Analysis of Strength Characteristics of Cement Concrete Prepared with Fly Ash

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Abstract- *Making High Performance Concrete, which is primarily used as a construction material in significant and mega infrastructure and projects, is a massive undertaking. Though recent improvements have surpassed the hurdles to high-performance concrete preparation, the usage of green ingredients such as Fly Ash is still limited. Aside from green ingredients, there are a variety of conventional and mineral admixtures on the market today, such as Fly Ash, that improve the quality and performance of concrete. Various mechanical parameters, including as compressive strength, flexural strength, and split tensile strength, are used to assess the quality of a concrete mixture.*

The primary goal of this study is to determine the structural strength of high-performance concrete using green and pozzolaniccementitious materials as supplemental cementitious materials. This research primarily focuses on the creation of empirical correlations for calculating the 7-day and 28-day compressive strength of concrete mixes with sufficient workability across a wide range of water/cement ratios. Detailed laboratory tests are carried out on practically all available Supplementary Cementitious Materials, such as Fly Ash, in the Madhya Pradesh state of India's vicinity. This research aids in determining the impact of Fly Ash on the strength properties of HPC. The adoption of an alternate material for Ordinary Portland Cement reduces harmful gas emissions and has an impact on cement plant output capacity. This research will help to improve and speed up decision-making in the pre-construction and post-construction stages of infrastructure projects. Furthermore, the empirical model presented above can be used for any types of high-performance concrete that uses extra cementitious materials. These generated correlations can provide superior engineering judgement and aid in the decision-making process for the HPC's structural evaluation during the pre-construction and post-construction stages.

I. INTRODUCTION

1.1 Conventional Concrete:

The most common construction material on the planet is cement Concrete. Cement Concrete is a composite material made up of cement (binding material), aggregate, and water in the right proportions to fulfil the needs of the construction activity at hand, especially in terms of workability, durability, strength, and cost. Concrete is typically prepared on-site in our country, and as a result, it must be closely monitored and managed to ensure that it functions as intended. Every step of the Concrete manufacturing process must be handled with caution.

The various stages of manufacturing Concrete are:

1) Batching
2) Mixing
3) Transporting
4) Placing
5) Compacting
6) Curing
7) Finishing

1.2 Special type Concrete:

1.2.1 HPC:

It's a misconception to believe that supplemental cementitious elements were utilised in Concrete solely because they were available and for economic reasons. These materials have some distinct advantages that can't be achieved with ordinary Portland cement alone (Neville, 1995). It is common knowledge that supplemental cementitious materials (SCMs) such as Silica Fume (SF), Alccofine, and FA (FA) are required for the production of high-performance Concrete (HPC). The concept of high-performance computing (HPC) has evolved over time. It was initially compared to high-strength Concrete (HSC), which has certain virtues but does not provide a complete and accurate image. Other qualities of the Concrete must be considered as well, which can occasionally take precedence over the strength criteria. Different writers and academician have offered various definitions for HPC (HPC). As a result, HPC is linked to long-lasting Concretes.

1.2.2 Polymer Concrete:

New building materials with better qualities are required in the construction sector to meet the current use domains for modern construction or repair operations. In the previous few decades, polymer application on Concrete has advanced dramatically. Polymers are utilised as a solitary binder or as part of a cement-aggregate mixture.

There is no cement in polymer Concrete; instead, the particles are held together by resins. Concretes with synthetic resin, Concretes with plastic resin, and plain Concrete with resin can all be made depending on the type of polymer used. There is no hydrated cement paste in the composite. Polymer Concrete has a number of advantages over Portland cement Concrete, including quick hardening, high mechanical strengths, increased chemical resistance, and durability. The high cost of resin, which limited the application of polymer Concrete domains, is one of the most severe limitations. The qualities of polymeric Concrete, as well as the type of filler and aggregates used, curing temperature, component dosage, and other factors, influence its performance. Silicates, quartz, crushed stone, gravel, limestone, calcareous, granite, clay, and other materials can be used as aggregates. The filler is especially crucial near the aggregate. Fine materials such as FA, silica fume, phosphor-gypsum, cinder, and others can be employed.

1.2.3 Fibre Reinforced Concrete:

Fibre reinforced Concrete (FRC) is a type of Concrete that contains fibrous material to improve structural strength. It is made up of short discrete fibres that are uniformly dispersed and orientated randomly. Steel, synthetic, and natural fibres are examples of fibres. With varied Concretes, geometries, distribution, fibre materials, orientation, and densities, the nature of fibre reinforced Concrete changes.

