Investigation of Silica Fume and Metakaolin as PartialReplacement for Cement in Fiber-Reinforced Concrete

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Submitted by

Chhaya Mishra

(Roll No. 2104790005002)

Under the Supervision of

Mr. Anuj Verma

(Assistant Professor& Head)

Department of Civil Engineering

Rajshree Institute of Management & Technology,

Bareilly (U.P)

Affiliated to

DR. A.P.J Abdul Kalam Technical University Lucknow

(Formerly Uttar Pradesh Technical University)

June, 2023

DECLARATION

I hereby declare that the work presented in this report entitled **“Investigation of Silica Fume and Metakaolin as Partial Replacement for Cement in Fiber-Reinforced Concrete "**,I affirm that I conducted the research presented in this report. The content contained herein has not been submitted for the purpose of obtaining any other degree or diploma from any other University or Institute.

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Name: Chhaya Mishra

Roll. No. : 2104790005002

Branch : Civil Engineering

(Candidate Signature)

CERTIFICATE

This is to certify that the thesis entitled **"Investigation of Silica Fume and Metakaolin as Partial Replacement for Cement in Fiber-Reinforced Concrete"**I certify that this thesis, submitted by Chhaya Mishra, fulfills the requirements for the award of the Master of Technology degree in Civil Engineering at the Rajshree Institute of Management & Technology, Bareilly. The research work presented in this thesis has been conducted under my supervision and is an authentic record of her efforts. No part of this thesis, in its entirety or in part, has been previously submitted to any other Institute or University for the purpose of obtaining any degree or diploma.

Signature

Mr. Anuj Verma

Assistant Professor

Department of Civil Engineering Date:

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Chhaya Mishra

Roll No: 2104790005002

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ABSTRACT

The purpose of this research is to examine the feasibility of using silica fume and metakaolin as cement substitutes in fiber-reinforced concrete. Analysis of the produced concrete mixtures' mechanical qualities, durability, and microstructural features is the goal. The potential of SCMs like silica fume and metakaolin to improve concrete's performance while also lowering its environmental effect has garnered a lot of attention in recent years.

In this well-regulated study, we replaced different proportions of cement with silica fume and metakaolin in multiple concrete formulations. The resulting mechanical properties were analyzed by measuring and comparing compressive strength, flexural strength, and split tensile strength against a control mixture that did not contain supplementary cementitious materials (SCMs). Additionally, the study assessed the durability aspects such as resistance to chloride ion penetration and carbonation.

This study looked into how silica fume and metakaolin could be used as partial cement replacements to improve the mechanical properties and longevity of fiber-reinforced concrete. By adding supplementary cementitious materials (SCMs), the general mechanical properties of the material were significantly improved. Also, compared to the control mixture, the concrete samples with SCMs had a higher resistance to chloride ion entry and carbonation.

The microstructural analysis revealed that silica fume and metakaolin promoted the formation of denser cementitious matrix and reduced the porosity of the concrete. The interfacial transition zone between the fiber and the matrix was also enhanced, leading to improved bond strength.

CHAPTER 1
INTRODUCTION

INTRODUCTION

Concrete's high mechanical strength, long lifespan, and low production cost make it a popular construction material worldwide. Traditional concrete, however, has shortcomings like weak tensile strength and brittleness. The use of fibers to reinforce concrete can remedy these issues. Incorporating fibers into concrete creates a composite material with all the advantages of concrete plus toughness, ductility, and increased resistance to cracking.

Silica fume is produced during the processing of silicon and ferrosilicon alloys. Because of its huge surface area and strong reactivity, it is an excellent pozzolan for enhancing concrete's properties. Concrete's durability, toughness, and simplicity of use can all be improved by mixing with silica fume. In contrast, metakaolin is a pozzolan made by calcining kaolin clay at very high temperatures. It is a highly reactive substance, similar to silica fume, that can enhance the qualities of concrete.

The goal of this study is to find out if silica dust and metakaolin could be used instead of cement in fiber-reinforced concrete. First, the study will explain what fiber-reinforced concrete is and talk about its benefits. Then, it will go into detail about how silica dust and metakaolin can be used to improve the way concrete works. Lastly, the study will show the results of experiments done on samples of fiber-reinforced concrete in which some of the cement was replaced with silica dust and metakaolin.

Fiber-Reinforced Concrete

By incorporating fibers into the mix, the mechanical qualities of fiber-reinforced concrete are enhanced. Steel, glass, carbon, and synthetic polymers are just some of the materials that can be utilized to create FRC fibers. Typically, fewer than 5% by volume of these fibers are added to the concrete mixture.

Concrete's flexural strength, toughness, impact resistance, and fatigue resistance can all be enhanced by the incorporation of fibers. By decreasing cracking and increasing resilience to environmental degradation, fibers help increase concrete's longevity. Bridge decks, parking garages, and airport runways are just few of the many structural uses for FRC.

When kaolin clay is subjected to high temperatures during the calcination process, a pozzolan called metakaolin is created. Amorphous silica and alumina make up the bulk of this fine white powder. The strong reactivity of metakaolin and its potential to improve concrete's characteristics have made it a popular additive. Metakaolin not only makes concrete stronger and last longer, but it also makes it easier to shape and place. The small particle size and high surface area of metakaolin result in a more cohesive concrete mix, which reduces the need for additional water and enhances the flowability of the mix. This makes metakaolin an ideal material for use in self-consolidating concrete (SCC) and high-performance concrete (HPC).

There is evidence that building with metakaolin results in a smaller carbon footprint. The cement industry is responsible for the vast majority of concrete's carbon dioxide emissions because cement is the principal binder. The carbon footprint of concrete can be lowered by using less cement when using metakaolin as a partial replacement. As a highly reactive pozzolan, metakaolin can increase the durability, workability, and mechanical qualities of concrete. It is ideally suited for use in high-performance and sustainable concrete applications due to its capacity to generate additional cementitious elements and increase the cohesiveness of the concrete mix.

1.1 CEMENT

Cement is typically used in conjunction with aggregate, which consists of things like sand and gravel. Mortar for masonry uses cement, and concrete uses cement in combination with sand and gravel.

Cement is a very fine powder made from a variety of minerals. When combined with water, this powder makes a glue-like paste that sets rock solid. Cement's characteristics vary based on its constituent parts and the degree to which the powder has been refined.

Concrete's primary ingredient is cement. It's widely used in the building industry because of its low cost and great quality.

Building cement is often an inorganic material (lime or calcium silicate) that, depending on its capacity to set when exposed to water, is classified as either hydraulic or non-hydraulic.

1.2 CEMENT PRODUCTION

The two main ingredients in cement production are limestone and clay or shale. After being mined from the quarry and crushed into a fine powder, these raw ingredients are subsequently mixed in the appropriate quantities.

Raw feed, often called kiln feed, is a raw material mixture that is cooked to temperatures between 1400 and 1500 degrees Celsius in a rotating kiln. A rotating kiln is essentially just a long tube with a long flame sticking out of one end. These tubes can be up to 200 meters in length and as little as 6 meters in diameter. The raw feed enters the kiln at the bottom, where it is cooler, and exits at the top, where it is hotter.

Clinker is the name for the material that forms in the kiln. It is usually made up of rounded lumps that are between 1mm and 25mm across.

After the clinker has cooled, it can be temporarily stored in a clinker store or sent straight to the cement mill.

The clinker is turned into a fine powder by the cement mill. The clinker is usually ground up with a small amount of gypsum, which is a form of calcium sulfate. When water is added to the cement, the gypsum controls how it sets.

