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Experimental Study on the Mutual Influence of Fly Ash, Silica Fume & Fibers on Strength Enhancement of Portland Cement

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***Abstract:** Mineral additives have a wide range of applications today because of their benefits such as waste evaluation for ecological balance and improving the physical and mechanical qualities of cement or concrete. Fly ash and silica fume are two of the wastes. These raw materials were subjected to physical, chemical, mineralogical, and molecular analysis for this purpose.*
Engineered cementitious composites (ECC) with excellent tensile strain capacity and repeated cracking often contain fly ash (FA) as a key component. Silica fume can either be "added" (added individually at the concrete mixer) or mixed with a composite cement that is manufactured in a factory. This essay examines the advantages and usefulness of using fly ash and silica fume. Silica fume can typically be used with chemical admixtures, and it is typically used with a super-plasticizer, just like with conventional concretes.
Tests should be conducted to determine the right dose levels as the performance of admixtures may depend on the unique characteristics of the source of the cementation's material (as with OPC cement). Supplementary cementing materials (SCMs) are utilized in concrete to partially replace the Portland cement component and exhibit pozzolanic and/or cementitious qualities. High-performance concrete contains an essential component called supplemental cementing material. In particular, when great strength and durability turn out to be the most desired attributes of high-performance concrete, the insertion of supplemental cementing material is crucial.
Several well-known supplemental cementing materials, including fly ash, silica fume, and powdered granulated blast-furnace slag, are presented in this work.
The impact of using steel fibers, fly ash, silica fume, and various combinations of them are evaluated in this paper. This study aims to ascertain how fly ash, silica fume, and fibers interact with Portland cement to increase concrete strength, reduce internal cracks, and increase tensile strength.
Keywords: Ecological balance, Fly ash, Silica fumes, Fibers, Supplementary cementing materials.

I. INTRODUCTION

The artificial material that is most frequently used worldwide is concrete. As of 2006, around 7.5 billion cubic meters of concrete are produced annually, or more than one cubic meter for each person on the earth. It is the foundation of the country's infrastructure and has an impact on practically everything we come into contact with daily. Clinker, cement, and concrete production processes are famous for their high CO2 emissions, massive energy consumption, and intensive use of natural resources. Concrete normally contains a tiny amount of a chemical admixture, and a mineral admixture is frequently used to replace some of the cement. The concrete commonly contains large amounts of coarse and fine aggregate, a moderate amount of cement and water, and a small amount of admixture.

Due to benefits including lessening the use of natural resources and eliminating wastes kept at waste storage locations without affecting the environment, the use of waste materials in the construction industries has become one of the topics of research during the last few years. Natural and industrial wastes and byproducts, which formerly got little to no attention, are now the subject of attention. Both disposal and health risks are issues with these materials. Recent decades have seen a surge in a study into the use of industrial by-products as supplemental cementitious materials, both from an ecological and financial standpoint.

It is generally known that silica fume and Class F Fly Ash (PFA) can partially substitute PC (Portland cement) in concrete. In most cases, the long-term strength and durability of concrete containing PFA and silica fume equal or surpasses that of PC concrete. Typically, examples of mineral admixtures included silica fume and fly ash.

This project enables us to know the strength of various combinations of concrete which willprovide ease in the study and gives an eagle eye over the observation.

1) To research how normal-weight concrete's compressive strength changes after conventional curing.
2) To research how Normal Concrete with Fly Ash Only under Conventional Curing develops compressive strength.
3) To examine the growth of compressive strength in normal concrete when silica fume is the only addition and ordinary curing is used.
4) To research how normal concrete with steel fibers added solely during standard curing develops its compressive strength.
5) To investigate how normal concrete that has only been conventionally cured and added fly ash and silica fume develops compressive strength.
6) To research how normal concrete's compressive strength changes when steel fibers and silica fume are added under traditional curing.
7) To research how Normal Concrete with Steel Fiber and Fly Ash solely during normal curing develops compressive strength.
8) To investigate how Normal Concrete with the addition of Fly ash, Silica fume, and Steel fibers only during standard curing develops compressive strength.
9) Additionally, to track the development of compressive strength for various mixtures, pattern grades, and water-cement ratios.