The use of fibres as a reinforcement material is not a new notion. Asbestos fibres were utilised in the early 1900s to make Concrete, and in the 1950s, the notion of composite materials was considered, with fibre reinforced Concrete being one of the areas of discussion. Once the human health concerns linked with asbestos were revealed, there was a need to find a replacement for the substance used in Concrete and other building materials. Steel, glass and synthetic fibres like polypropylene fibres were employed in Concrete by the 1960s, and research into the latest fibre reinforced Concretes (FRC) is still on-going.

1.3 Supplementary cementing materials (S.C.M.):

In recent years, supplementary cementing materials (SCMs) such as Meta-kaolin, Alccofine, and GGBS have become more popular as cement replacement materials. They aid in achieving both increased performance and cost savings. These compounds improve the Concrete's long-term performance by reducing permeability, resulting in increased durability.

1.3.1 Meta-kaolin:

Demands in the construction industry are driving up the demand for high-strength, high-performance Concrete. Efforts to improve the properties of Concrete over the last few decades imply that cement replacement materials combined with chemical admixtures can increase the cement Concrete's durability and corrosion resistance. HRM (High Reactive Meta-kaolin) is a pozzolanic substance that can be used to make extremely long-lasting Concrete composites. However, there is inadequate evidence to comprehend the behaviour of this mineral component in Concrete mixtures. This paper discusses some recent findings about the role of meta-kaolin in high strength, HPC.

1.3.2 GGBS:

Grinding Granulated Blast Furnace Slag (GGBS) is a non-metallic substance made up of calcium and other base silicates and aluminates. The molten slag is quickly refrigerated in water, forming glassy sand-like grains, which are then crushed to a fineness of less than 45. Grinding Granulated Blast Furnace Slag (GGBS) generated by grinding granulated blast furnace slag complying to IS 12089 can be used as a partial replacement for OPC if homogeneous blending with cement is guaranteed, according to IS146:2000.

When grinding granulated blast furnace slag (GGBS) is used in place of cement, the amount of water required to achieve the same slump is reduced. It also reduces hydration heat. The main benefit of using grinding granulated blast furnace slag (GGBS) is that it reduces permeability and increases chemical resistance. As a result, grinding granulated blast furnace slag (GGBS) is best suited for use in marine structures or saltwater Concrete.

Large pours to reduce the risk of early-age thermal cracking, Concrete exposed to sulphates or abrasive soils, and Concrete exposed to chlorides are all examples of applications for this slag in combination with Ordinary Portland Cement (OPC).

1.3.3 Alccofine:

ALCCOFINE is a carefully processed product made from high-glass-content slag with high reactivity, which is obtained by a controlled granulation process. Low calcium silicates make up the majority of the basic ingredients. ALCCOFINE 1203 provides reduced water consumption for a given workability, even up to 75 percent replacement level as per Concrete performance requirements, thanks to its unique chemistry and ultrafine particle size. ALCCOFINE 1203 can also be used as a high-range water reducer to increase strength or as a super workability aid to increase flow.

1.3.4 Micro-Silica:

Foundry dust that was left over was used as a partial replacement for sand. Due to the reaction between the foundry dust and the specific brands of chemical admixtures used, the use of foundry dust in self-consolidating Concrete (SCC) resulted in a high air content (7 percent to 10%) and low density of Concrete. Furthermore, when the amount of steel-containing foundry dust in the Concrete increased, the colour of the Concrete changed from dark grey to black. The necessity for high range water lowering admixture grew as the foundry silica-dust content increased to 20% and above; however, the amount of viscosity-modifying admixture fell by up to 33% up to a silica-dust content of 30%. It was determined that silica-dust material from the foundry sector can be utilised to partially replace cement, FA, and sand in SCC. More extensive work is in progress.

1.3.5 Rice Husk Ash:

Rice production has risen substantially in India in recent years, making it the most important crop. Rice husks are a waste product that is produced in large numbers. At the same time, while they are used as a fuel in the rice paddy milling process in various parts of the country, they are regarded as waste in our county, producing pollution and disposal concerns. Due to growing environmental concerns as well as the need to conserve energy and resources, efforts have been undertaken to burn rice husks under controlled conditions and use the ash as a supplemental binding material. Furthermore, rice husks have the potential to be an excellent source of energy.

II. LITERATURE REVIEW

Concrete has a number of advantages as the main material for the construction in comparison to the other construction materials. It’s the most easily available material every where in the world and it possesses the excellent resistance to water as comparison to wood and steel. Therefore, concrete has become a more durable and long-lasting material. In addition, the plastic consistency of the fresh concrete makes it easier to be formed into a range of shapes and sizes using prefabricated formwork **(P. Kumar Mehta, 1986)**.