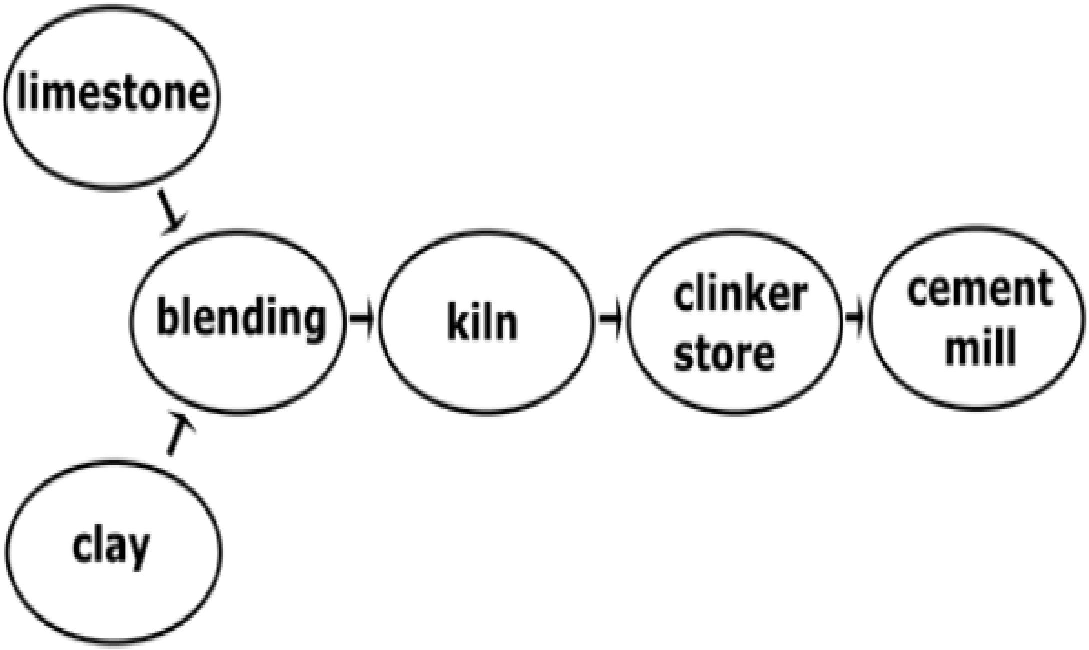

Fig. 1.1: Basic components of the cement production process

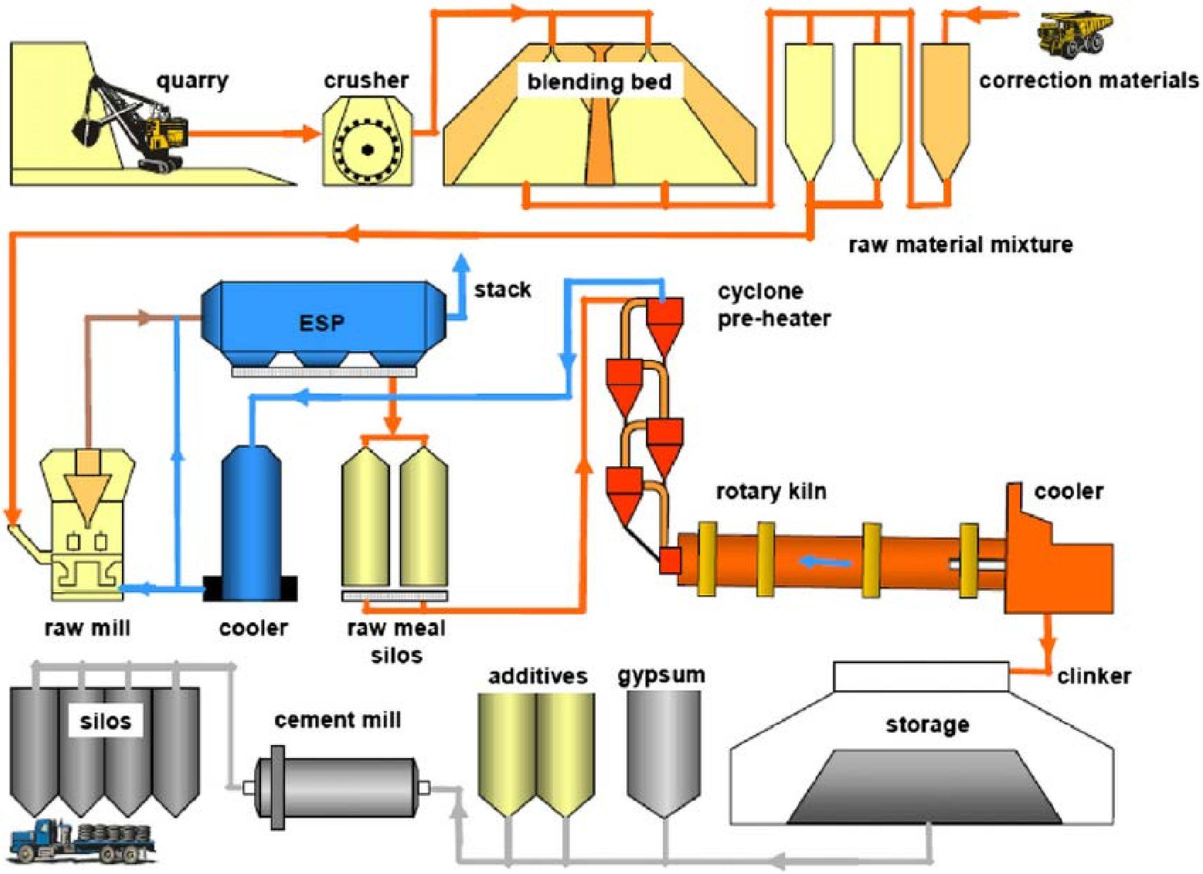

Fig. 1.2: Schematic representation of cement production

1.3 CEMENT COMPOSITION

1.3.1 CHEMICAL PROPERTIES OF CEMENT

The primary components of Portland cement are listed below, and they constitute approximately 90% of its volume.

Table 1.1 Chemical Properties of Portland cement

Chemical content	Amount (%)
Calcium Oxide (CaO)	60-67
Silicon dioxide (SiO_2)	17-25
Aluminium oxide (Al_2O_3)	3-8
Iron oxide (Fe_2O_3)	0.5-6
Magnesium oxide (MgO)	0.1-4
Sodium oxide (Na_2O)	0.2-1.3
Potassium oxide(K_2O)	0.2-1.3
Sulfur Trioxide (SO_3)	1-3

1.4 ENVIRONMENTAL IMPLICATIONS OF CEMENT

The production of Portland cement consumes a considerable amount of energy and releases a significant amount of carbon dioxide (CO2) into the atmosphere. This process is responsible for approximately 7% of global CO2 emissions. Furthermore, cement production generates substantial dust. Consequently, there is a growing need to develop alternative materials in light of these environmental consequences.

1.5 SILICA FUME

Micro silica, or silica fume, is a byproduct of the production of silicon and ferrosilicon. SiO2 vapors are produced when ultra-pure quartz is heated to very high temperatures. These vapors cool to room temperature, where they oxidize and condense forming tiny particles of non-crystalline silica. The majority of the byproducts from the manufacturing of silicon metal and ferrosilicon alloys with a high silicon concentration are non-crystalline silica. In comparison to the original ferrosilicon alloy, the silica fume produced during its production contains less silicon and has fewer pozzolanic qualities. The type of alloy being made is related to the percentage of silica dioxide in the silica fume. As a byproduct of making elemental silicon or silicon-containing alloys in electric arc furnaces, a substance known as "very fine non-crystalline silica" is generated. It typically appears as a fine gray powder resembling a combination of Portland cement and fly ash. Posizonic and cementation properties may be displayed. The mechanical characteristics can be significantly improved by using silica fume as a pozzolanic admixture. Compressive strengths in the order of 100-150 MPa can be more easily achieved in the lab when silica fume is combined with super plasticizers. By reducing permeability and refining the pore structure, silica fume enhances concrete's resistance to sulfate assault by limiting the passage of harmful ions. Silica fume concrete's anti-corrosion properties for embedded steel will increase along with its improved longevity.

When silicon and silicon alloys are manufactured, silica fume is created as a byproduct. It comes in several styles, the dandified one being the most popular. The crystalline silica dust used was tested to both IS: 1331(PART1) 1992 and ASTM C (1240-2000) standards for purity. Micro silica, also known as condensed silica fume, is another name for the waste material used as a pozzolanic. This waste material is produced when silicon or ferrosilicon alloy is made by reducing high-purity quartz with coal in an electric arc furnace.

1.6 SILICA FUME SOURCE

Very fine, non-crystalline silica is a byproduct of making metallic silicon or ferrosilicon alloys in electric arc furnaces. Coal, quartz, and wood chips are the primary ingredients. Instead of being dumped into landfills, the smoke generated by furnace operations is collected and resold as silica fume.

If you're dispensing, transporting, or storing silica fume, you should know that the powder's particles are a hundred times finer than those in conventional Portland cement. To address these issues, the material is sold in several different forms. The chemical makeup and reaction rates of a substance are unaffected by its physical form, which merely differs in particle size. The many functions are affected by this distinction. As a result, it's important to give some thought to the application before settling on a silica fume type.

1.6.1 PHYSICAL PROPERTIES OF SILICA FUME

The production method and the type of silica utilized in the fumes determine their characteristics. There are spherical particles involved. According to Table 1, its particles are a powder with dimensions one hundred times smaller than those of Portland cement. There are three different kinds of silica fume: powder, condensed, and slurry. The color of the resulting metal depends on a number of factors, including the type of wood chips used, the furnace's temperature, the ratio of wood chips to coal, the exhaust temperature, and the metal itself.

Silica dust has a bulk density of between 500 and 650 kg/m3. Ultra-fine particles are made larger as they loosely agglomerate during the densification process. As a result, there is less dust when using the powder than there was when it was in its more potent forms. Common applications include wet mixing machines at ready mixed concrete plants, pre-cast production facilities, and concrete roof tile factories.

Table 1.2 details the parameters of the silica fume utilized as a cement substitute in this project.

Table-1.2: Physical Properties of Silica Fume

Property	Results
Colour	Dark grey
Practical size	<1μm
Specific surface	15,000 to 30,000 m^2/kg
Bulk density	695 g/cm3
Specific gravity	2.2
Moisture content	0.78%
Sio2	92.83%
Al2o3	0.69%

*As per manufacturers manual

1.6.2 CHEMICAL PROPERTIES OF SILICA FUME

When silicon or ferrosilicon is created primarily from the reduction of quartz in an electric arc furnace, silica fume is the byproduct. Arc furnaces require a lot of electricity, hence they can only be built in nations with reliable power grids.

The chemical reaction is intricate and sensitive to changes in production temperature. In the beginning, the SiC formed has crucial intermediary responsibilities.

