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Combined Impact of Polypropylene Fibers and Silica Fume on M30 Concrete Grade

P.V. Hari Krishna[1]; Nanganam Lokesh Kumar[2]; Alladi Sudheer[3];
Marrikunta Hruthik Kumar[4]; Karamsetty Venkata Sudev[5]
Assistant Professor[1],
Dept. of CIVIL, QIS College of Engineering andTechnology, Ongole,
Andhra Pradesh–523272, India

Abstract:- This research project investigates the combined influence of silica fume and polypropylene fibers on the mechanical properties of M30 grade concrete. Silica fume, known for its ability to enhance concretestrength and durability, is introduced at varying percentages (0%, 10%, and 20%), while polypropylene fibers, chosen for preventing cracks and improving strength, are added at different levels (0%, 0.5%, and 1%). The project employs systematic experimentation, testing concrete mixes with different proportions of silica fume and polypropylene fibers at various curing periods for 7 days and 28 days to assess their impact on mechanical properties. The research seeks to identify the most effective mix design for achieving desired strength outcomes in M30 grade concrete. Silica fume is recognized for its ability to enhance concrete impermeability and strength, while polypropylene fibers offer benefits such as controlling shrinkage cracking and improving impact resistance. This research contributes to advancing construction materials by optimizing the utilization of silica fume and polypropylene fibers in concrete mixes. The findings aim to provide valuable insights for industry professionals seeking to improve the quality and performance of high-grade concrete structures. The search results indicate that the inclusion of silica fume helps the dispersion of fibers and increases the specimens' strength more than the addition of silica fume alone. Polypropylene fibers are also added to improve mechanical qualities.

I. INTRODUCTION

Concrete, as one of the most widely used construction materials, continuallyundergoes innovations to improve its strength, durability, and overall performance [1]. In this context, the combined influence of supplementary materials such as silica fume and polypropylene fibers has garnered significant attention due to their potential to enhance concrete properties [2]. Silica fume, a byproduct of silicon and ferrosilicon alloy production, is renowned for its ability to improve concrete strength and durability by filling voids and enhancing the cementitious matrix. On the other hand, polypropylene fibers, owing to their inherent characteristics, offer advantages such as crack control and improved impact resistance when integrated into concrete mixes [3]. The integration of silica fume and polypropylene fibers into concrete mixes offers a promising avenue for enhancing structural integrity and longevity. Silica fume's ability to enhance the cementitious matrix and reduce permeability complements the crack control and impact resistance provided by polypropylene fibers [4]. Consequently, this exploration of synergies between silica fume and polypropylene fibers contributes to advancing construction material and techniques, offering valuable insights for improving the quality and longevity of concrete structures [5]. The primary goal of this study is to ascertain how silica fume and polypropylene fibers work in concert to improve the mechanical qualities of M30 grade concrete. M30grade concrete must perform well in terms of strength and durability since it is frequently utilized in a variety of building applications [6]. Through systematic experimentation and analysis, this study seeks to provide concrete recommendations for optimizing mix designs to achieve desired mechanical properties in M30 grade concrete [7]. The findings presented in this paper not only contribute to the academic understanding ofconcrete technology but also hold practical implications for industry professionals involved in construction projects aimed at delivering better, longer-lasting buildings and infrastructure foreveryone [8].

II. LITERATURE REVIEW

Enhancing concrete mix designs for better mechanical qualities and durability has been the subject of numerous studies. By adding silica fume and steel fibers to concrete mixtures, Mahmoud Motahari Kareina et al. showed notable improvements in the mixtures' capacity to absorb water as well as their compressive, tensile, andflexural strengths [1]. Similar to this, Hossein Sasanipour et al. highlighted the function of silica fume in strengthening the matrix of concrete, especially in self- compacting concrete (SCC) that contains recycled concrete aggregates (RCA), hence improving resistance to agents of degradation [2]. Hui Guo and colleagues examined the impact of steel and polypropylene fibers on concrete with high strength, emphasizing their role in enhancing toughness and tensile strength [3]. The advantages of fly ash, silica fume, and coconut fibers in concrete were investigated by Prof. Mehran Khan et al., who demonstrated improvements in a range of mechanical properties [4]. Additionally, Jinxu Mo et al. investigated the effects of rubber powder and polypropylene fiber on mechanical properties and damping efficacy, particularly under seismic circumstances, while