Muthu, K. U., M. S. Ramaiah (2008) Self Compacting Concrete technology is broadly accepted as a quality product and investigations show that Nan Su’s method is simple to apply and can be used for producing high strength self-compacting concrete (HSSCC). The investigation of SCC under fatigue loading is in a very few cases. In the near future new concrete like Basalt fibre concrete, Bacterial concrete, Geopolymer concrete and Nano composites will find suitable applications in the construction industry. The investigations related to the Light weight concrete applications in structural concrete are in progress and a rational method of mix design of Foam Concrete (FC) is required. The application high volume Fly ash technology to the construction of rigid pavements is found to be appropriate for sustainable developments. The above application would help to solve the many environmental issues.

Patel., Vatsal, Shah., Niraj (2013) effect of Mineral and Chemical Admixtures used to improve the performance of concrete. High Performance Concrete (HPC) can be prepared to provide optimized performance characteristics for a given loading and exposure conditions along with the requirements of cost, service life and durability. The success of High Performance Concrete (HPC) requires more consideration on proper Mix Design, Production, Placing and Curing of Concrete. For each of these operations controlling parameters should be achieved by concrete producer for an environment that a structure has to face and survive against them.

Brooks et al. (2000) after studying the effect of silica fume, metakaolin, fly ash and ground granulated blast furnace slag on setting times of high strength concrete (HSC), they concluded that there was increase in the retarding effect up to 10% replacement of the cement by supplementary materials like Metakaolin and as the percentage replacement is increased, the retarding effect is reduced.

III. MIX DESIGNING

3.1 Method of Concrete Mix Design:-

Concrete mix design is the process of selecting suitable Concrete materials and determining their relative proportions with the goal of producing a Concrete with the needed strength, workability, and durability while being as cost-effective as feasible. In our study mix design was done by BIS mix design method which is based on Bureau of Indian Standards **(14) BIS: 10262-2009**.

Target Mean Strength of the Concrete Mix:-

Target strength for mix proportioning
f 'ck= fck + 1.65 σ
Where,
f 'ck = target average strength at 28 days
fck = characteristic strength at 28 days and
σ = standard deviation
From Table 4.1 (IS 456:2000) Standard Deviation, σ = 4 N/mm^2
Therefore, target strength = 25 + 1.65 x 4 = 31.6 N/mm^2

Table-1 Proportion of Different Materials in our Mix

Cement	Fine Aggregate	Coarse Aggregate	Water
394	700.78	1113.954	197 litres
1	1.779	2.827	0.50

3.2 Preparation of Trial Mixes:-

Based on the Bureau of Indian Standard (BIS) Concrete mix design method, four trials mixes were prepared. Two trials mixes were prepared with W/C ratio of 0.55 and other two mixes were prepared with W/C ratio of 0.50. The 6 cubes were casted for each mix and were tested at 7 and 28 days. The mix proportions for various constituents have been summarized in Table-2.

Table-2 Quantities Per Cubic Meter for Trial Mixes (M25)

Mix No.	W/C Ratio	Slump (mm)	Water (Lit/m^3)	Cement Kg/m^3	Sand Kg/m^3	Coarse Aggregate Kg/m^3	Average Cube Strength at 7 Days (MPa)	Average Cube Strength at 28 Days (MPa)
Mix-A	0.50	50	186	372	749.7	1142.4	18.75	29.1
Mix-B	0.50	100	197	394	700.78	1113.954	18.96	31.6
Mix-C	0.55	50	186	372	724.6	1143.4	17.85	28.45
Mix-D	0.55	100	197	394	700.8	1113.9	18.35	29.35

The Mix-B was selected as the design mix because its average cube strength is very close to the target mean strength of the Concrete with appropriate content of cement among all the mixes.

3.3 Prepared Mixes For Testing of The Strength:-

We prepared the various mixes of Concrete for the testing of strength with the variable percentage of supplementary cementitious material i.e. (5%, 10% and 15%) of FA.