“At temperatures > 1520° C

$SiO_2 + 3C = SiC + 2CO$

At temperatures > 1800° C

$3SiO_2 + 2SiC = Si + 4SiO + 2CO$

The unstable gas diffuses in the furnace where it reacts with oxygen to give the silicon dioxide

4SiO+2O2 = 4SiO2”

Upon the concrete's hardening, the initial impacts occur as the pozzolanic action of silica fume begins. The combination of silica fume and calcium hydroxide results in the formation of calcium silicate and aluminates hydrates, as depicted in Table 1.3. These compounds play a crucial role in densifying the concrete base, enhancing its strength, and reducing its porosity.

Table-1.3: Chemical Properties of Silica Fume

Chemical composition	Silica fume
SiO_2	81.35
Al_2O_3	4.48
Fe_2O_3	1.42
CaO	0.8
MgO	1.47
SO_3	1.34

1.7 SILICA FUME IN CONCRETE

Silica fume is known by a variety of names, including microsilica, condensed silica fume, volatilized silica, and silica dust. Silica fume, according to the American Concrete Institute (ACI), is a very fine type of silica that is not solid. Because it is made by mistake when pure silicon or silicon alloys are made, it is a waste material. Silica dust is a fine, grey powder that resembles fly ash or Portland cement in appearance. It serves as a pozzolanic material as well as a mortar. Silica fume makes a significant improvement to the performance of concrete when added as a pozzolanic additive. It extends the lifespan of steel and makes concrete stronger by preventing rust.

1.7.1 EFFECT ON MECHANICAL PROPERTIES

Slump loss in concrete is exacerbated by adding more silica fume to the mix. Silica fume particles are harmful to the concrete's consistency and workability due to their large surface area. Due of these issues, silica fume concrete has not yet gained widespread use. Either by itself or as a covering for the silica fume, silane considerably improves the mortar's consistency when employed in a silica fume mix.

Reducing vibrations helps with things like keeping buildings steady, lowering risk, and maximizing efficiency. Both rigidity and damping capacity are necessary for effective vibration reduction. The use of silica fume has been shown to improve the material's stiffness and damping capability. Noise barriers and pavement overlays are only two examples of the many types of constructions that might benefit from sound or noise absorption. Silica fume enhances the soundproofing properties of concrete.

1.7.2 EFFECT ON STRENGTH

Silica fume concrete is renowned for its exceptional compressive strength. Through various experiments, it has been shown that by adjusting factors such as cement type, mix design, plasticizers, silica fume content, aggregate type, and curing methods, it is possible to achieve a significant increase in strength ranging from 30% to 100% compared to regular concrete mixes.

Tensile, flexural, and compressive strengths all correlate in the same way in silica fume concrete as they do in traditional concrete. Compressive strength can be increased by using silica fume, which also increases tensile and flexural strength. When silica fume concrete is used for spanning gaps, laying down flooring, or constructing roads, this is a crucial factor. Slab thicknesses can be decreased while still retaining high compressive strengths thanks to an increase in tensile strength. As a result, both the slab's weight and its price are decreased.

As with other types of concrete, silica fume concrete is more brittle the stronger it is. Elastic modulus deviates from tensile strength in that it shows only a little increase relative to compressive strength. As a result, tall buildings can be made out of high and ultra-high strength concrete without sacrificing flexibility.

The adhesion to substrates and the finer phase of silica fume concrete set it apart from standard concrete. The presence of silica fume has been proven to alter the aggregate-cement contact. Bonding to the steel fibers is greatly improved by applying silica fume.

Concrete's tensile and flexural characteristics can be enhanced and drying shrinkage minimized with the use of microfibre admixtures made from materials including glass, carbon, polypropylene, and steel. In order to effectively utilize fibers in cement, it is important to ensure good dispersion, even though their consumption rates are low (e.g., 0.5% by weight of cement for carbon fibers). When untreated silica fume is incorporated into microfiber reinforced cement, the fine particles of silica fume assist in the mixing of microfibers, leading to an enhanced dispersion of fibers. The incorporation of silica fume strengthens the fiber-matrix interface by decreasing the interfacial zone's brittleness and the number and size of cracks.

1.7.3 EFFECT ON DURABILITY

Freeze-thaw resistance in silica fume concrete is typically adequate at silica fume contents of less than 20%. The capacity to survive in both freezing and thawing conditions is known as "freeze-thaw durability." Concrete tends to shrink when subjected to temperature cycling because of the presence of water, which freezes and thaws and causes variations in volume. The freeze-thaw durability is improved by using air gaps (or air entrainment) as cushions to compensate for the fluctuations in volume. Addition of silica fume compensates for mortar's poor air void system, making it more resistant to freeze-thaw cycles. Therefore, the use of air entrainment is still recommended.

When raw silica fume is added to concrete, it makes it harder for chloride ions to pass through. This method also makes it harder for the dirt to take in water. At a microscopic level, the hydration process in concrete includes the pozzolanic interaction of silica fume and free lime, which leads to the formation of calcium silicate hydrate. When unprocessed silica fume is added to cement paste, the compressive creep rate drops from 1.3105 min1 to 2.4106 min1. Also, using silica dust makes cement paste shrink.

1.7.4 EFFECT ON TEMPERATURE

Insulating buildings successfully requires concrete with a low thermal conductivity. However, high-thermal-conductivity concrete can help mitigate the effects of temperature differences within buildings. Mechanical properties of the structure could degrade as a result of thermal stress brought on by temperature differences. Temperature differences between a bridge's deck and the ground below are not uncommon. Bridges do not need thermal insulation because they are not subject to temperature changes like buildings are. This calls for bridges and similar structures to be built using concrete that has a high thermal conductivity.

1.8 STEEL FIBERS

They also lessen the concrete's permeability and stop water from leaking through. Improved resistance to impact, abrasion, and shattering was achieved in concrete by using certain types of fiber. Actually, there is evidence that including fiber in concrete weakens the material. The volume fraction (VF) of a composite material is the quantity of fiber by volume that was added to the concrete mix. The normal range for VF is.1% to 3%. By dividing the length of the fiber by its diameter, the aspect ratio may be determined. Finding the equivalent diameter of a non-circular fiber is the first step in calculating its aspect ratio. When the aspect ratio of the fiber is increased, the flexural strength and toughness of the matrix (concrete or mortar binder) should be increased if the fiber has a higher modulus of elasticity than the matrix. Too lengthy of filaments, though, and the material as a whole becomes tough to deal with. Recent research has demonstrated that fiber addition to concrete barely affects the material's impact resistance. This is a significant finding because common belief holds that adding fiber reinforcement to concrete improves its ductility. The findings also demonstrated that microfibers are superior to longer fibers in terms of impact resistance.

The flexure, impact, and fatigue strengths of concrete are greatly increased by the addition of steel fibers. Incorporating these fibers into concrete as a fracture arrester would greatly enhance the material's static and dynamic qualities. Fibre reinforced concrete's compressive strength improved as its steel fiber percentage rose. The shear strength is greatly improved by the incorporation of steel fibers. The ASTM A 820 standards for steel hook fibers (type-1 cold drawn wire) have been met. Steel hook fiber with the following properties is used in this work.

Table- 1.4: Properties of Steel Hook Fibers

S.No	Type	Hooked end
1	Diameters of fibers	0.60mm
2	Length of fibers	30 mm
3	Aspect ratio (L/D)	50

1.8.1 CRIMPED STEEL FIBRES

Carbon steel or stainless steel is used to make the crimped steel fibers. Metals may be drawn through progressively smaller dies to create wire because of their ductility. High Strength Fibre Reinforced Concrete's mechanical qualities are a direct result of the materials' high rigidity. However, the aspect ratio of the cross sectional area determines the material's pliability. A rod's adaptability increases by a factor of four as its diameter is halved. The material has a tensile strength of 345-1380 Mpa. According to ASTM, a minimum strength of 345 Mpa must be met. Steel fiber has a modulus of elasticity of 200 Gpa. The melting point is 16000 C. It's possible that the crimped fiber cross section is round and undulating. Although longer fibers have been used, the average fiber length is under 150 mm. Typically, the length-to-diameter ratio falls around between 30 and 100.

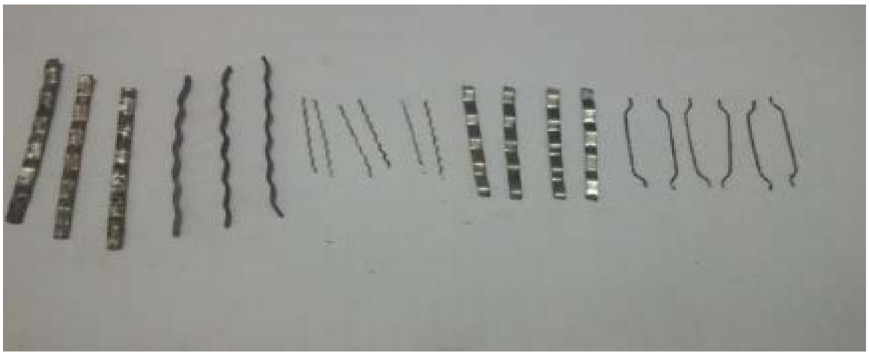

Fig. 1.3: Different types of steel fibres

1.9 STEEL FIBER IN CONCRETE

Regular concrete has a low tensile strength, is hard to shape, and cracks easily. The low tensile strength of concrete comes from the fact that the material is full of small cracks. Adding small, closely spaced, and evenly spread strands to concrete can make it much stronger in both compression and bending. Fiber reinforced concrete is the name for this building material. Concrete that has been strengthened using fibers that have been strategically interwoven throughout the material is called fiber reinforced concrete. Discrete fibers are not to be confused with continuous meshes, woven fabrics, or lengthy wires or rods.