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Mahyuddin Ramil et al. investigated the resilience of concrete reinforced with coconut fibers [5]. Divya S. Dharan et al. concentrated on the impact of blended polypropylene fibers on the characteristics of concrete, proposing ideal fiber proportions for enhanced strength parameters [6]. The origins, characteristics, and uses of silica fume in the cement and concrete industries were discussed by Branko Bandelj et al., who also highlighted the material's contribution to improving mechanical and durability properties [7]. Last but not least, A. Alavi Nia et al. examined test procedures for determining the impact strength of Fiber- Reinforced Concretes (FRCs), emphasizing the benefits of steel and polypropylene fibers onimpact resistance [8]. Together, this research advances concrete technology, provide industry professionals with useful solutions, and deepen our grasp of material science [9].

III. MATERIAL AND ITS PROPERTIES

A. Cement

OPC 53 Grade cement is a high-strength cement that complies with BIS specification IS:12269-1987, requiring a minimum specified strength of 53 MPa or 530 kg/sqcm after 28 days of curing, according to the sources that have been provided. Because of its exceptional strength and longevity, this grade of cement is ideal for a number of applications where high- strength concrete is required, including the building of skyscrapers, bridges, flyovers, chimneys,runways, and major load-bearing buildings.

Benefits of OPC 53 Grade cement include good early strength, durability, and lower cement amount requirements, which save money. On the other hand, it releases hydration heat more quickly, which, if not well controlled by curing procedures, may cause micro cracking in concrete.

Fig 1: OPC 53 Grade Cement

A. Coarse Aggregate

The larger, heavier, and less finely divided components of concrete that provide the final product strength and durability are referred to as coarse aggregate. It consists of substances such as slag, crushed stone, and gravel. IS: 383 states that fractions with a size range of 20 mm to 4.75 mm are used to create coarse aggregate.

Fig 2: Coarse Aggregate

B. Fine Aggregate

Fine aggregate consists of fractions that range from 4.75 mm to 150 microns. River sandand crushed sand are used to produce fine aggregate conforming to IS 383 standards.

Fig 3: Fine Aggregate

Fine aggregate ensures that the cement paste is properly distributed and bonds to the mixture, making concrete mixtures more workable and cohesive.

C. Silica Fume

Due to its tiny particle size and high silicon dioxide (SiO_2) content, silica fume, a highly reactive pozzolanic substance, is used Concrete's durability, constructability, and mechanical qualities are all improved by thissubstance.

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Table 1: Test Certification of SILICA FUME

Parameters	Method	Result
Physical StateExamination	By Visual	Solid
Oduor	By Observation	Characteristic Powder
Appearance	By Visual Examination	Amorphous Powder
Color	By Visual Examination	Grey
pH of 5%Solution	IS 2720 (Part-26) 1987 (RA 2016)	10.05
SpecificGravity	ASTM D854 - 14	0.269
Moisture	STM D 2116 -19	1.51%
Silica as SiO2	IS 1917 (Part-3) 1992 (RA 2015)	83.72%

Silica fume is a crucial mineral admixture that is widely utilized in high-strength concrete in the manufacturing of high-strength and high-performance concrete.

Fig 4: Silica Fume

High-performance concrete is used in many different applications, such as nuclear plants, bridges, and marine settings. It works by strengthening the concrete's bond, abrasion resistance, and compressive strength while lowering its permeability to chloride ions, which prevents corrosion in settings high in chloride.