Table-3 Prepared Mixes for Tests of Strength of Concrete with Fly-Ash

Mix No.	W/C Ratio	Fly-Ash Content in % of Cement Wt	Water (l/m^3)	Cement Kg/m^3	Sand Kg/m^3	Coarse Aggregate Kg/m^3
Mix-I	0.50	5 %	197	394	730.78	1113.954
Mix-II	0.50	10 %	197	394	730.78	1113.954
Mix-III	0.50	15 %	197	394	730.78	1113.954

IV. EXPERIMENT RESULTS AND DISCUSSION

4.1 Workability Test Results:-

After performing the number of slump cone tests on the prepared mixes with variable percentage of supplementary cementitious materials are mentioned below. The workability of cement Concrete test results indicates a slight decreasing trend of workability when the percentage of supplementary cementitious increased. Table-4 shows the average slump recorded during the test.

Table-4 Slump Cone Test Results with FA

% Content of FA in the Concrete mix	Slump (mm)
5	90
10	85
15	85

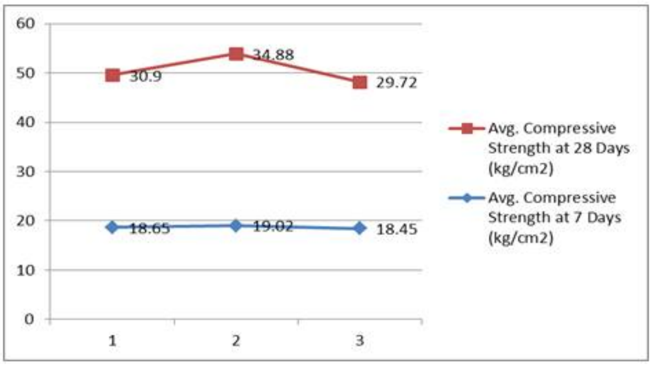
4.2 Strength of HPC:-

The strength of all the prepared mixes was determined at the ages of 7 days and 28 days for the various replacement levels of FA with cement Concrete. The values of average strength for different mixes prepared by replacement of cement by supplementary cementitious materials in the range 5 %, 10% and 15 % at the completion of different curing periods (7 days and 28 days) are given in the various Tables below.

Table-5 Combine Table for Strength of HPC with FA

S. No.	FA Content (%)	Avg. Strength at 7 Days (kg/cm^2)	Avg. Strength at 28 Days (kg/cm^2)
1	5	18.65	30.90
2	10	19.02	34.88
3	15	18.45	29.72

By these test results we can say that the strength of HPC can be increased up to approximately 9 % by replacing cement with 10 % FA as compared conventional Concrete mixture.



Graph-1 Combine Graph for Strength of HPC with FA

V. CONCLUSION AND RECOMMENDATION FOR FUTURE WORK

5.1 Conclusion:-

After the detail analysis and consideration of the test results we surely can say that the replacement of cement by supplementary cementitious material (SCM) in our case FA significantly affects the 7 days and 28 days strength of the HPC (HPC). From the significant difference, it can be evidently seen that the replacement of cement by supplementary cementitious material (SCM) in certain amount i. e. 10 % of the weight of cement increases the strength up to 8 % to 10 % approximately than conventional Concrete specimen. Experimental test results also show the similar trend. Hence, the results of the statistical analysis are equivalent to the experimental results. From the experimental investigation this research work can be concluded as follows:-

1. The replacement of cement by FA does not affect very much the workability of the cement Concrete mixture.
2. The gradual increase seen in the strength of HPC (HPC) at the 7 days and 28 days curing age with 5 % and 10 % replacement of cement by FA but after that it starts reducing the strength with increase of the replacement level.
3. The replacement of cement by FA increases the strength of Concrete mix for all curing ages up to a certain point. After that there is an abrupt reduction in the strength of the HPC (HPC), because at higher dosage of SCMs, Concrete loses its ability to make a proper bond between the all ingredients of Concrete.
4. The Concrete mix which was prepared with the replacement of cement by FA in the range 10 % with 0.55 W/C ratio posses the maximum as well as good workability. Therefore this mix is for maximum strength.

5.2 Recommendation for Future Work:-

Further researches and investigations were and should be carried out to understand more mechanical properties of HPC. Several ways for future studies in this field are mentioned below:-

1. Investigations and lab testing should be done to study on the various mechanical properties of (HPC). Such application of these supplementary cementitious materials was recommended in testing on Concrete slabs, beams and walls.
2. Conducting more tests such as abrasion value, shear test, impact value, blasting or creeping of Concrete on theses Concrete mixes.
3. The combination of two or more supplementary cementitious materials may tend to provide more efficient mechanical properties of a structure, so further investigation can be carried out by the combination of different types supplementary cementitious material into the Concrete mixture.
4. The mechanical properties of HPC may be different in various temperatures. So the tests on freeze-thawing conditions were recommended for future study.
5. The effect of various admixtures on the properties of HPC can also be checked in future.

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