Statistical Analysis of Strength and Durability of Concrete in Brakish Water Environment

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Abstract. In the modern world, chemical or mineral admixtures have been used in place of *cement* as well as an additional binding ingredient in a number of research initiatives. The newest development in concrete technology involves adjusting many factors in both fresh and hardened concrete. Fresh concrete has the following qualities: wet density, workability, slump, compactability, heat of hydration, flowability, and pumpability. Hardened concrete has the following properties: hardness, permeability, density, and water absorption. The aforementioned characteristics can be altered by adding the proper admixtures. Several research have been done on water quality and concrete mixed with different admixtures. Furthermore, research is being done on how they affect altering the properties of concrete. In this study fly ash was added as substitute for cement in the following percentages: 0%, 10%, 20%, 30%, 40%, 50%, and 60%. If desired, silica fume can also be added as an extra ingredient to concrete. The Konaseema District of the South Indian state of Andhra Pradesh, namely the Odalarevu, is the research area for this project. The brackish nature of the groundwater in this location makes it unsuitable for drinking or use in the manufacturing of concrete. An investigation of the influence of groundwater on durability and strength properties of concrete has been carried out. Furthermore, the concrete was built using water that had been cleaned, and its strength was evaluated. Measurements of the half-cell between the steel and the specimen's surface are regularly taken in order to evaluate the degree of corrosion. A technique that accounts for both the rate of corrosion and the allowable reduction in reinforcement diameter has been proposed for calculating a structure's service life.

Keywords: Strength, Durability, Concrete, Brakish waters, Statistical Analysis

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1 Introduction

Concrete can have materials called additives added to it to change some of its desired properties and improve the material's overall strength and durability. Concrete is essentially just a paste and aggregate mixture. Several ingredients, including silica fume, fly ash are mixed with concrete to get the desired result. The quality of the paste determines the type of concrete. For concrete to be robust and durable, proper component proportioning, mixing, and compacting are crucial.[1-3]

Admixtures can be applied to concrete to change a few key, desirable characteristics. The need for high strength concrete has risen due to human activities like the fast industrialization and urbanisation of the world. The modern world must rise to the problems of building massive structures. As a result, the deadline for meeting concrete's performance and strength requirements is approaching alarmingly quickly.

Fly ash has been used by a few cement factories in the past several years to make "Pozzolona Portland Cement," however the total amount of fly ash used is still relatively low, with the most of it ending up in landfills. Fly ash classified as Group C is a high-lime ash derived from lignite coal. Rarely, it might have 24% lime in it. Increased lime ash content has cementitious properties by nature. [4-6]

High volume fly ash (HVFA) concrete replaces the portland cement component with a significant amount of fly ash. It has been discovered that replacement levels up to 60% are effective. It has been demonstrated that HVFA concrete uses less resources and is more resilient than OPC concrete. HVFA technology has been applied in the field; fly ash has replaced 50% of OPC in road construction projects in India. Workability, easier flowability, pumpability, and compactability can all be enhanced by applying fly ash. [7-9]

Furthermore, the inclusion of fly ash can improve resistance to sulphate attack, alkali-silica reactivity, and other types of degradation, as well as reduce the heat of hydration when compared to conventional mixtures. HVFA concrete resists drying, autogenous, and thermal shrinkage cracking with remarkable dimensional stability. It also has exceptional resistance to corrosion from reinforcing, alkali-silica expansion, and sulphate assault. When power finishing is not needed, high volume fly ash concrete dries faster and offers a better surface finish. Because of its slower setting time, joint cutting and power-finishing processes for slabs will take longer to affect. Because of its highly favorable lifespan cost and cheaper material costs, HVFA concrete offers higher cost economy.[10-13]

These concrete offer enhanced environmental friendliness due to the large volumes of fly ash that are disposed of sustainably, the decreased carbon dioxide emissions, and the increased productivity of resources within the concrete building sector. Fly ash and silica fume were used to create high-strength concrete, and their longevity was investigated. By substituting some of the cement in the high strength concrete with fly ash (FA) and silica fume (SF), the compressive strength of the mixture was assessed. [14-16]