D. Polypropylene Fiber

Synthetic fibers called polypropylene fibers, or PP fibers, are utilized in many different applications, particularly in building materials like concrete. These fibers feature characteristics including antistatic, non- magnetic, and non-conductive qualities in addition to being rigid, stable, and heat- resistant. They provide advantages like resistance to chemicals, durability, and high tensile strength. Because of their versatility, polypropylene fibers work well in a wide range of temperatures. They are frequently included with cement in construction to increase the tensile strength and decrease cracking in concrete.

Fig 5: Polypropylene Fibers

Additionally, these fibers are utilized in the textile industry to make carpets, fishing nets, ropes, fake grass, and other products. All things considered, polypropylene fibers are prized for their capacity to reasonably and successfully reinforce fabrics while providing a number of advantageous qualities. PP fibers are discrete, short fibers that are used in concrete to improve resistance to impact, abrasion, and water penetration, as well as to prevent and control fractures. These fibers increase the concrete's uniformity, increase its flexural and compressive strengths, and improve its ability to absorb energy. Polypropylene Fibers ensure uniform dispersion, which lessens problems like bleeding and segregation and produces a more consistent concrete mix. Benefits from larger fibers include improved tensile, flexural, and impact resistance. Polypropylene Fibers and other polypropylene fibers are made of both crystalline and non-crystalline materials. Based on manufacturing conditions, polypropylene fibers usually have a crystallinity of 50–65%. With a density of roughly 0.91 gm/cm3, polypropylene is among the lightest synthetic fibers on the market.

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E. Super Plasticizer SP430

A super plasticizing additive called Conplast SP430 is added to concrete to increase its strength and workability. It is a solution free of chlorides that contains polymers of sulphonated naphthalene. This addition improves concrete flow, lowers water content, hastens early strength development, and increases durability. Conplast SP430 can be used in precast concrete and other applications needing high early strengths. It is compatible with different types of cement. It offers advantages like better workability, decreased permeability, and increased cohesiveness inconcrete mixtures and conforms with industrial standards such as BS:5075 Part 3 and IS:9103:1999. To obtain comprehensive detailsregarding SP Conplast 430, such as its composition, suggested applications, and application guidelines.

IV. TEST PROCEDURES

A. Specific Gravity of Materials:

➢ *Cement*

One important characteristic of cement that shows its density in relation to the density of a reference material (usually water) is its specific gravity. A straightforward formula is used to calculate specific gravity, which entails weighing the cement in a Le Chatelier flask, adding kerosene, and figuring out the specificgravity based on the weights of the various parts. Because it influences elements like workability, strength, and moisture content, which can affect the overall quality of the concrete mix, cement specific gravity is important for designing concrete mixes. Before using cement, its specific gravity must be determined in order to guarantee proper mix design, prevent problems with moisture content, and ensure that the cement particles are ground to a high enough quality.

➢ *Aggregates*

One of the essential characteristics of aggregates is their specific gravity, which measures the weight difference between a specified volume of aggregate and an equivalent volume of water. Whenevaluating the strength, quality, and water- holding capability of building materials such as aggregates, this statistic is essential. Lower specific gravity levels indicate weaker aggregates in comparison to those with higher specific gravity values, which helps determine the robustness and resilience of materials. Depending on the size of the aggregates being tested, various procedures are used to conduct a specific gravity test in order to determine the specific gravity of the aggregates. While smaller particles are tested using a Pycnometer, larger aggregates are treated differently. Precision tools such as a balance, oven, wire basket, and containers for filling and hanging the basket with water are used in this test. The testing process entails cleaning, immersing, weighing, surface-drying, and computing specific gravity, apparent specific gravity, and water absorption from the aggregate sample after it has been surface- dried in water.