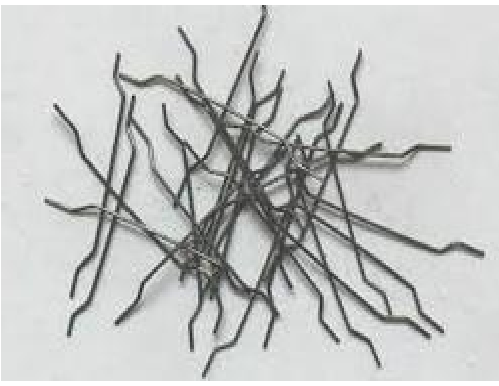

Fig. 1.4: Steel Fiber

Fiber-reinforced concrete is a composite material that is essentially just regular concrete with tiny threads interwoven throughout. In compression, concrete excels, but in tension, it fails miserably. Due to this tensile end weakness, even relatively light loads can cause concrete to break. Over time, these cracks will extend to the compression end of the member, where they will cause the end to fail. Drying shrinkage can also lead to cracking in the concrete. In essence, these are tiny fissures. These fissures get larger and more numerous over time, eventually causing the concrete to crumble. The main cause of the concrete's demise is the appearance of cracks. There have been various attempts to improve the tensile strength of concrete. Adding steel reinforcement is a tried-and-true procedure with a long track record of success. However, steel bars are only effective against localized tension in concrete. The cracks in the reinforced concrete continue to spread until they reach the bar. This calls for steel reinforcement in many directions and at close intervals. That's just not conceivable in the real world. The answer to this issue is fiber reinforcement. Fibers are being incorporated into concrete as a means of increasing its tensile strength. These fibers serve as crack arrestors, stopping the cracks from spreading. The arrangement of these fibers is random and uniform. Fiber reinforced concrete is the term for this material.

1.10 FACTORS INFLUENCING HIGH STRENGTH FIBRE REINFORCED CONCRETE

Many conditions must be in place for the matrix to be effectively reinforced and for stress to be transferred from the matrix to the fiber. Many of these criteria are dependent on one another and have a substantial yet convoluted impact on the composite's characteristics.

There are several key factors that influence the performance and characteristics of high-strength fiber reinforced concrete (HSFRC).

The type and composition of fibers used in HSFRC are critical. The tensile strength and properties of different fibers, such as steel, polypropylene, carbon, or glass, might affect the total tensile strength and durability of the concrete. Higher aspect ratios, in general, improve mechanical properties and load transfer. The link between the fibers and the cementitious matrix is critical for optimal load transfer. Surface treatment of the fibers or the inclusion of chemical additives can improve the binding strength and overall performance of HSFRC. The HSFRC mix design is critical for achieving the necessary properties. Cement, aggregates, water, and other additives must be appropriately balanced to obtain the best workability, density, and strength. The effectiveness of HSFRC is also affected by the curing conditions. The development of strength and durability in concrete is affected by curing temperature, curing time, and moisture conditions.

Load-bearing capacity and crack resistance are both affected by the orientation and distribution of fibers inside the concrete matrix. Techniques such as fiber dispersion, layering, or random distribution can be employed to achieve the desired reinforcement effect.

1.11 SCRAP STEEL

Steel scrap is collected from a wide variety of sources due to its high recyclability. Inside the steel mill, there may be scrap that has been damaged or is the last of its kind. It's also found in demolished buildings, shipping containers, and old cars.

Our homes also provide an additional source of scrap metal. Steel cans (from food to pet food to spray to paint) are infinitely recyclable, and are therefore collected as part of council curbside collections.

Because it can be endlessly reused and recycled, steel is an ideal material for the circular economy. Used or repurposed steel in the form of Scrap is the steel industry's secondary raw material, behind iron ore. ndia has a significant number of small steel factories that employ electric arc furnaces (EAFs) and induction furnaces (IFs) to produce steel using scrap metal and other inputs. As of March 2019, there were 47 EAFs and 1128 IFs in operation in the country, with scrap being the primary raw material for these furnaces. The National Steel Policy 2017 (NSP-2017) aims to enhance the competitiveness of the steel sector by increasing the steel production capacity to 300 Million TPA by 2030, with approximately 35-40% of the production expected to come from EAFs and IFs. While scrap metal is predominantly utilized by the secondary steel industry, it also finds usage in the primary sector. In fact, it accounts for around 15% of the charge mix of basic oxygen furnaces (BOFs). This usage of scrap metal in the primary sector aids in improving productivity, reducing costs, and fulfilling other process requirements. The overall objective is to bolster the steel sector, making it internationally competitive, by optimizing the utilization of scrap metal and increasing the efficiency of steel production processes. The expansion of the steel industry and the realization of the NSP-2017 goal depend critically on the affordability of raw materials. As a result, the development of the EAF/IF sector and the primary sector depends in large part on the accessibility of scrap metal of the proper grade in sufficient quantities.

To lessen the impact of greenhouse gas emissions, scrap-based steelmaking technologies have been considered. This will be a major effort by the steel industry to reduce emissions of greenhouse gases. In addition to lessening negative effects on the environment, this will help provide the groundwork for sustainable development by embracing the 6Rs principle of reduction, reuse, recycling, recovery, redesign, and remanufacture. The value of scrap was identified in the NSP-2017. As envisioned by the NSP-2017, this Scrap Policy exists solely to facilitate the sorting (quality-wise), collection, processing, and recycling of scrap.

By establishing a framework for the necessary steps, the strategy aims to ensure that the downstream industry has a consistent and reliable supply of processed scrap. Steel scrap is present in a variety of materials, including mill scrap, used structural components like beams, reinforced steel, and plates, plant and machinery components like pipes and tubes, used automobiles and household items, automotive scraps, ship and rail sector scraps, etc. Due to the fact that other companies, like shipbreaking, are governed by separate laws or regulations, they are not covered by the existing policy.

Around the world, more and more steel is being made with trash as the main raw material. This is because recycling scrap has many benefits, such as protecting valuable natural resources. Every ton of scrap metal that is recovered saves 1.1 tons of iron ore, 630 kg of coking coal, and 55 kg of limestone from being used. Specific energy use will also go down a lot, from about 14 MJ/Kg for the BF/BOF route to less than 11 MJ/Kg for the EAF/IF route, which is a 16–17% decrease in energy use. It also saves 40% of the water we use and 58% of the greenhouse gases we put into the air.

Scrap Preparation

Scrap iron and steel are used extensively during the production of new iron and steel. Some of these scraps (prompt scrap) are generated during production and recycled right back into production, while others (obsolete scrap) are brought back to the industry from other sectors or after having been used in iron and steel-containing final goods. When compared to outmoded scrap, which has amassed after long delays between manufacture and return to the industry and typically contains larger amounts of contaminants, prompt scrap is of a more uniform grade and more quickly available.

The quantity of scrap used is constrained by the quality of the scrap used. Some waste products have exceptionally high concentrations of trace elements. The amount of trace elements in high-quality steel must be kept to a minimum. Rebar and other low-quality steel products are currently made from scrap. Steel made in an electric arc furnace is traditionally of lower grade, however this is changing. Steel scrap grade has been falling, and rising steel quality may present significant hurdles for recycling in the long run.

The higher the energy cost per ton of production desired, the worse the grade of the scrap. Increases in the utilization or quality of quick scrap will not significantly enhance energy efficiency because it is a waste product of the industry itself and does not replace raw material inputs. To the degree that outmoded scrap may replace ore-based steel manufacturing, only an increase in its use can result in a net decrease in energy demand. Some basic oxygen furnaces and electric arc furnaces preheat scrap to boost productivity while using scrap and replace expensive electric energy with cheaper fuels.

Both commercial and domestic settings contribute to the production of scrap metal. A "scrapper" is a person who offers to collect scrap metal from those who don't have any use for it.

Wrecking yards, also known as scrapyards, junkyards, or breaker's yards, are common places to find and recycle scrap metal before it is melted down and used to make something new. In most cases, customers will need to bring their own tools and manpower to scrapyards in order to retrieve desired components, and some facilities may even insist that visitors sign a waiver of liability form before gaining access to their facilities. Metals (stainless steel, aluminum, etc.) are often sold by weight at scrapyards, and the prices are far lower than the going retail rate.

Steel is only one of several materials that may be recycled with a scrap metal shredder. Appliances like cars and whiteware like ovens, dishwashers, and washers and dryers are suitable examples. Recycling materials like plastic, copper, aluminum, and brass requires a lot of manual labor. When the steel is shredded into small enough fragments, they can be extracted using a magnetic field. Other methods are needed to separate the non-ferrous waste stream.

Completely recyclable, India imports the industry’s refuse

Steel scrap is the one kind of garbage the country really wants more of. Steelmakers and the casting industry in India have been forced to rely on imports since domestic production of steel scrap falls short of demand.

Steel scrap imports into India totaled five million metric tons (mt) in 2013–14, making the country the third-largest importer of the metal in the world behind Turkey and South Korea. There may not be any reliable statistics available, however educated guesses place annual production of steel scrap at roughly 10 mt. Keeping track of transactions is challenging because most of the commerce in scrap metal, including steel's, is conducted by enterprises in the unorganised sector, whose dealings are primarily in cash, according to Amar Singh, General Secretary, Metal Recycling Association of India.