2 Materials and Methods

This experiment involved varying the percentages of class C fly ash (30%, 40%, and 50%) and silica fume (6% and 10% by weight of cement). The water-to-binder ratio of the concrete mix was kept constant at 0.4, and superplasticizer was added in accordance with the necessary level of workability. It has been shown that contaminants in water used to mix concrete reduce its strength and longevity. Tests on concrete are used to analyse the extent to which contaminants in mixing water contribute to a loss in strength and durability. The research area's groundwater has brackish quality with a TDS value of greater than 2000 mg/L. Water that is brackish is more salinized than fresh water.

When treated water and groundwater were used in the manufacture of the concrete, its strength and durability were evaluated. Investigations were conducted on the impact of impurities in fly ash and fly ash mixed with combinations of silica fume in water mixes used in place of cement. When brackish water is utilised to make concrete, the variations in workability of the fresh mixes made with the partial substitution of cement with the previously indicated fly ash combinations are examined.

The purpose of the present work is to evaluate the strength characteristics of concrete made with treated water and various amounts of fly ash and silica fume in place of cement. Tests are conducted on the fly ash plus 20% silica fume percentage or the fly ash plus 30%, 40%, 50%, and 60% of fly ash plus 20% silica fume.

To evaluate numerous replacement percentages of fly ash and silica fume (fly ash plus 20% silica fume or fly ash plus 30%, 40%, 50%, and 60% of fly ash plus 20% silica fume) in relation to the strength qualities of concrete made using groundwater. To evaluate how long-lasting concrete made with treated water and different replacement percentages of fly ash and silica fume (fly ash plus 20% silica fume or fly ash plus 30%, 40%, 50%, and 60% of silica fume) will be. To assess the durability of concrete.

3 Experimental Work

Tests on the aggregates, cement, and admixtures used in the construction of concrete are carried out in a laboratory setting in accordance with the criteria supplied by the pertinent IS requirements. Using the procedures described in IS 3025-1983, samples were gathered and examined in cleaned polythene bottles to assess the quality of treated water and groundwater. Since the acceptability of groundwater for concrete is equivalent to its suitability for human consumption, drinking water standards were interpreted within the constraints outlined in IS 10500-1991.

The other control mix is made by substituting 20% silica fume for the cement. To complete the additional cement replacement, fly ash contents and 20% silica fume are added. These 14 mix criteria are used while casting the specimens. Separate methods were used for the casting of concrete: groundwater and filtered water. We have performed regression analysis, cluster analysis, descriptive statistics, and correlation analysis. Regression analysis was used to create two linear equations for treated water and groundwater produced concrete that represent the link between the qualities of the fresh concrete and its strength. The study's findings could be used as a standard to gauge how treated water and groundwater-prepared concrete differ in terms of strength and longevity.

A numerical measure used in statistical analysis describes the properties of a sample. These strategies allow one to investigate a data set's properties and arrive at a single numerical output for the purpose of studying the data set's wholesomeness. Twelve characteristics of the raw materials and fresh concrete that determine the strength for fourteen different combinations are selected for statistical study in this research. Two methods were utilized to complete the task: one way used purified water to prepare the concrete, while the other method used groundwater. As the 28-day compressive strength of concrete is frequently used to characterize its characteristic strength, the same index is used in this statistical analysis.

DATA SET

The amount and quality of raw materials used, the characteristics of freshly mixed concrete, and the application techniques all affect the strength. Eleven material and fresh concrete variables that affect the hardened concrete's strength are taken into account during the statistical analysis carried out in this work. The dependent variable on these eleven independent parameters is compressive strength. Eight of the eleven variables are characteristics of the materials, two are attributes of the fresh concrete, and one is a quality of the hardened concrete. Table 1 provides a summary of the different components.