B. Slump Cone Test (Workability)

One technique to gauge how workable fresh concrete is before it cures is the slump cone test. This test is essential for determining how smoothly concrete flows and can reveal whether a batch of concrete has been mixed incorrectly. In order toperform the technique, new concrete is poured into a metal mould called a slump cone or Abram’s cone in three stages, with each layer being compacted before the cone is removed and the concrete's slump is measured. The workability of the mix can be inferred from the shape of the slumped concrete; distinct types of slumps, such as genuine slump, shear slump, or collapse slump, indicate different qualities of the concrete.

C. Compressive Strength Test

Concrete sample strength is specificallyevaluated using the compressive test on a (150mm x 150mm x 150mm) cube. This test, which is usually carried after 28 days after the concrete has cured, is essential for assessing the strength and durability of concrete structures and making sure they adhere to performance and safety requirements. In essence, the compressive test establishes the concrete's characteristic compressive strength, or the threshold below which only 5% of test results are predicted to occur. The procedure adheres to accepted norms, like those specified by Indian Standards, to guarantee accuracy and uniformity throughout testing facilities and projects. These guidelines cover the methods, requirements for the tools, and testing variables needed to perform accurate compressive tests. A uniform rate of loading 140kg/sq.cm is maintained. The process normally starts with the casting of standard- sized concrete cubes, which are typically 150 mm in size, from concrete mix representative samples. To replicate real- world conditions and encourage appropriate hydration and strength development, these cubes go through a controlled curing process. Following the curing time, the cubes are compressed under regulated conditions with the use of specialist testing apparatus. The maximum load supported prior to failure is recorded as the machine steadily increases force until the cube breaks. The compressive strength of the concrete sample is calculated by dividing this load by the cube's cross-sectional area. The outcomes of these tests are essential for guaranteeing that concrete satisfies the necessary strength requirements for a range of building applications. This information is used by engineers to verify design hypotheses, evaluate structural integrity, and direct quality controlprocedures while building.

V. METHODOLOGY

A. Mix Proportion

(Concrete Mix Design for M30 Grade according to IS:10262-2009)

- Grade of concrete – M30 grade
- Nominal size of concrete - 20mm
- Type of cement - O.P.C 53 grade
- Minimum cement content - 360 kg/m3 fromIS: 456
- Maximum cement content - 450 kg/m3 fromIS: 456
- Maximum water cement ratio - 0.45

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- Slump - 75-100mm
- Exposure - extreme condition
- Type of aggregate – crushed angular aggregate
- Chemical admixture - super plasticizer(Conplast SP:430)

Table 2: Material Requirement for 1m3

Cement	**90 kgs**	**1**
Fine aggregate	718.7 kgs	**1.64**
Coarse Aggregate(20mm)	735.18 kgs	
Coarse Aggregate(10mm)	500.68 kgs	**3.16**
Water	163 lit	**0.42**

There are nine distinct mix proportions for concrete with varied aggregate levels (0%, 10%, and 20%) and polypropylene fiber percentages (0%, 0.5%, and 1%). These mixtures are essential for strengthening the concrete and preventing cracks. The following are the mix proportions:

B. Different Types of Mixes

For the cubes mentioned above, we are performing compression testing for 28-day curing ages. We can ascertain the strength of the concrete mix at various curing ages with the aid of the outcomes. Six cubes are needed for a single mix, three for seven days and three more for twenty-eight. Nine distinct concrete mixes are being tested by us. Theexperiment will then test a total of 54 cubes. This will enable us to examine any patternsor variances in the compressive strength of each mix at various curing ages accordance with the specified mix design and requirements. Layer newly mixed concrete into cube molds, making sure to fully compact each layer to eliminate any air spaces. Remove any extra concrete and level down

Table 3: Different types of Mixes

Mix-1	0% PPF	0% SF
Mix-2	0% PPF	10% SF
Mix-3	0% PPF	20% SF
Mix-4	0.5% PPF	0% SF
Mix-5	0.5% PPF	10% SF
Mix-6	0.5% PPF	20% SF
Mix-7	1% PPF	0% SF
Mix-8	1% PPF	10% SF
Mix-9	1% PPF	20% SF

Fig 6: Materials used in Concrete Mix

The information gathered from these experiments will be very helpful in refining the designs of concrete mixes for upcoming projects. These various combinations have a substantial impact on workability, strength, and crack resistance, among other qualities of both fresh and hardened concrete.

