Compressive Strength Assessment of High-performance Concrete using fly ash and Silica Fume

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Abstract:

In this study, fly ash and silica fume will be used as partial substitutes for cement in M60 grade concrete to assess the strength of high-performance concrete (HPC). When the micro silica and fly ash were added improved HPC's mechanical characteristics. For fly ash and silica fume, the ideal replacement levels were discovered to be 15% and 10%, respectively.

silica fume may increase compressive strength in concrete mixes up to a specific point (7.5% of the cement weight), beyond which it starts to lose strength. However, the tensile and shear strength was shown to be adversely affected by the addition of silica fume, with a considerable decline seen as the proportion of silica fume rose. The work emphasizes the need to determine the amount of silica fume in HPC combinations with care to maximize strength qualities and minimize possible downsides.

Construction projects all around the world in the construction industry like, industrial buildings, hydraulic structures, bridges, and highways, are increasingly choosing to use high-performance concrete (HPC). A sizable amount of concrete has been used in buildings as a result of the growing usage of HPC. The study gives a thorough account of the evolution of HPC in civil engineering, highlighting its distinctive characteristics and needs in comparison to traditional concrete. Additionally, it covers current developments in the field of HPC. The report also discusses the use of chemical and mineral admixtures to improve HPC performance. The paper's overall goal is to present a thorough grasp of HPC's applications in civil engineering and its continuous advances.

Keywords: Fly ash, Silica Fume, High Strength, Conventional Concrete.

Introduction:

A type of concrete known as high-performance concrete was created to exceed more stringent requirements for strength, dependability, and durability. Making use of micro silica and fly ash as replacements of cement is one technique to accomplish these qualities. By-products of numerous industrial processes including fly ash and silica fume are frequently added to concrete to increase strength and durability.

There have been a lot of studies done recently on the strength evaluation of HPC using different proportion of cementitious material. It has been discovered that adding these minerals to concrete improves its mechanical characteristics, and lowers the possibility of cracking. Concrete that satisfies particular specifications for compressive strength and water-cement ratio, among others, is referred to as HPC by the Strategic Highway Research Program (SHRP). Special performance and homogeneity standards that cannot be met by regular mixing, putting, and curing procedures must also be met by HPC. Cement, fine and coarse aggregates, water, mineral admixtures, and chemical admixtures are the materials utilized in HPC.

When used to build concrete structures, High-Performance Concrete (HPC) has a number of benefits, which are outlined below:

Benefits of using HPC

1. Simple in placing as the properties like strength don't change.
2. Resistance to chemical attack.
3. Early strength has been achieved by concrete.
4. Toughness.
5. extended lifespans in harsh conditions.

The use of less material, the need for fewer beams, less maintenance, a prolonged life cycle, and improved aesthetics are only a few of the economic and non-performance advantages of HPC. Even while high-strength concrete is regarded as a particular kind of HPC, not every HPC is necessarily high-strength concrete.

Materials:

The selection of high-quality materials is necessary for HPC manufacturing. For the creation of HPC, additional components like SCM and chemical admixtures are required in addition to the standard concrete elements like cement, FA, CA, and water.

Cement

Fine aggregate

Coarse aggregate

Micro silica

Fly ash

Superplasticizer

Cement

The physical and chemical characteristics of the cement, which affect the compressive strength of concrete, must be chosen carefully. Concrete's ability to build strength is largely dependent on the type and quantity of cement used. According to the standards outlined in IS: 8112-1989 and IS: 12269-1987, depending on the desired strength of the concrete mix, the cement grade of either 43 or 53 is used. A higher grade of cement is advised in order to maximize the mix proportions for high-performance concrete (HPC) and create stronger concrete. Therefore, the choice of cement has a big impact on the overall durability and strength of the concrete mix.

Initial setting time – 48min

Final setting time – 480min

Specific gravity – 3.15

Fine Aggregate

The FA particle grading and shape play a key role in the manufacture of HPC. Less water is required by FA with a smooth texture and rounded particle form. In order to maximize the mix's compaction and workability, it is advised to maintain the volume of FA to a minimum.

Specific gravity – 2.51

Coarse Aggregate

The kind of coarse aggregate used also affects the strength of concrete in HPC. It has been noted that employing smaller aggregate sizes often results in stronger concrete. However, bigger-size aggregates are frequently favored in order to achieve the ideal balance between creep and drying shrinkage. Usually, coarse aggregates are limited to a maximum size of 10mm or 12mm. Therefore, choosing the right size of coarse aggregate is crucial for ensuring that the HPC has the necessary strength and durability.

Specific gravity – 2.83

Water Absorption – 2.13%

Crushing strength – 22.42%

Impact test – 28.11%

Fly ash

The term "fly ash" describes the finely separated byproduct that is created when coal is burnt to produce electricity. It is mostly made up of tiny glass spheres and coal in a particulate form. Fly ash, formerly thought of as a waste by-product that was challenging to dispose of, is now valued for use as an additive in concrete. Fly ash is a byproduct of the burning of coal produced by power stations; the chemical makeup of the fly ash varies depending on the kind of coal. Based on its chemical makeup, fly ash may be divided into two types: Class-C and Class-F. The amount of SiO_2, Al_2O_3, and Fe_2O_3 in each class is the main distinction between them. Class-C's total content is between 50 and 70%, whereas Class-F's is larger than 70%. CaO makes up the remaining material in both groups.