Automobiles, building, and shipbreaking are the biggest producers of scrap steel. Most scrap metal is melted down and recycled into new products, however a significant portion of scrap metal from ship breaking is re-rolled by steel mills into bars and rods for use in the building sector.

Useful 'waste' Steel scrap is special because it can be melted down and used to create brand new steel items. The local steel industry, the fourth largest in the world, has a significant market for steel scrap, making it relatively easy to dispose of.

Approximately 40% of all steel produced worldwide comes from scrap metal, making it the most recyclable resource on the planet. Whether using an electric arc furnace or an induction furnace, scrap steel is the principal input.

This method accounts for over 60% of India's total crude steel output of 82 mt. The energy needed to transform scrap metal into steel is 74% lower than that needed to transform iron ore and coal into steel. In reality, the mining of iron ore and the burning of coal are both reduced by 1.1 tons for every ton of recycled steel. In comparison to traditional steel production, which generates a lot of carbon dioxide, recycled steel cuts down on emissions by 58%. The main issue is that, being labor-intensive and disorganized as it is, safety standards are frequently disregarded.

1.12 METAL RECYCLING INDUSTRY

Many different types of metals are processed by the metal recycling business. Most metals can be recycled, although the most common ones are steel scrap, iron (ISS), lead, aluminum, copper, stainless steel, and zinc. Ferrous and non-ferrous metals are the two primary types. Ferrous metals are those that contain iron.The metal recycling industry plays a crucial role in sustainable resource management and the circular economy. It involves the collection, processing, and reuse of various metals, including steel, aluminum, copper, and others.One of the primary benefits of metal recycling is the conservation of natural resources. By recycling metals, the need for extracting and refining raw materials from the earth is reduced, leading to energy savings and decreased environmental impact. Recycling metals also helps in mitigating greenhouse gas emissions associated with primary metal production.The metal recycling industry contributes significantly to waste reduction and landfill diversion. Instead of ending up in landfills, scrap metal is collected and processed for reuse, minimizing the strain on limited landfill capacity and reducing environmental hazards.Moreover, metal recycling offers economic benefits. It creates job opportunities in collection, sorting, processing, and manufacturing sectors. The industry also contributes to the overall economy by generating revenue through the sale of recycled metal materials.

Need of the Study

Due to its high quality mechanical and durability features, fiber reinforced concrete (FRC) has found widespread use in the building industry. A cement base, aggregates, and fibers make up FRC. Standard concrete, however, has issues like weak tensile strength, fragility, and cracking. Fibers added to concrete can increase the material's tensile strength, ductility, and toughness, helping to solve these problems.

Concrete's characteristics can be enhanced with the help of supplementary cementitious materials (SCMs) including silica fume and metakaolin. These substances react with calcium hydroxide to produce new cementitious compounds; they have a pozzolanic composition. Porosity can be decreased and concrete's durability enhanced with the use of SCMs.

The manufacturing of silicon metal and ferrosilicon alloys generates a fine powder known as silica fume. Highly reactive particles of silica fume can increase concrete's packing density and make it easier to deal with. In addition, silica fume can be added to concrete to greatly boost its compressive strength and lower its permeability.

However, metakaolin is a pozzolanic clay made from calcined kaolin. Concrete's workability, compressive strength, and longevity can all be enhanced by the addition of metakaolin. Metakaolin can be used to lessen the amount of water needed to make concrete, which in turn makes it denser and more compact. Strength, durability, and workability are just few of the areas where fibers and SCMs combined in concrete can excel. Fibers added to concrete can increase its tensile strength and ductility, while SCMs can boost its compressive strength and longevity. High-performance concrete that is also crack-resistant, long-lasting, and economical can be made with the help of FRC combined with SCMs.Understanding the mechanical and durability features of FRC requires research into the material using silica fume and metakaolin as partial replacement of cement. The research may also shed light on the feasibility of combining FRC with SCMs in building projects. By minimizing the need for cement, the usage of FRC with SCMs can further lessen the environmental toll of making concrete flexural strength. Using SCMs, FRC can be made more resistant to chloride ion penetration, carbonation, and sulfate attack. Toughness and ductility are crucial for structural applications, and they can be improved further by incorporating fibers into FRC.

Scope of the Research

Fiber-reinforced concrete (FRC) can be studied in many different ways when silica dust and metakaolin are used to replace some of the cement. Here are some ideas for what to study:

Mechanical properties: silica fume and metakaolin as partial cement replacements for the modulus of elasticity, bending strength, and compressive strength. FRC's mechanical properties can be studied by looking at its fiber makeup and aspect ratio.

Durability properties: Studying the impact of chloride ions, carbonation, and sulfate attack on FRC reinforced with silica fume and metakaolin is possible. FRC's durability can also be studied in relation to fiber composition and aspect ratio.

Workability: The feasibility of using silica fume and metakaolin to partially replace cement in FRC may be assessed by this study. The impact of the materials on the workability of FRC can be determined by measuring the slump, flow, and compacting factor.

Microstructure: Scanning electron microscopy (SEM) and X-ray diffraction (XRD) are useful tools for studying the microstructure of silica fume and metakaolin reinforced FRC. Pore structure, hydration products, and the fiber-matrix contact can all be investigated depending on the types of materials used.

Cost analysis: Using silica fume and metakaolin as partial cement replacements, the production cost of FRC can be compared with that of traditional concrete. Fiber content and aspect ratio's impact on FRC pricing can also be calculated.

Environmental impact: Researchers can look at what happens to the environment when silica fume and metakaolin are used to replace some cement. You can compare the carbon impact, embodied energy, and embodied carbon of FRC to those of standard concrete.

Application in structural elements: FRC made using silica fume and metakaolin can be studied to see if it can be used to partially replace cement in beams, columns, and slabs. It is possible to investigate how different materials affect the strength and deformation behavior of FRC.

The qualities, performance, and applications of FRC that uses silica fume and metakaolin to partially replace cement are all open to investigation. This study has the potential to improve the design and production of high-performance concrete by shedding light on the benefits of combining FRC with SCMs in construction.

CHAPTER 2

LITERATURE SURVEY

2.1 Literature Survey

Quite a bit of study has been done on fiber reinforced concrete (FRC) that uses silica fume and metakaolin to partially replace cement. Here are some key findings from the literature:

Uysal, M., Al-mashhadani, M. M., et al, (2018). The study looked at how well metakaolin-based geopolymer binders worked and what happened when colemanite waste and silica fume were added as partial replacements. To figure out how well mortar worked, its compressive strength, flexural strength, water absorption, and mass were measured. Both the compression and bending strengths of the mixture with colemanite waste and silica fume were higher than those of the control mixture. When 10% colemanite waste and 10% silica fume were mixed together, the compressive strength was at its highest. This was a 48% increase over the control mix.. Flexural strength was 46% greater in the mixture containing 5% colemanite waste and 10% silica fume compared to the control mix. The geopolymer mortars also had less water absorption and density after being mixed with the colemanite waste and silica fume. Increases in colemanite waste and silica fume led to a greater decrease in density and water absorption.

Akcay, B., & Tasdemir, M. A. (2018). The study examined the performance of self-compacting concrete and fiber-reinforced concrete when incorporating silica fume and metakaolin with equal fineness. The inclusion of silica fume and metakaolin resulted in enhanced compressive and flexural strengths for both self-compacting and fiber-reinforced concretes.Slump flow was greater in the self-compacting concrete made with silica fume than in the one made with metakaolin, indicating greater workability. The metakaolin-fortified fiber reinforced concrete was more durable than the silica fume variant. In addition, the study discovered that silica fume influenced the self-compacting concrete's compressive strength more than metakaolin did the fiber reinforced concrete's flexural strength. This implies that the mineral additive selected should be tailored to the demands of the concrete's intended use.

Venkat, G. N., Chandramouli, K., et al,(2021). In this experiment, silica fume, metakaolin, and GGBS were utilized in place of some of the cement while M-sand served as the fine aggregate. We investigated the compressive strength, split tensile strength, flexural strength, water absorption, and density of concrete with different amounts of each mineral addition. In the investigation, it was discovered that all three mineral admixtures improved the mechanical properties of the concrete. The investigation also came to the conclusion that there were no appreciable differences between concrete built with conventional river sand and concrete created with M-sand as the fine aggregate. This shows that M-sand may compete favorably with river sand in the concrete sector.

Nežerka, V., Bílý, P., et al, (2019). Concrete's ITZ thickness and strength were studied in connection to fly ash, and metakaolin. varied mix proportions were prepared using varied amounts of each mineral addition, and the concrete was evaluated by measuring the thickness and strength of the ITZ. After adding silica fume, fly ash, and metakaolin, the ITZ became less thick. This is because of the more even dispersion of cementitious ingredients throughout the concrete, a result of the increased packing density and decreased porosity. Compared to silica fume and fly ash, metakaolin proved more effective at reducing ITZ thickness. The study also indicated that the addition of mineral admixtures increased the ITZ's durability. Stronger bonds between the cement paste and the aggregates are thought to be responsible for the enhanced ITZ strength that was achieved by increasing the density and decreasing the porosity of the concrete. Compared to fly ash, silica fume and metakaolin had a more noticeable effect on ITZ strength. Incorporating silica fume, fly ash, and metakaolin into the ITZ was shown to decrease its thickness while simultaneously increasing its strength, according to the study. The choice of mineral admixture should depend on the specific performance requirements of the concrete. Furthermore, the reduction in ITZ thickness and improvement in ITZ strength can lead to better overall performance and durability of concrete structures.