VI. TEST PROCEDURE

A. Concrete Cube Preparation

Prepare the concrete mixture in the surface. Attach a distinctive label to every cube so that they can be recognized during testing.

B. Slump Cone Test

One essential technique for determining the consistency and workability of freshly mixedconcrete is the slump test. The process is setting up a slump cone on a level surface, adding layers of concrete to it, and then taking the cone off to let the concrete settle. The settlement, or "slump," that results is assessed to evaluate the flow and deformation properties of the concrete. This test is essential to make sure the concrete can be easily completed, compacted, and placed in accordance with building specifications. Building industry experts can determine whether a concrete mix is appropriate for a certain application bycomparing the slump value to predetermined ranges.

Fig 7: Concrete Mixing and Slump Cone test

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C. Demolding and Additional Curing:

Following the first curing phase, remove the cubes from the moulds with caution, making sure to cause the least amount ofsurface disruption possible. - Remove anysurface markings and attach labels for the cubes' identification. - For the remainder of the curing time, immerse the cubes in a curing bath full of fresh, clean water. Typical times range from seven to twenty- eight days, depending on the needs of the test.

Fig 8: Curing of Cubes

The cubes go through the following steps in the previously indicated curing process:

After the first curing period, carefully remove the cubes from the moulds. Remove any weak spots on the surface, or surface laitance, and give the cubes labels so they may be identified. Immediately immerse the cubes in a fresh, clean water curing bath. Lastly, before breaking the cubes, cover the moulds with plastic sheeting and let them cure for at least 24 hours. After that, the cubes need to be kept in a water tank at 27 ± 2°C until testing. For every mix, the curing should be done for seven and twenty-eight days.

Fig 9: Casted and Cured Specimens before Compressive Testing

D. Compressive Strength Test

Make sure the cubes are adequately cured and have reached the necessary age for testing before proceeding. - Assemble the compression testing apparatus in accordance with manufacturer instructions and requirements. Align the cube specimen properly by placing it on the lower platen of the testing apparatus. Apply a consistent, progressive compressive force at a predetermined pace (usually 0.2 or 0.3 MPa/s) until failure happens. After noting the greatest force the cube could withstand, use the following formula to determine its compressive strength:

Compressive Strength = Greatest Force / Cross-Sectional Area of Cube.

Fig 10: Placing of cube in Compressive Testing Machine

VII. REPORTS AND DISCUSSIONS

The graph shows how silica fume and polypropylene fiber (PPF) affect concrete's compressive strength. The baseline is a control sample that has been given no additions. To examine their effects, different ratios of PPF (0%, 0.5%, & 1%) and silica fume (0%, 0.5%,& 1%) were added. It turns out that silica fume significantly improves concrete's compressive strength. Significantly, the control sample had a very low compressive strength of 38.47 N/mm2, but the sample that included 20% silica fume had the greatest compressive strength ever measured, at 42.54 N/mm^2.