Silica fume

Micro silica, commonly referred to as silica fume, is a leftover from the silicon and ferrosilicon alloy industries. According to the nitrogen adsorption technique, it has a very large surface area that normally ranges from 15,000 to 30,000 m^2/kg. About 100 times smaller than the typical size of a cement particle, silica fume has an average particle diameter of 0.15 m. Microsilica may be added to concrete to produce high-strength concretes, which is advantageous for generating early-age concrete strength.

Admixture

The characteristics of concrete are significantly improved by chemical admixtures. These additives are used to increase workability and durability, decrease water consumption, increase strength growth, lengthen the setting time, manage the pace of hardening, and increase air entrainment. To create various admixtures, chemical admixtures frequently include lignosulfonates, hydroxylated carboxylic acid, melamine, polysaccharides, naphthalene condensates, and organic and inorganic accelerators in a variety of compositions.

Chemical and mineral admixtures are both utilized to create high-performance concrete (HPC). Trial mixes are essential to determining how these admixtures affect the kind of cement being utilized. Usually, adding 1-2% plasticizer to cement per unit weight is enough. However, applying too much plasticizer might cause concrete to segregate hence, not advisable to use much.

Literature Review

Dr. Rakesh Srivastava1, Yogendra Kumar, Rupesh Kumar, Saurabh Kumar,2012. Investigation of High-Strength Concrete Using Fly Ash and Silica Fume. The study found that using silica fume in concrete improves compressive strength, and resistance against chloride penetration, and reduces water absorption, while a reduction in the water-binder ratio improves resistance against chloride ion penetration but reduces compressive strength.

Judita Grazulyte, Audrius Vaitkus, Ovidijus Sernas, 2009. The research suggests that adding silica fume to HPC significantly enhances its performance in compression, tension, bending, and cyclic loading, likely due to the denser microstructure resulting from the reaction between amorphous silica in silica fume and lime in cement, but workability decreases with increasing silica content due to reduced water-cement ratio.

S. Bhanjaa, B. Sengupta. Use of silica fume as supplementary material. In order to analyze the strength of silica fume concrete for creating high-strength concrete mixes, studies based on 28-day strength have recommended updated strength water-cementitious material ratio relationships for concrete including cement plus silica fume as a supplemental cementitious material.

Ali M Mansor, Ahmed M Hamid. Effect of silica fume on strength of HPC up to a particular proportion of additions, adding SF to HPC significantly improves the concrete's compressive strength. According to reports, concrete's tensile and shear strengths are reduced by the use of SF in HPC. 7.5% was discovered to be the ideal SF content for HPC, producing the highest compressive strength.%.

J. Chena et. al.(2017), High-performance concrete is created by mixing fly ash microspheres with condensed silica fume. Condensed silica fume and fly ash microsphere can be added to cementitious materials to improve their packing density, flowability, and strength, which results in high-performance concrete with a reduced (W/CM) ratio. At low W/CM ratios, the inclusion of FAM and CSF can significantly enhance flow spread.

Experimental Analysis on HPC

In natural normal concrete for M60 grade. Cube Concrete we used cement 100./., flyash. 0% silica fume 0%, and water cement ratio 0.25, and Strength we get seven days compressive test value is 41.08N/mm^2 and Compressive 28 days we get 68.66N/mm^2 target strength.

For mix 1, Cementaneous material is kept the same partial replacement of cement with fly ash silica fume cement used 90%, fly ash 5%, and silica fume5% for the same water cement ratio the 7 days compressive strength is found to be 43.12N/mm^2 and 28 days strength value is 70.32N/mm^2.

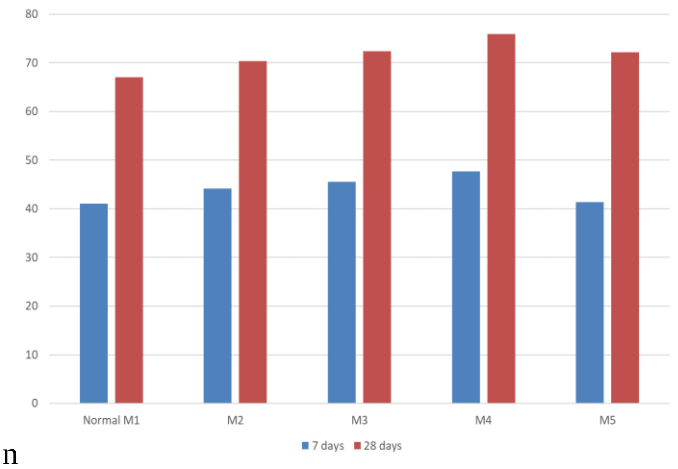
For mix 2, the replacement of cement is 80%, fly ash 10%., and silica fume 10% and the water-cement ratio is same i-e., 0.25. Cube after curing of the cube we get 7 days compressive fest value of 45.56 N/mm^2 and 28 days compressive Strength value is 72. 4 N/mm^2.