Ali, A., Aijaz, A., et al, (2018). Metakaolin was studied for its potential as a nylon fiber reinforced concrete (NFRC). In order to improve its strength and durability, nylon fiber reinforced concrete (NFRC) incorporates nylon fibers into the mix. A mineral addition, can be used to replace some of the cement. According to a literature search, the mechanical characteristics of normal fiber reinforced concrete (NFRC) can be improved by employing metakaolin as a partial cement substitute. Nylon fibers added to the concrete not only make it stronger, but also make it less likely to crack and more resistant to impact. The study also discovered that metakaolin can help reduce the concrete's permeability, making it more resistant to environmental elements including freeze-thaw cycles and chemical attacks, increasing the material's durability and useful life. Nylon fibers are used to reinforce concrete and increase its longevity by decreasing creep and shrinkage.

Ding, J. T., & Li, Z. (2002). Researchers found that silica fume made the concrete work better by filling in holes, and that metakaolin worked as a pozzolan by reacting with calcium hydroxide to make more calcium silicate hydrates. Both mineral admixtures improved more resistant to things like freeze-thaw cycles and chemical attacks. Researchers also discovered that by lowering the concrete's water need and boosting its rheological qualities, metakaolin can make it easier to work with. However, silica fume's high surface area and reactivity can decrease the concrete's workability. Metakaolin and silica fume were shown to enhance concrete's strength, durability, and workability in the study. The mix design should be optimized to produce the desired qualities, and the choice of mineral addition should be based on the concrete's unique performance needs.

Singh, L., Kumar, A., et al, (2016) Adding silica fume to concrete also makes it denser and makes it less likely to soak up water. This change can be explained by the fact that the concrete's microstructure has been improved, which means that the packing density has gone up and the number of holes has gone down. At least in part, the improved microstructure that came from adding silica fume can be blamed for the concrete's better mechanical qualities and less porousness.

Sai, K. V., Rao, V. P., et al, (2023). This review looks at how silica fume and metakaolin can be used as new grouting materials. Grout is a fluid mixture that is used in building, mining, and geotechnical engineering, among other places, to fill gaps, strengthen structures, and seal joints. Silica fume and metakaolin are two examples of mineral additives that can be used to improve the qualities of grout. Adding silica fume, a leftover of the silicon and ferrosilicon industries that is a very reactive pozzolan, can make grout stronger and last longer. Metakaolin, a kind of calcined kaolin clay, can enhance the rheological characteristics of grout and reduce its porosity. According to the study, grout performs significantly better when silica fume and metakaolin are added. Additionally, the addition of these mineral admixtures can produce grout that is more environmentally friendly and sustainable. The review discovered that silica fume and metakaolin have been studied for usage in grout in a number of applications, including soil stabilization, tunneling, and underground building. Based on the unique needs of the application, the ideal mix design and dose of the mineral admixtures should be chosen.

Nazir, U. U., Jandiyal, A., et al, (2016). In this article, we take a look at the use of metakaolin in cement. Calcinating kaolin clay to extremely high temperatures creates metakaolin, a pozzolan. It's a typical mineral additive that can be used as a cement substitute to boost the durability and strength of the final product. Incorporating metakaolin into concrete can greatly enhance its qualities, according to the review. Strength in compression, tension, flexure, and durability are all boosted in concrete. Concrete that has been treated with metakaolin is less likely to be damaged by things like freeze-thaw cycles or chemical attacks. The review also discovered that by incorporating metakaolin into concrete, a more eco-friendly and long-lasting method of producing concrete can be achieved. Since less cement is needed, less energy is used, and less greenhouse gasses are released, when metakaolin is used in the manufacture of concrete. The assessment also touched on the difficulties of using metakaolin in concrete, such as the material's expensive price and the risk that it would reduce the concrete's workability and slow down its setting time. Mix design and optimization of metakaolin dose and particle size distribution can help overcome these obstacles.

Bilal, H., Chen, T., et al, (2021). Pervious concrete's strength and durability were investigated after being strengthened with silica fume, metakaolin, and SBR latex. Different mix proportions were created with varying amounts of each mineral ingredient and SBR latex, and their performance was evaluated by assessing the pervious concrete's compressive strength, flexural strength, water permeability, and freeze-thaw resistance. Adding silica fume, metakaolin, and SBR latex to the mix increased the pervious concrete's strength and longevity, the results showed. SBR latex enhanced the concrete's toughness and durability, while silica fume and metakaolin boosted its compressive and flexural strengths. In addition, SBR latex increased the pervious concrete's freeze-thaw resistance, whereas silica fume and metakaolin decreased its water permeability. A combination of 5% silica fume, 10% metakaolin, and 3% SBR latex was shown to be the optimal mix design for pervious concrete with the best strength and durability performance. Concrete with these mix proportions has a water permeability of 210 L/m2/h, a flexural strength of 4 MPa, and a compressive strength of 28 MPa.According to the results, pervious concrete's strength and durability can be greatly enhanced by adding silica fume, metakaolin, and SBR latex. Use of mineral admixtures and SBR latex can be a sustainable and ecologically friendly method to concrete manufacturing; the appropriate mix design should be chosen based on the concrete's unique performance needs.

Dalvi, J., Bhoyar, R., et al, (2022). In addition, sisal fiber can lessen concrete's propensity to crack and shrink, boosting the material's longevity and resistance to things like freeze-thaw cycles and chemical attacks. Sisal fiber has a low modulus of elasticity and may experience fiber-matrix debonding, all of which were discussed in this review. Mix design and adjustment of fiber length and dose can help overcome these obstacles. The evaluation demonstrated that the addition of 1% sisal fiber to a mixture of silica fume and metakaolin can significantly enhance the mechanical characteristics and durability of concrete. To get the best results from your concrete, you need to tailor your mix design to its intended purpose, and sisal fiber offers a green and sustainable alternative. More study is required to determine the best methods of incorporating these components into concrete and gauging their durability.

Nikhila, C. J., & Kumar, J. C. (2015). The study examined the possibility of using metakaolin in high strength concrete in place of some of the cement. On concrete with various proportions of mix components and metakaolin, tests for compression, split tensile, flexural strength, and durability were performed. The findings of this study demonstrate that using metakaolin in place of some cement can significantly enhance the mechanical properties of high-strength concrete. At 15% metakaolin replacement, the maximum values for compressive strength, split tensile strength, and bending strength were discovered. The metakaolin reduced the concrete's porosity and strengthened it against chemical and freezing dangers. The study also discovered that a cleaner and more environmentally friendly method of producing concrete can be achieved by mixing metakaolin with high strength concrete. Metakaolin can help cut carbon pollution and energy use by making it possible to use less cement when making concrete.The study found that using metakaolin as a partial replacement for cement might significantly improve the mechanical characteristics and durability of high strength concrete. The optimal replacement level for concrete can be determined by the goals sought. As an environmentally preferable replacement for cement, metakaolin shows promise as a viable option for making concrete that is both strong and long-lasting.

Ofuyatan, O. M., Olowofoyeku, A. M., et al, (2019). The study investigated the incorporation of silica fume and metakaolin on self-compacting concrete (SCC). SCC is a type of concrete that is highly flowable and can be placed in confined spaces without the need for compaction. The SCC's performance was measured by measuring its flowability, compressive strength, flexural strength, and durability after being mixed with different mixes of silica fume and metakaolin. Adding silica fume and metakaolin to SCC enhanced its flowability, strength, and durability, as observed. Increased flowability and enhanced filling ability resulted with the use of silica fume and metakaolin, which also reduced SCC's water requirement. Compressive strength at 70 MPa, flexural strength at 8 MPa, and water absorption at 5% are the results of this mix design for SCC. According to the results, SCC performance can be greatly enhanced by adding silica fume and metakaolin. The optimal mix design must be decided upon after carefully considering the SCC's required levels of performance. Silica fume and metakaolin are two examples of mineral admixtures that can make SCC manufacture more eco-friendly and long-lasting.

Dubey, S., Chandak, R., et al, (2015). The main goal of this study was to find out if metakaolin could be used to replace some of the OPC in a concrete recipe. We used different mix amounts and metakaolin concentrations to test the performance of concrete in terms of its compressive strength, flexural strength, and durability. When metakaolin was used in place of some of the OPC, the mechanical properties of the concrete were found to be better. With more metakaolin, both the compressive and bending strengths went up until they were at their highest at 10% replacement. Metakaolin also made the concrete less porous, which made it more resistant to chemical attacks and freeze-thaw cycles. When metakaolin was used to make concrete, it was also found to be better for the environment. By lowering the amount of cement used for concrete production, metakaolin can help cut down on both carbon emissions and energy use. According to the results, mechanical characteristics and durability of concrete can be enhanced when OPC is partially replaced with metakaolin. The unique performance criteria of the concrete should be used to calculate the best replacement amount. When compared to conventional OPC-based concrete manufacturing, using metakaolin has the potential to improve sustainability while retaining mechanical characteristics and durability, making it an attractive choice. To determine the best way to incorporate metakaolin into concrete and gauge its durability, more study is required.