II. LITERATURE REVIEW

1) W.D.Pratiwi, F.D.D.Putra, Triwulan, Y.Tajunnisa, N A Husin, and K D Wulandari(2019)have put an effort into "A review of concrete durability in the marine environment". Marine areas have a lot of concrete buildings. Seawater is hostile to concrete and reinforcing because of its saline concentration. Due to the quantity of fly ash in Indonesia and the presence of aluminum species in fly ash, concrete using fly ash as SCM is an excellent candidate for usage in marine construction in Indonesia.
2) J.Y. Richard Liew and Bing-Lin Lai (2021) have experimented on “Supplementary cementitious materials”. Utilizing supplementary cementitious materials (SCMs), such as fly ash, blast furnace slag, and natural pozzolans lowers the cost of making concrete while also offering technical advantages. Utilizing SCMs can lessen hydration heat while extending the life of the UHPC. Since the incorporation of SCMs can change the UHPC's mechanical properties, it is advised to use the ideal amount of SCMs to prevent this from happening.
3) Dr. Banti A. Gedam (2019) has investigated “Improved durability of concrete using supplementary cementitious materials” Concrete infrastructures must figure out how to use eco-friendly additives to increase their serviceability and sustainability in the twenty-first century. Concrete construction depends on the concrete's endurance to meet this demand. It has been found that using SCM in concrete to partially replace the OPC helps to boost the durability of concrete.
4) Vagelis Gpapadakis (2000) has studied on “Effect of supplementary cementing materials on concrete resistance against carbonation and chloride ingress”. Using silica fume, low- and high-calcium fly ash, and other supplementary cementing materials (SCM), the durability of Portland cement systems is examined in this work. To characterize the carbonation propagation and chloride penetration in concrete using SCM, new parameter values were estimated, and preexisting mathematical models were changed.
5) Kim Hung Moa Tung-Chai Lingb U Johnson Alengarama Soon Poh Yapa Choon Wah Yuena (2021) has investigated the Overview of the use of additional cementitious ingredients in lightweight aggregate concrete In terms of structural design, transportation, and handling expenses, lightweight aggregate concrete (LWAClower)'s density results in financial savings. Compared to regular concrete, LWAC has better insulating qualities and is more resilient to the effects of earthquakes. However, there isn't much information available regarding the use of SCM that are porous, such as rice husk ash, palm oil fuel ash, pumice powder, volcanic ash, and more. As a result, more research is needed to properly comprehend their effects on LWAC.
6) Yunusa Alhassan, Michael Attah Onugba, and Emmanuel Oluwamayomikun Andrew(2022) have studied “Experimental Study on the Effect of Fly Ash on Concrete”. The strength characteristics of concrete made with fly ash (FA) as a partial replacement for cement were examined in an experimental investigation. For the manufacturing of concrete, F.A. is a good SCM. Fly ash use in concrete production will result in better environmental waste management and profitable industrial waste utilization. For the manufacturing of concrete, a maximum weight substitution of fly ash for cement of 20% is advised.
7) Ms.R.Sangavi and Mrs. J. Umanambi (2019) have investigated “Comparative Study on Strength Behavior of Slag Concrete with Conventional Concrete”. To some extent, conventional concrete contributes to the amount of CO2 emissions. You can cut back on emissions.

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With the use of agricultural and manufacturing wastes including fly ash, silica fume, and blast furnace slag, different types of concrete have developed. They use a remarkably small amount of energy. Today, there is a rising demand for building supplies. We are looking for innovative alternative materials to help alleviate this issue. Phase II will see the end report provided once the test results from the FAL-G concrete have been compared to those from regular concrete.

8) M.S. Krishna Hygrive, I. Siva Kishore, and KJB Chari, (2017) have studied "comparative study n compressive strength of fly ash concrete" We are aware of the serious environmental damage caused by cement manufacture, which involves the discharge of the majority of the carbon along with other pollutants. To produce cubes and prisms that are cured in regular water for up to 28 days, fly ash is added to concrete in a variety of amounts. These cubes and prisms are then tested for their properties using the Slump cone test, the Compaction factor test for newly-poured concrete, and the Compressive strength test for hardened concrete. The outcomes are then examined. The experimental work has helped in the development of new mix designs and in learning about the additional properties of fly ash concrete.

III. MATERIALS AND PROPERTIES

A. Cement

A binder is a substance that binds objects together by setting, hardening, and adhering to them. Cement is one such substance. Ordinary Portland cement of grade 53 that complies with IS: 12269-1987 was used in this investigation, and its parameters were assessed and tabulated by IS: 4031-98.