For mix 3, the replacement of cement is 70%, fly ash 15%, and silica fume 15%.the 7 days strength is found to be 47.73N/mm^2 and 28 days compressive strength value is 75.87N/mm^2.

For mix 4, replacement of cement with fly ash and silica fume in cement 60%,flyash 20%, and silica fume 20%.compressive strength is found to be for 7 days is 45.3N/mm^2 and 28 days strength is 71.14N/mm^2.

It has been seen that the replacing of cement with fly ash and silica fume in 5%,10%, and 15% strength is found to gradually increase further replacement of cement with silica and fly ash cement at 60%, fly ash at 20%, silica fume20% the strength is found to be gradually decrease .

Graph plot between 7 and 28 days compressive strength



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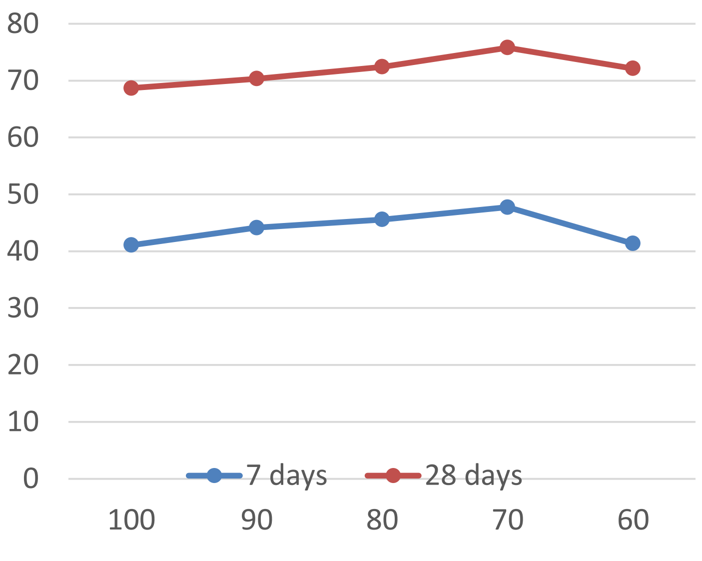
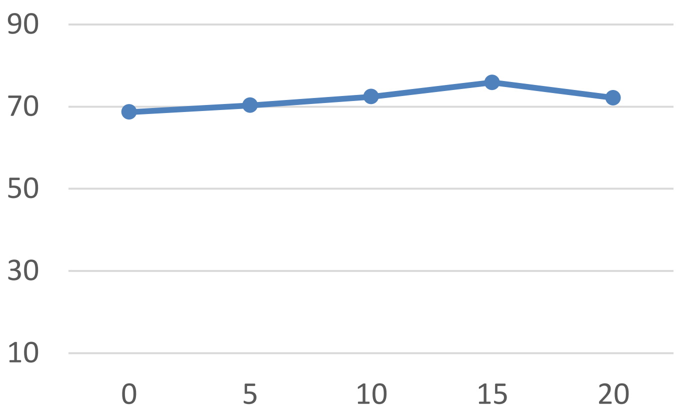
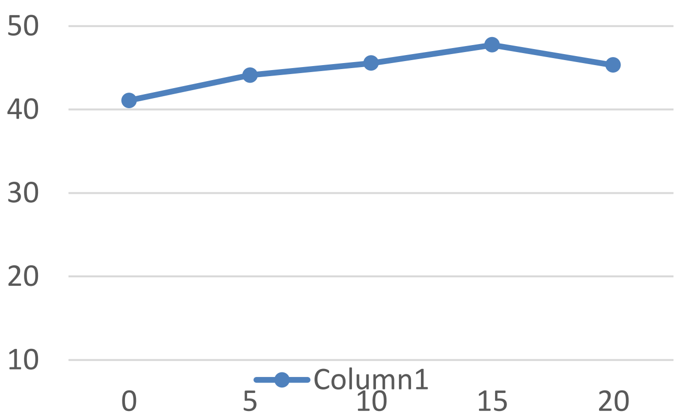
Graph plot between compressive strength of 7 and 28 days vs cement content



Graph plot between compressive strength and addition of fly ash and silica fume(28 days)



Graph plot between compressive strength and addition of fly ash and silica fume(7 days)



Conclusion

Based on the experimental investigation of data collected till now following conclusions were obtained: - From the beginning to completion of the project, the topic has been well discussed with our guidance throughout the project. The suggestion about the silica fume, fly ash and its properties that how it effects the properties of concrete by using the different percentages of it such as 5%,10%, 15% and 20%. This result shows increament in the strength up to 15% replacing of silica, fly ash with cement content. Beyond these values, the compressive strength of the specimen decreases. The workability of concrete decreases with increasing silica content, fly ash. Construction cost is reduced by use of these materials.

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