Aiswarya, S., Prince Arulraj, G., et al, (2013). The use of metakaolin to concrete is the subject of this review. When kaolin clay is subjected to high temperatures, it transforms into metakaolin, a pozzolan. It is a typical mineral additive that can be used as a cement substitute to boost the durability and strength of concrete. Incorporating metakaolin into concrete can greatly enhance its mechanical qualities and longevity, according to the review. The assessment also noted that greener and more sustainable methods of producing concrete can be attained with the incorporation of metakaolin. By lowering the amount of cement used for concrete production, metakaolin can help cut down on both carbon emissions and energy use. Challenges, such as the high cost of metakaolin and the possibility of detrimental consequences on workability and setting time of the concrete, were also identified in the review. Mix design and optimization of dosage and particle size distribution of metakaolin can help overcome these obstacles. Based on what was found in this review, incorporating metakaolin into concrete can greatly enhance its mechanical qualities, longevity, and environmental friendliness. The optimal mix design for the concrete should be decided upon after carefully considering the desired performance characteristics. As an environmentally preferable replacement for cement, metakaolin shows promise as a viable option for making concrete that is both strong and long-lasting. To determine the best way to incorporate metakaolin into concrete and gauge its durability, more study is required.

Mazen Musmar (2013) researches the tensile strength of steel-fiber reinforced concrete and comes up with a formula to predict its split cylinder strength for MPa values between 20 and 102. The mathematical equation for the split tensile strength agrees well with the experimental results.

T. Shanmugapriya and R. N. Uma (2013) resulted in the conclusion that growing environmental consciousness has made it more appealing to find beneficial uses for industrial byproducts than to just dispose of them. The smelting of silicon and ferrosilicon creates a byproduct known as silica fume (SF). CONPLAST SP 430 was used as the Super Plasticizer, and the W/B (water binder ratio) was adjusted to 0.32.Different mix proportions were used to cast cubes, beams, and cylinders, which were then examined at 7, 14, and 28 days old. The research indicated that when cement was partially substituted with silica fume, the resulting material had compressive strength, flexure strength, and split tensile strength suitable for building.

Shrikant Harle and Ram Meghe (2013) In comparison to other fibers, the finished alkali-resistant glass fibers (Cem-FIL anti-crack HD) perform admirably. It was also determined that there was an increase of roughly 15–20% in flexural strength and split tensile strength and an increase of around 20–25% in compressive strength.

Ghutke and Bhandari (2014) figured out that silica fume can stand in for Portland cement in some cases. Industrial silica fume does not contain any metals and poses no health risks. It can be used to make concrete and enhances the material's qualities, such as its compressive strength. The major purpose of this research is to determine the optimal replacement rates for use in India. In order to get there, several aspects of silica fume-infused concrete have been studied. In addition, the optimal replacement percentage is determined by comparing regular concrete to concrete mixed with silica fume.It is demonstrated that, up to a certain percentage, compressive strength increases when cement is substituted with silica fume (10% replacement of cement by silica fume).However, the replacement strength diminishes as silica fume is added to cement.

Atul Naik & Sandeep Gaikawad (2015) According to the findings, the compressive strength of the concrete improves when SF is used to replace 12 percent of the cement. Steel fibers added to concrete improve its post-peak behavior, which stops cracks from spreading after they've started. Fiber-reinforced concrete is stronger and more durable than regular concrete because it can sustain greater strains. the combination of PPC, fly ash, SF, and steel fibers offers improved mechanical properties and performance for the concrete. The presented mathematical models provide valuable insights into the concrete's strength, elasticity, and behavior under different conditions.

Pradeepa (2015) In order to accomplish these goals, a research project looked into the flexural behavior of self-compacting concrete (SCC). The fresh and hardened characteristics of fiber-reinforced self-compacting (FRSC) concrete and regular concrete were compared. Additionally, the ideal glass fiber and superplasticizer doses for SCC performance were established. According to the study, 1% and 1.25%, respectively, were the optimal concentrations for glass fiber and superplasticizer. These chemicals were added, and the mechanical characteristics of the concrete significantly improved. The split tensile strength significantly improved by 12%, while the compressive strength increased by 5.3%. These results demonstrate how adding glass fiber and superplasticizer to self-compacting concrete can improve its performance and strength properties.

Faraz Khan and Juned Ahmad (2015) investigated the effects of adding Styrene Butadiene Rubber (SBR) latex to steel fiber reinforced concrete to alter its characteristics. Maximum strength was achieved by experimenting with steel fiber concentrations of 0%, 0.25, and 0.5 percent and latex concentrations of 5, 10, and 15 percent. Steel fibre was shown to be most effective at a dosage of 1%, with increased compressive, split tensile, and flexural strength gradually decreasing beyond this point. Maximum flexural strength was achieved using a mixture of 10% latex and 1% steel fibre.

Ramesh and Dr. Neeraja D. (2015) examined the influence on RC beam of using steel, polypropylene, and glass fibers in varying percentages. Different percentages of fibre were tested to determine the optimal proportion for each type of fibre based on crack pattern, initial cracking load, ultimate load carrying capacity, and maximum deflection of the beam. Steel fibers were discovered to be effective in preventing crack development, and the analysis confirmed that FR beam aids in enhancing several structural behaviors. They also demonstrated that steel's bridging effect is superior to that of the other two fibres.

Vijay M. Mhaske et al. (2016) high strength fibre reinforced concrete (HSFRC) M90 grade mechanical properties were looked into. High strength concrete (HSC) is made by combining cement, fly ash, and silica in the optimal amounts during the DOE mix design process. Variations in fiber volume percentage are made between 0% and 4% in 0.5% steps. A total of 54 people were cast and evaluated, with each person being 100 mm cube or cylinder in size. Civil engineering concrete technology lab's whole members cured for 7 and 28 days in the curing tank.

A. Annadurai et al (2016) The focus of this research is on the flexural characteristics of high-strength concrete of Grade M60. To do this, the concrete will be reinforced with either steel fibers with hooked ends or polyolefin straight strands, depending on the desired strength. The high strength concrete is then reinforced with steel fibers using an experimental method that involves mixing in volume fractions of 1% and 2% of hooked-end steel fibers. Additionally, steel fibers (at the same volume fractions) and polyolefin fibers will be combined to create hybrid fiber-reinforced high strength concrete examples. Each sample will be cast in a steel mold measuring 100 millimeters by 100 millimeters by 500 millimeters. Study objectives include determining how varying fiber types and volume fractions affect the flexural behavior of high strength concrete through experimental testing.. As a benchmark, we used a specimen made from M60 high-strength concrete. Other specimens were used as research controls.

Ram Kumar and Jitender Dhaka (2016) examine the effects of replacing a portion of the cement in an M-35 concrete mix with silica fume at percentages of 0%, 5%, 9%, and 15% by weight. This report gives the results of a 7-day and 28-day experimental evaluation of the material's compressive strength, flexural strength, and split tensile strength. Experimental studies show that silica fume can be added to concrete to make it stronger and last longer than regular concrete does at any age. Therefore, Silica Fume should be encouraged for greater performance and environmental sustainability as it reduces the amount of cement needed for construction.

Namani Saikrishna & Syed Moizuddin (2017) Steel fibers of the round crimped type with an aspect ratio of 45.45 (length 25 & diameter 0.55) were used in the compressive strength and split tensile strength tests, and silica fume was added at 5%, 7%, 10%, and 15% of the cement weight. The cubes of concrete are examined at 7, and then again at 28 days of age. Finally, a comparison is made between steel fiber concrete and regular concrete in terms of strength.

K.Vidhya et al. (2017) The two main focuses of this experiment were cement weight and steel fiber percentage, including hooked end and crimped fibers. For steel fiber-reinforced concrete beams, compressive strength, tensile strength, and flexural behavior were assessed. A variety of fiber contents were used to test how well the concrete performed. To determine ductility, third-point stress was applied to the specimens, and midspan deflections were measured using a dial gauge. By examining load deflection curves and calculating toughness indices in line with ASTM C 1018-97 standards, ductility was measured. This study looked at how different amounts of steel fiber affected the ductility and mechanical properties of beams made of M40 grade concrete. The performance of the tested specimens was evaluated by measuring deflections and analyzing load deflection curves. High-strength concrete samples reinforced just with steel fibers were found to be much weaker than both the control specimen and the high-strength concrete specimens, it was observed that the flexural performance of the hybrid fiber specimen, consisting of a volume fraction of 2% with 80% steel fibers and 20% polyolefin fibers, exhibited significantly superior characteristics.

2.2 LITERATURE SURVEYED

Journal articles published between 2010 and 2017 have varying focuses and depths of study, but all have produced solid findings when reviewed collectively.

Because of this, we're working to perfect a concrete that prioritizes not just its strength but also its workability, performance, durability, and cost-effectiveness. To solve this problem, a low water-cement ratio combined with pozzolanic components and a super plasticizer is ideal. Silica fume has multiple uses due to its high pozzolanic activity, which makes it suitable for use in the production of high-performance concrete. Silica fume, when mixed into a batch of concrete, increases the material's strength and durability both before and after it sets. Fiber reinforced concrete is becoming increasingly popular due to its beneficial effect on a number of concrete's qualities, and it is also finding many uses in a variety of structural disciplines.