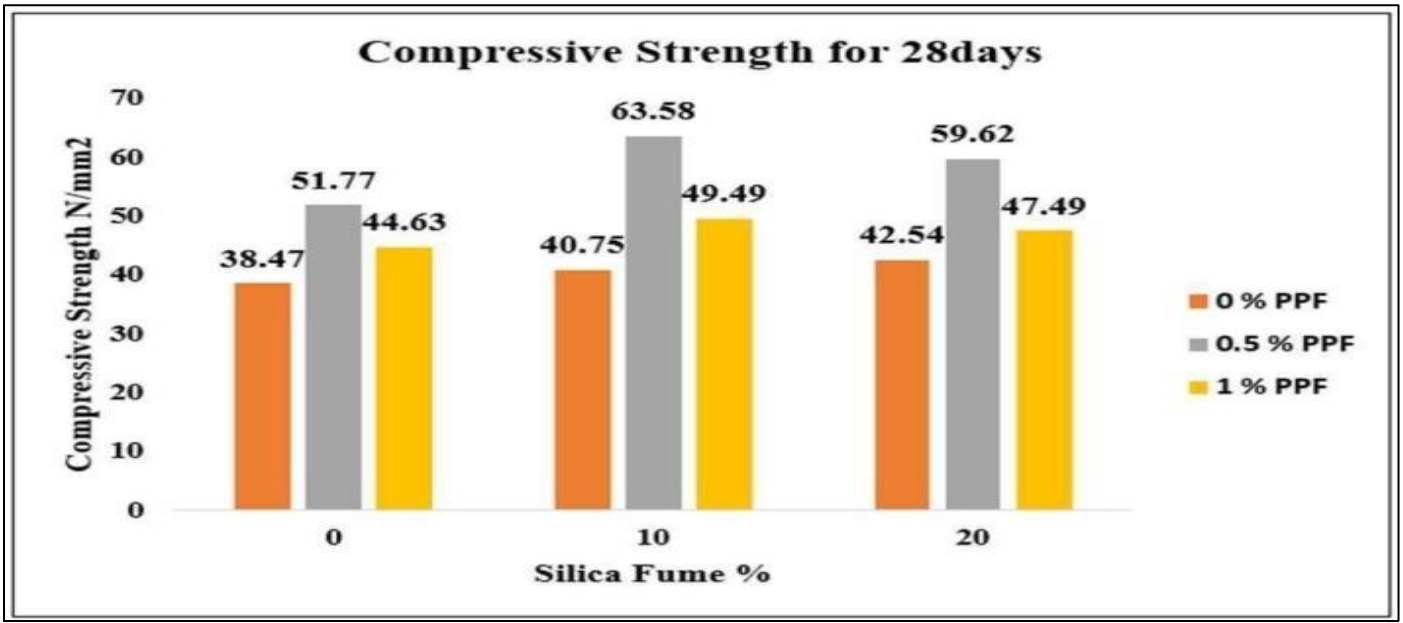

Fig 11: Graph between Compressive Strength Values for % Silica Fume @ 0%, 0.5% & 1% Polypropylene Fiber

The findings show that adding silica fume to concrete greatly improves its compressive strength. In particular, the control sample exhibited a compressive strength of just 38.47 N/mm2, but the 20% silica fume sample displayed the maximum compressive strength at 42.54/mm.

VIII. CONCLUSIONS

- Concrete cubes were subjected to an experimental investigation on compressive strength by the addition of polypropylene fibers and the substitution of silica fume for cement. The study led to the following conclusions being made.
- The desired mean strength of M30 grade concrete, for prescribed mix proportions, was attained after 28 days and recorded as 38.47 N/mm2.
- Based on the results, it was determined that, in the absence of polypropylene fibers, 20% was the ideal replacement percentage of silica fume with cement.
- When silica fume is not introduced, the ideal proportion of polypropylene fibers is determined to be 0.5%.
- The substitution of polypropylene fibers and silica fume separately yielded optimal levels of 0.5% and 20%, respectively. The combination of 10% silica fume and 0.5% polypropylene fibers produced the highest compressive strength, which was measured at 63.58 N/mm^2.
- Using silica fume will keep permeability low, while using polypropylene fibers will save maintenance costs by decreasing permeability and micro cracks, increasing durability in the process.
- We discovered in my thesis study that the strength was steadily increased by adding 10% silica fume and 0.5% polypropylene fiber. Consequently, we conclude that the optimal ratios are 10% silica fume and 0.5% polypropylene fiber.

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