B. Aggregates (Fine and coarse aggregates)

In addition to water and Portland cement, concrete also needs aggregates, which are inert granular materials like sand, gravel, or crushed stone. To create an appropriate concrete mix, aggregates must be free of absorbed chemicals, clay coatings, and other fine pollutants that could cause concrete to decay. Between 60 and 75 percent of the total volume of concrete is made up of two different categories of fine and coarse particles. The majority of the particles in fine aggregates is frequently comprised of natural sand or crushed stone and typically passes through a 3/8-inch filter. A coarse aggregate is defined as any particle larger than 0.19 inches, which often has a diameter of between 3/8 and 1.5 inches. Gravel makes up the majority of the coarse aggregate used in concrete, while crushed stone makes up the majority of the remaining material.

C. Classification of Aggregates

Crushed rock is utilised as coarse aggregate in India, whereas river sand is used for fine aggregate. Recently, the scarcity of stone dust has necessitated the development of artificial sands, particularly in southern states. The physical, chemical, and thermal qualities of aggregates have a significant effect on the results of concrete.

D. Fly Ash

The by-product of burning pulverized coal in electricity-generating power plants is fly ash. Mineral impurities in coal including clay, feldspar, quartz, and shale fuse in suspension during burning and float out of the combustion chamber with the exhaust gases. As the fused material cools and solidifies as it rises, spherical glassy particles called fly ash are created. Fly ash is eliminated from the exhaust gases using electrostatic precipitators or bag filters. The fine powder is different chemically even though it resembles Portland cement. Fly ash and calcium hydroxide, a result of the chemical interaction between cement and water, interact chemically to produce additional cementitious compounds that improve a number of the desired properties of concrete. All fly ashes exhibit cementitious tendencies to varying degrees, depending on the chemical and physical properties of the fly ash as well as the cement.

Fig 1: Fly ash

E. Silica Fumes

Silica fume is a by-product of the production of elemental silicon or alloys containing silicon in electric arc furnaces. At a temperature of roughly 2000°C, high-purity quartz is reduced to silicon, creating silicon dioxide vapor, which oxidizes and condenses at low temperatures to produce silica fume. Silica fume particles typically range in size from 0.1 to 0.3 m and are spherical (De Belie et al., 2017; Jiao et al., 2017; Thomas, 2013). Sometimes, individual particles might come together to create microscopic agglomerates that can range in size from 1 to 100 m. The specific gravity of silica fume ranges from 2.20 to 2.30. The surface area of silica fume particles, which ranges between 13,000 and 30,000 m2/kg, can be measured using nitrogen absorption equipment.

Fig 2: Silica fumes

F. Steel fibers

A type of metal reinforcement is steel fiber. The term "steel fiber for reinforcing concrete" refers to short, discrete lengths of steel fibers with an aspect ratio (ratio of length to diameter) ranging from about 20 to 100, with various cross-sections, and that are sufficiently small to be distributed randomly in a mixture of unhardened concrete using the customary mixing techniques. Concrete's physical qualities can be qualitatively altered by adding a particular proportion of steel fiber, considerably enhancing the material's tenacity, durability, and resistance to cracking, impact, fatigue, and bending.

IV. METHODOLOGY

In this chapter, the method adopted for carrying out this experimental investigation,particularly for the methods adopted for carrying out the tests, casting, curing, etc.,

A. Collection Of Materials

The materials used in this experimental investigation are cement, Fine aggregate, Coarse Aggregate, and Clinker aggregates have to be collected and ensure that the materialswere free from impurities.

B. Testing of Materials

All the collected materials have to be tested and checked whether they are as per theconcerned IS Codes. And all the tests conducted on different materials were included in thisnext chapter.

C. Calculation Of Trail Mix And Testing Of Properties Of Trail Mix

After obtaining the properties of all the materials a mix design has to be done as per the BIS method and a trail mix has to be performed to confirm the different flow properties, curing and strength have to be analyzed.

If the obtained results were not satisfying and don't meet the standard value of the IScodes again trail mix has to be calculated.

D. Finalization of Mix design & Casting of Cubes

If the trial mix was confined, all the other required tests have to be done. The other specimens have to be cast concerning the finalized mix design which is included in theAnnexure.

E. The Casting Of Cubes With Finalized Mix Design

With the fixed mixed design, cast the specimens with normal convection concrete andClinker concrete.

F. Curing of Concrete Specimens

After the casting of specimens, the specimens have to be de-molded after 24 hours. Inthis experimental investigation, the following three methods were adopted

Normal conventional Curing.