Table 1. Information Strengthening Concrete and 28-Day Compaction Strength For Concrete Made With Purified Water (Fag-711kg, Cag-1283 kg, Water-160 L, SP-5.7L, TDS -730 mg/l)

Mix ID	Comp strength N/mm^2	Cement in kg	FA in kg	SF in kg	Slump in mm	Density Kg/m^3	WA %
CONTROL	45.7	382	0	0	32	2374	0.69
10FA	44	342	38	0	30	2373	0.71
20FA	42.5	304	76	0	32	2372	0.62
30FA	40	266	114	0	33	2371	0.58
40FA	34.36	228	152	0	34	2370	0.65
50FA	26.33	190	190	0	36	2369	0.81
60FA	18.47	152	228	0	38	2368	0.75
CON20SF	46.35	304	0	76	30	2370	0.42
10FA20SF	39.16	266	38	76	31	2369	0.49
20FA20SF	38.67	228	76	76	30	2368	0.47
30FA20SF	29.96	190	114	76	29	2367	0.53
40FA20SF	26.48	152	152	76	30	2366	0.69
50FA20SF	25.63	114	190	76	32	2365	0.89
60FA20SF	13.33	76	228	76	31	2364	1.38

Table 2. Information Supporting the Groundwater-Prepared Concrete's Strength and 28-Day Compressive Strength (Fag-711kg, Cag-1283 kg, Water-160 L, SP-5.7L, TDS -4060 mg/l)

Mix ID	Comp strength N/mm²	Cement in kg	FA in kg	SF in kg	Slump in mm	Density Kg/m³	WA %
CONTROL	31.98	382	0	0	32	2374	0.676
10FA	29.56	342	38	0	30	2373	0.6
20FA	28.86	304	76	0	32	2372	0.613
30FA	27.6	266	114	0	33	2371	0.56
40FA	25.8	228	152	0	34	2370	0.63
50FA	21.7	190	190	0	36	2369	0.8
60FA	16.4	152	228	0	38	2368	0.746
CON20SF	36.68	304	0	76	30	2370	0.4
10FA20SF	29.2	266	38	76	31	2369	0.48
20FA20SF	28.4	228	76	76	30	2368	0.46
30FA20SF	25.6	190	114	76	29	2367	0.52
40FA20SF	22.5	152	152	76	30	2366	0.68
50FA20SF	18.64	114	190	76	32	2365	0.88
60FA20SF	15.84	76	228	76	31	2364	1.31

4 Results and Discussion

The compressive strength of treated water-produced concrete: a detailed statistical report Fourteen different blends have their compressive strength evaluated after 28 days, and the mean and standard deviation are computed for a statistical analysis. Tests were conducted on cube samples made with purified water. 28.25 N/mm2 is the recommended level of compressive strength. After taking into consideration the goal strength's nearest rounded value, the mix was adjusted for 30 N/mm2. Table 3 provides a summary of the descriptive data about the compressive strength of treated water-prepared concrete.

Table 3. Specifications of the Compressive Strength of Treated Water-Based Concrete

Mix ID	Comp-strength in N/mm²	Deviation
CONTROL	45.7	11.87
10-FA	44.1	10.47
20-FA	43.5	8.97
30-FA	40.6	6.47
40-FA	34.46	0.83
50-FA	26.43	-8.3
60-FA	18.46	-15.66

CON-20-SF	46.65	13.72
10-FA-20-SF	39.66	6.53
20-FA-20-SF	38.57	6.04
30-FA-20-SF	29.46	-4.67
40-FA-20-SF	26.68	-8.15
50-FA-20-SF	25.43	-8.6
60-FA-20-SF	13.63	-21.3

(Mean-33.63, Std. deviation-10.42)

The average compressive strength is 33.63 N/mm^2 after 28 days. The mean compressive strengths of all combinations were greater than what was intended. Six mixtures yielded a negative departure from the mean and eight generated a positive deviation. In thirteen mixes, the standard deviation value is more than unity. There is variation in the compressive strength findings between the different combinations. A single mix 40 FA had a low mean deviation of 0.73.

