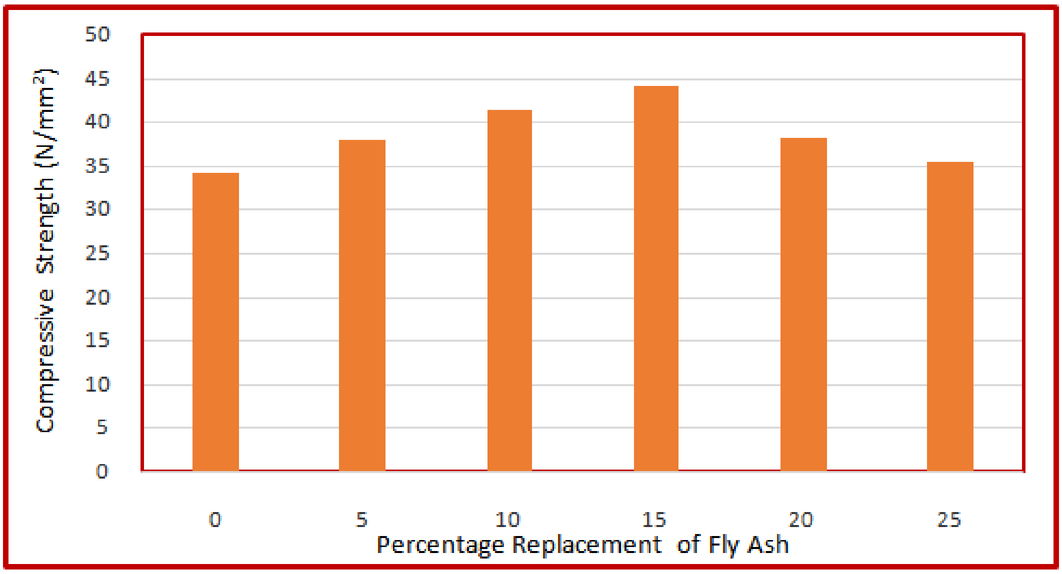


**Figure 4.2 –** Compressive Strength of SWC Samples

The results of normal water and sea water cured samples tested after 28 days are shown in Table 4.3 below. Comparing the conventional mix values of NWC and SWC the variation is negligible even though the compressive strength of sea water cured sample is less.

**Table 4.3** Test Results of Cube Samples under different curing conditions

| Fly Ash Replacement (%) | Average Compressive Strength after 28 days ($N/mm^2$) | |
|---|---|---|
| | Normal Water Curing (NWC) | Sea Water Curing (SWC) |
| 0 | 34.2 | 33.5 |
| 5 | 38 | 35.7 |
| 10 | 41.4 | 37.4 |
| 15 | 44.1 | 38.6 |
| 20 | 38.2 | 34.6 |
| 25 | 35.3 | 32.2 |

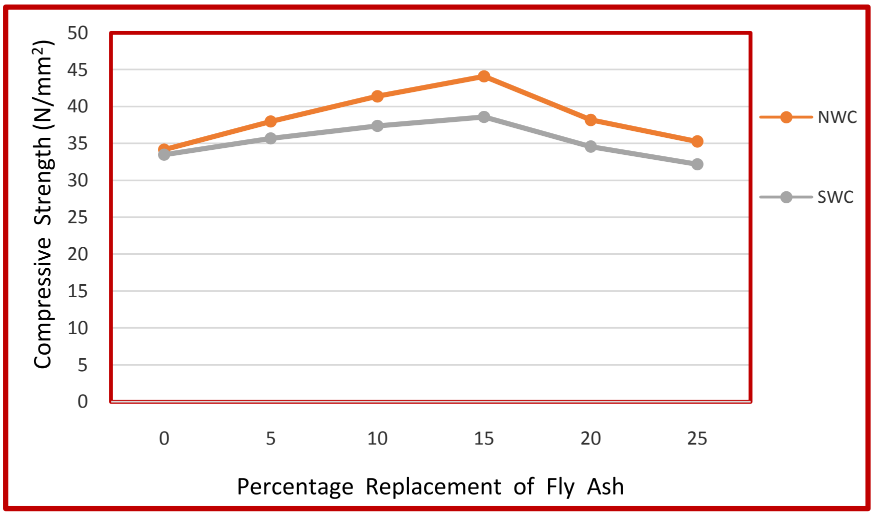


**Figure 4.3 –** Compressive Strength of Normal Water and Sea Water Cured Samples

The above Figure 4.3 reveals the compressive strength of both normal and sea water cured samples. It can be seen that in both NWC and SWC samples the maximum strength is attained at 15% replacement of cement with fly ash in concrete mix.Moreover the percentage increase in strength is almost same while comparing5% and 20% FA replaced Normal water and Sea water cured samples. A similar trend is observed when 10% and 25% FA replaced mix strengths are analysed. The increase and decrease in strength is linear in nature from 10 to 15% and from 20 to 25% FA replacements respectively.

## V. CONCLUSION

Based on the above research the following conclusions are arrived:

- Tests carried out on cube samples reveal that maximum strength is attained at 15%replacement of cement with fly ash which is considered as optimum FAreplacement in concretemix cured with normal and sea water for 28 days.
- The compressive strength of 15 percentFAreplaced normal water cured mix is 22 percent higherthan the conventionalmix strength which is found to be 44.1 N/mm$^2$
- The compressive strength of 15percent FA replaced sea water cured mix is 13percent higher than control mix strength which is found to be 38.6 N/mm$^2$
- It is also evident that compressive strength values of concrete mixed with various proportions of fly ash is higher than the control mix values.
- The variation of strength between control mix and 25% FAreplaced mix is negligible since it produces minimum strength.
- Comparing the optimum strength values of normal and sea water cured samples the variation is found to be 12 percent.
- A proportionate increase in strength is observed for every 5percent increase in fly ash content in the concrete mix irrespective of the curing method.
- The fly ash replaced concrete samples which are cured in normal and sea water does not have significant impact on the compressive strength of concrete cubes.

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