G. Normal Conventional Curing

Immerse the casted specimens into the water and cure them for 7 days and 28 days.

H. Testing of Cured Cubes

The cured cubes from the three methods were tested using UTM (universal testingmachine) to determine the compressive strength and readings have to be noted.

I. Conclusions

After obtaining the results, conclusions have to be written based on the experimentalinvestigations, few comparative graphs have to be drawn.

V. RESULT AND DISCUSSION

A. Results Of Cement Sample

Table I Results of Cement Sample

S.NO	Characteristics	Values obtained
1.	Consistency	30%
2.	Initial setting time	30min
3.	Soundness of cement	3mm
4.	fineness	4%
5.	Specific gravity	3.1

B. Tests Results Of Fine Aggregate

Table 2 Results of Fine Aggregate

S.NO	TEST	RESULTS
1.	Zone	II
2.	Specific gravity	2.66
3.	Fineness modulus	4.32
4.	Water absorption	1%

C. Tests Results of Coarse Aggregate

Table 3 Results of Coarse Aggregate

S.NO	Test	Result
1.	Specific gravity	2.55
2.	Fineness modulus	6.075
3.	Water absorption	0.2%

D. Fly ash

Table 4**:** Physical properties of SCM (Fly ash)

S. No	Test Conducted	Results
01.	Specific gravity	1.96
02.	Bulk density	1287 kg/m^3
03.	Water absorption	8.3 %
04.	Moisture content	39%

E. Silica Fumes

Table 5: Physical properties of SCM (Silica fume)

S. No	Test Conducted	Results
01.	Specific gravity	1.98
02.	Bulk density	428 kg/m^3
03.	Water absorption	2.3%
04.	Moisture content	18 %

F. Slump Cone

Table 6: Slump values for NWC and combinations of SCM concrete for M20 grade concrete

Type of concrete	Grade of concrete	Slump Value
Normal Convectionalconcrete	M20	52
Normal concrete + Fly ash	M20	54
Normal concrete + Silicafume	M20	52
Normal Concrete + Steelfibers	M20	53
Normal concrete + Fly ash +Silica fume	M20	48
Normal concrete + Silicafume + Steel fibers	M20	50
Normal Concrete + Steelfibers + Fly ash	M20	48
Normal concrete + Fly ash + Silica fume + Steel fibers	M20	50

Table 7: Slump values for NWC and combinations of SCM concrete for M40 grade ofconcrete

Type of concrete	Grade of concrete	Slump Value
Normal Convectionalconcrete	M40	50
Normal concrete + Fly ash	M40	48
Normal concrete + Silicafume	M40	44
Normal Concrete + Steelfibers	M40	50
Normal concrete + Fly ash +Silica fume	M40	48
Normal concrete + Silicafume + Steel fibers	M40	50
Normal Concrete + Steel fibers + Fly ash	M40	48
Normal concrete + Fly ash +Silica fume + Steel fibers	M40	50

G. Normal Water Curing

Normal concrete and SCM Concrete.

Table 8: Compressive strength for NWC and combinations of SCM concrete forM20 grade concrete

S. No	Concrete Grade	7 days	28 days
01.	Normal Convectional concrete	13.05	19.25
02.	Normal concrete + Fly ash	14.33	22.73
03.	Normal concrete + Silica fume	14.65	23.60

04.	Normal Concrete + Steel fibers	13.66	23.88
05.	Normal concrete + Fly ash + Silica fume	15.90	24.32
06.	Normal concrete + Silica fume + Steel fibers	16.54	26.28
07.	Normal Concrete + Steel fibers + Fly ash	18.13	28.17
08.	Normal concrete + Fly ash + Silica fume + Steel fibers	22.74	36.34

Table 9: Compressive strength for NWC and combinations of SCM concrete for M40grade concrete

S. No	Concrete Grade	7 days	28 days
01.	Normal Convectional concrete	18.69	34.67
02.	Normal concrete + Fly ash	20.16	37.667
03.	Normal concrete + Silica fume	20.64	37.15
04.	Normal Concrete + Steel fibers	19.32	32.52
05.	Normal concrete + Fly ash + Silica fume	22.41	36.51
06.	Normal concrete + Silica fume + Steel fibers	24.11	38.12
07.	Normal Concrete + Steel fibers + Fly ash	24.69	38.99
08.	Normal concrete + Fly ash + Silica fume + Steel fibers	26.13	42.37