COMPRESSIVE STRENGTH OF CONCRETE DESCRIPTIVE STATISTICS COMPLETED USING GROUNDWATER

The cube specimens from Groundwater, which were utilized in the compressive strength test, are being brought in for a descriptive analysis. For the specimens made from treated water, the same compressive strength is intended. Table 4 provides a summary of the descriptive data on the compressive strength of concrete treated with groundwater.

Table 4. Specifications of the Compressive Strength of Treated Water-Based Concrete

Mix ID	**Comp-strength inN/mm^2**	**Deviation**
CONTROL	31.86	6.64
10-FA	29.86	3.74
20-FA	28.66	3.64
30-FA	27.66	1.88
40-FA	25.78	0.28
50-FA	21.78	-3.62
60-FA	16.48	-9.62
CON-20-SF	36.58	11.66
10-FA-20-SF	29.25	3.88
20-FA-20-SF	28.54	2.68
30-FA-20-SF	25.66	-0.12
40-FA-20-SF	22.56	-3.32
50-FA-20-SF	18.84	-6.48
60-FA-20-SF	15.64	-9.68

(Mean-25.62 , Std. deviation-5.997)

After 28 days, the average compressive strength is 25.62 N/mm2. All combinations had mean compressive strengths that were below the desired level. Six combinations yielded a negative departure from the mean, while eight produced a positive one. In twelve mixes, the standard deviation value is more than unity. Compressive strength results vary according on the mixture. 40 FA and 30 FA 20SF—have revealed a small mean deviation.

CORRELATION: Statistical method for expressing the degree of linear connectedness between two variables is a correlation analysis. The groundwater quality measures and their corresponding values in the research region have been correlated. The correlation coefficient can be obtained using the following equation given below.

$$\mathrm{Correl}(X,\ Y) = \left[\sum (x-\bar{x})(y-\bar{y})\right] / \left[\sum (x-\bar{x})^2 (y-\bar{y})\right]^{1/2}$$

where the sample means of arrays 1 and 2 are denoted by x and y, respectively. If the combined correlation coefficient of any two sets of arrays is positive, then there is a high correlation between the parameters' attributes. Stated differently, the characteristics of a single array are dependent upon those of the other.

Any two sets of arrays with a negative correlation coefficient indicate that the parameters in one array are independent of the parameters in the other. This study examines the relationship between the compressive strength of concrete that has been created using groundwater and cement (0.89) and fly ash (0.96). It is strongly correlated with water absorption (0.78) and fresh concrete density (0.72). The correlation between it and the properties of slump in fresh concrete and silica fumes is 0.46 and 0.06, respectively, however it is not statistically significant in terms of compressive strength. Significant correlations between fly ash and silica fume and slump are 0.54 and 0.64.

Its significant correlations with compressive strength and water absorption are 0.25 and 0.46, respectively. In addition to compressive strength, density has a strong correlation (0.95) with cement, a considerable correlation and a correlation (0.53) with water absorption. Between 0.07 and 0.49, there is no discernible association with slump. Compressive strength is not the only property that water absorption significantly correlates with: fly ash, fresh concrete property density, and cement at 0.65, 0.53, and 0.71. The association between slump and silica fume is 0.25 and 0.03, respectively, however it is not statistically significant.

Regression Analysis

Regression analysis is done using SPSS 17.0. RA for the treated water-made concrete's compressive strength The factors that showed a substantial link with compressive strength in concrete made from treated wastewater are used in this regression analysis. Convergence of HFPO signifies the algorithm's ability to iteratively explore and refine parameters to improve segmentation task. The convergence of the HFPO-Transformer model is based on number of epochs in terms of loss function during training

Table 5. Summary of the Regression Model using Treated Water for the Concrete

S.No	Model	Predictors (Independent variables)	Dependent variable	Adjusted R square
1	1	Constant, Cement Slump, Density	28 days-Compressive Strength	0.945

Therefore, in a regression model, only one parameter from these two sets needs to be included. At the 10% level, one parameter is significant. A significance level of more than 10 percent is present for three metrics. Higher significance level factors won't have a notable impact on the dependent variable. However, there is a direct relationship between compressive strength and these characteristics.

Table 6. Summary of the Coefficients and Significance Level of the Regression Model for Concrete Treated with Water.

Model	Dependent variable	Predictors	Co-efficients	Significance
1	Compressive Strength(N/mm^2)	(Constant)	1.0913	0.26***
		Cement	0.0688	0.014**
		Slump	0.8075	0.263***
		Density	-0.003811	0.789***

Note that the symbols *, **, and *** denote significance at the 1%, 5%, and greater than 10% levels, respectively. The revised R square value of the regression model that was created between compressive strength and other relevant components is 0.945. This displays how well the created model fit the given information. The equation summarizes the general linear relationship between compressive strength and other parameters for water-prepared, treated concrete. Simplifying the parameter names results in Compressive Strength is equal to 0.0688 C + 0.8075 S - 0.003118 D where D stands for density in kilograms/m^3, S for slump value in milli meters, and C for cement in kilograms. The above generalized formula, which accounts for the cement content, slump, and density of the freshly mixed concrete, can be used to calculate the 28-day compressive strength.

RA FOR GROUNDWATER-PREPARED CONCRETE'S COMPRESSIVE STRENGTH

The correction factor is calculated by comparing changes in TDS content in both sources with differences in groundwater and treated water concrete's compressive strengths. Trial and error is used to determine the final value of the correction factor. Compressive Strength is equal to [0.0688 C +0.8075 S - 0.003118 D +1.0913], where C is the kilogram of cement, S is the millimeter of slump, and D is the kilogram of density per cubic meter.

When using ground water to make concrete, the formula can be used to determine the concrete's fresh parameters (such as slump and density) and cement content to determine the concrete's 28-day compressive strength. The equation for calculating the correction factor for any groundwater used in the production of concrete, as well as its 28-day compressive strength, is given in the table below.

Table 7. Factors Involved In The Correction Factor Translation

Water Type	**Factor for compressive strength**	**TDS contentin mg/L**	**TDS groundwater mg/L**	**Correction factor (ε)**
TreatedWater	1	730	X	1 - [(0.76 – 1) / (4020-730)] * [X-730]
Groundwater	0.76	4060		

We may evaluate the concrete's 28-day compressive strength prepared from any local ground water with the use of this equation.

5 Conclusions

The statistical analysis of the concrete parameters in this study indicates that the mean compressive strength from the treated water specimen is 3.63 MPa greater than the design mix strength. The mean compressive strength of the groundwater specimen is 4.38 MPa lower than the planned mix strength. In this study, the mean value projects the strength of the design combination. Given that the mix made with treated water has a standard deviation of 0.73 from the mean and the mix made with groundwater has a standard deviation of 0.18 from the mean, the amounts of mix 40FA that yield strength equivalent to mean strength in that specific context are appropriately taken into account.

The specimens generated using groundwater have smaller individual deviations from the mean and standard deviations. One could argue that mixes prepared with groundwater are more concerned with reaching a common compressive strength than mixes made with treated water. The results of the correlation analysis were as follows. The fifth quality has nothing to do with the previous traits. There is no relationship between these variables and no effect they have on any other parameter in the data set. The concretes made with treated water and the concretes made with groundwater exhibit the same pattern of correlation as well as relationships with seven metrics.

The 28 days compressive strength maximum positive variation is 3.8 N/mm^2, or 8.3% of the variance from the mix 20FAGW. In terms of compressive strength, the highest negative fluctuation in 28 days is 0.3 N/mm^2, or 0.7% of the variance from the mix CON20SFGW. The results of concrete groundwater samples are as follows: The biggest positive variation in 28-day compressive strength is 3.2 N/mm^2, or 8.9% of the variance compared to the mix CON20SFTW. The 28-day compressive strength minimum positive fluctuation is 1.8 N/mm^2, or 4.6% of the variance from the mix 10FA20SFTW.

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