H. Split tensile strengths of Normal concrete and SCM Concrete

Table 10: Split tensile strength for NWC and combinations of SCM concrete forM20 grade concrete

S. No	Concrete Grade	7 days	28 days
01.	Normal Convectional concrete	1.024	1.83
02.	Normal concrete + Fly ash	1.055	1.85
03.	Normal concrete + Silica fume	1.13	1.89
04.	Normal Concrete + Steel fibers	1.52	2.20
05.	Normal concrete + Fly ash + Silica fume	1.59	1.93
06.	Normal concrete + Silica fume + Steel fibers	1.83	2.36
07.	Normal Concrete + Steel fibers + Fly ash	1.85	2.39
08.	Normal concrete + Fly ash + Silica fume + Steel fibers	1.98	2.45

Table 11: Split tensile strength for NWC and combinations of SCM concrete for M40grade of concrete

S. No	Concrete Grade	7 days	28 days
01.	Normal Convectional concrete	1.144	2.23
02.	Normal concrete + Fly ash	1.25	1.95
03.	Normal concrete + Silica fume	1.33	2.08
04.	Normal Concrete + Steel fibers	1.87	2.20
05.	Normal concrete + Fly ash + Silica fume	1.66	1.79
06.	Normal concrete + Silica fume + Steel fibers	1.98	2.36
07.	Normal Concrete + Steel fibers + Fly ash	2.2	2.31
08.	Normal concrete + Fly ash + Silica fume + Steel fibers	2.29	2.55

I. *Durability Tests*

Table 12: Durability tests for NWC and combinations of SCM concrete for M20 grade concrete

S. No	Concrete Grade	The dry weight of concrete	Wet weight of concrete	Difference between dry weight and wet weight	Water Absorption percentage
01.	Normal Convectional concrete	1.803	2.10	0.297	14.14
02.	Normal concrete + Fly ash	1.62	1.85	0.23	12.43
03.	Normal concrete + Silica fume	1.59	1.79	0.2	20
04.	Normal Concrete + Steel fibers	1.82	2.12	0.3	30
05.	Normal concrete + Fly ash + Silica fume	1.68	1.92	0.24	24
06.	Normal concrete + Silica fume + Steel fibers	1.74	1.98	0.24	12.12
07.	Normal Concrete + Steel fibers + Fly ash	1.72	1.89	0.17	8.99
08.	Normal concrete + Fly ash + Silica fume + Steel fibers	1.86	2.12	0.26	12.26

Table 13: Durability tests for NWC and combinations of SCM concrete for M40 grade concrete

S. No	Concrete Grade	The dry weight of concrete	Wet weight of concrete	Difference between dry weight and wet weight	Water Absorption percentage
01.	Normal Convectional	1.93	2.40	0.47	19.58

	concrete				
02.	Normal concrete + Fly ash	1.75	2.105	0.355	16.86
03.	Normal concrete + Silica fume	1.72	2.0	0.28	14.00
04.	Normal Concrete + Steel fibers	1.96	2.37	0.41	17.29
05.	Normal concrete + Fly ash + Silica fume	1.84	2.1	0.26	12.38
06.	Normal concrete + Silica fume + Steel fibers	1.99	2.41	0.42	17.42
07.	Normal Concrete + Steel fibers + Fly ash	1.78	2.32	0.54	23.27
08.	Normal concrete + Fly ash + Silica fume + Steel fibers	2.05	2.53	0.48	18.97

VI. CONCLUSIONS

The experimental investigation in this thesis led to the following conclusions.

1) When there is high humidity, the early strength of concrete increases during curing, and strength increases a little afterward.
2) The heat emitted from SCM Concrete while it is first curing is lower than it is from regular concrete.
3) In the concrete that the SCM coupled with steel fibers, the formation of cracks was relatively reduced.
4) When compared to regular concrete and SCM concrete with fly ash added, SCM concrete experiences less fracture development.
5) The strength increases in SCM concrete where the steel fibers were added were seen to be more when compared with other combinations of SCM which has simply fly ash and Silica fume.
6) The compressive strength of SCM concrete is more when compared with normal conventional concrete.
7) When compared to ordinary concrete that has been supplemented with 12% fly ash, conventional concrete's strength is noticeably lower.
8) This leads to the conclusion that, when regular concrete is compared to SCM concrete with fly ash, silica fume, and fibers, SCM concrete gains strength in both splits tensile and compressive strength.

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