The mentioned literature publications bring to light the attributes, significance, influence, and impact of various fibers on strength and durability properties for the purpose of study and future research. The following inferences can be made from the existing literature.

1. One must do an optimality study on different fibers since the optimal dosage of fibers affects the mechanical properties (compressive strength, tensile strength, toughness, impact, flexural, etc.).
2. When dose is added, the type of fibers used, the selection of fibers, the qualities of the fibers (such as length, diameter aspect ratio), and the influence of the fibers on the properties of the concrete all shift. Choosing the right fiber, fiber type, etc., is of utmost importance.
3. Many of concrete's qualities are vastly enhanced by the addition of fibers of varying types. By incorporating fibers, concrete is shown to undergo significant changes in quality.
4. Fourthly, fiber reinforcement with extra cementations By enhancing the concrete's workability and its inherent qualities, materials like fly ash and silica fumes can boost the material's overall performance.
5. Fibres are added to concrete only for the purpose of making it self-compacting, high-performance, high-strength, etc.

2.3 PRESENT WORK

In this experimental study, the compressive strength and flexural strength of concrete were examined by incorporating silica fume at varying percentages (5%, 7%, 10%, and 15%) of the cement's weight. Additionally, different percentages of steel fibers of the round crimped type with an aspect ratio of 45.45 (length 25 & diameter 0.55) were added (0.5%, 1%, 1.5%, and 2%) by weight of the concrete. Cubes were tested to determine the concrete's strength at 7, 21, and 28 days. The beams were also tested for strength after 28 days. At 7, 21, and 28 days, the strength of steel fiber-reinforced concrete was tested, and the findings were compared to those of regular concrete. The goal of this study was to determine the effects of varying the percentages of steel fiber and silica fume on the flexural and compressive strengths of concrete.

2.4 OBJECTIVE OF STUDY

The goal of this study is to look at what happens to M50 grade concrete when silica fume and steel fiber are used to replace some of the cement. This will help find out how strong the concrete is when it is compressed and when it is bent. Silica fume was used to replace some of the cement in amounts of 5%, 7%, 10%, and 15% by weight. Also, 0.5%, 1%, 1.5%, and 2% of steel fibers were added to the weight of round, twisted concrete with an aspect ratio of 45.45 (length:diameter=0.55). Bureau of Indian guidelines were used for all of the tests.

CHAPTER 3
METHODOLOGY AND EXPERIMENTATION

3.1 MATERIAL USED

The materials used in this investigation are…

1. “Cement
2. Fine aggregate
3. Coarse aggregate
4. Water
5. Steel fibers
6. Silica fume
7. Chemical Admixture
8. Metakaolin”

3.1.1 CEMENT

Cement is an important construction material that is used to build infrastructure and houses all over the world. It is a fine powder made from finely ground limestone, clay, shale, and other rocks that are heated to high temperatures in a kiln. The result is called clinker, and it is finely ground to make cement. One of the main uses of cement is to bind various building elements, such as aggregates, sand, and water, to create concrete. It is one of the most crucial components of concrete since it provides the finished building with cohesiveness, strength, and longevity. Due to its exceptional adhesive qualities, cement can create strong bindings between many materials. The process of "hydration," in which water combines with cement particles to create calcium silicate hydrate, the primary binding component of concrete, makes concrete tougher over time. Cement comes in a variety of varieties to satisfy various construction needs. Ordinary Portland cement (OPC) is the most used form, although blended cements with greater qualities and less impact on the environment include slag cement and Portland pozzolana cement (PPC).

Table 3.1: Properties of Cement

Properties	Obtained
Specific gravity	3.15
Initial setting time	65 min
Final setting time	175 min
Consistency	30 %

Fig. 3.1 Cement

3.1.2 SILICA FUME

Silica fume is a byproduct of the electric arc furnace technique for making silicon and ferrosilicon alloys; it is a highly reactive pozzolanic substance. Its large specific surface area is the result of its composition of very small particles with a typical average diameter of 0.1 micrometers. Silica fume is known to improve the performance of concrete because of its unique features. As an extra cementitious ingredient, it can make the concrete stronger, last longer, and have other technical benefits. One of the best things about silica dust is that it reacts well with pozzolans. Due to the small size and amorphous nature of its particles, silicon dioxide (silica fume) quickly joins with the calcium hydroxide that is made when cement cures to make extra calcium silicate hydrate (C-S-H) gel. Because of this, the microstructure of the concrete gets thicker and the pores get smaller, making the material stronger and less porous. It can be used instead of cement, and Table 3.2 shows some of its other benefits.

Table 3.2: Properties of Silica Fume

Property	Value
Colour	Dark to Light Gray
Bulk density	450-650 g/cm^3
Specific gravity	2.22
Moisture content	1 %
SiO_2	92%

Fig. 3.2: Silica Fume

3.1.3 FINE AGGREGATE

The fine material used in these experiments was sourced locally and sieved at 4.75 millimeters. A 2.80 specific gravity was measured for it. The fine aggregate qualities are listed in the table below.

Fig.3.3: Fine aggregates

Table 3.3: Properties of fine aggregate

Property	Value
Bulk density	1.49 g/cm3
% of voids ratio	34.23 %
Voids Ratio	0.58
Specific Gravity	2.258
Fineness modulus	2.9

3.1.4 COARSE AGGREGATE

Coarse aggregate, also called crushed stone or gravel, is a crucial part of concrete and plays a significant role in the structural strength and performance of concrete mixtures. It is made up of particles with diameters ranging from about 4.75 millimeters (mm) to 20 mm, though bigger sizes can also be used for certain tasks.

Fig. 3.4: Coarse aggregates

Table 3.4: Properties of coarse aggregate

S.NO	Property	Test Result
1	Specific Gravity	2.74
2	Bulk density(Kg/m)	1468(loose state) 1611(dry rodded)
3	Fineness Modulus	7.17

3.1.5 STEEL FIBRE

In order to enhance the mechanical properties and performance of concrete, steel fiber, also known as steel reinforcement fiber, is a type of reinforcement material. It is made of small, separate steel fibers that are usually made in different shapes, such as straight, hooked, or crimped. When steel fibers are added to concrete, they act as a reinforcement component, giving the concrete more tensile strength and enhancing its resistance to breaking and fracture. The fibers form a three-dimensional network inside the concrete matrix. This network fills in cracks and spreads stress more evenly across the structure. This helps make the concrete stronger and last longer as a whole. When used in concrete, steel fibers have a number of benefits. They can increase the concrete buildings' flexural strength, impact resistance, and fatigue resistance. Steel fibers can also enhance shrinkage resistance and reduce the likelihood of plastic shrinkage cracks forming.

Fig. 3.5: Crimpled steel fiber

3.1.6 WATER

Ordinary clean potable water is used for both mixing & curing.

3.1.7 CHEMICAL ADMIXTURE

Chemical admixtures are chemicals that are added to concrete while it is being mixed to change its properties and make it work better. These admixtures are typically added in specific amounts based on the desired results and are typically in liquid or powder form. Chemical admixtures improve the workability, increased strength, durability, and placement and curing properties of concrete. Here are some common kinds of chemical admixtures and what they do. Water reducers, which are also called plasticizers or superplasticizers, make concrete workable while reducing the amount of water it needs. Increased strength, better flowability, and less permeability are the effects of this.

3.1.8 Metakaolin

When kaolin clay is heated, it changes into a pozzolanic chemical called metakaolin. Metakaolin's chemical makeup can change based on the type of kaolin clay used and how it was heated. But here is an example of how metakaolin is usually made of chemicals:

Table 3.5 Metakaolin’s Chemical Composition

Component	Chemical Formula	Typical Range (% by weight)
Silicon dioxide	SiO_2	50-60%
Aluminum oxide	Al_2O_3	30-40%
Iron oxide	Fe_2O_3	<1%
Titanium dioxide	TiO_2	<1%
Calcium oxide	CaO	<1%
Magnesium oxide	MgO	<1%
Sodium oxide	Na_2O	<1%
Potassium oxide	K_2O	<1%
Loss on ignition	LOI	0.5-5%

Fig 3.6 Metakaolin

3.2 MIX DESIGN

3.2.1 GENERAL

Glass powder is incorporated into the concrete mix according to the guidelines outlined in the standard known as IS 10262: 2009. Concrete mix configuration is the process of selecting the appropriate concrete ingredients and determining the optimal proportions that will produce, at this time, concrete that satisfies the requirements of the intended use, i.e. concrete with a specified minimum compressive strength, desired workability, and strength. Even with these constraints, it should be possible to achieve maximum efficiency with the concrete component of the mix. Concrete innovation right now is the proportioning of the elements, which is crucial for both quality and economics.

3.2.2 PRINCIPAL OF CONCRETE MIX PLAN

Concrete mix proportioning is the process of determining the proportional quantities of ingredients for a concrete pour of a specified volume. Concrete Mix Design, the process of deciding how much of each material to use, is not to be confused with a simple diagram. Reasonable experience, analyses of test results with various ingredients, and observational data can all be used as basis for proportioning. The process of recipe formulation involves the consideration of ingredient costs and characteristics.

Conditions needed for laying and finishing fresh concrete, as well as characteristics of hardened concrete, such as its quality, durability, volumetric soundness, and so on. The concrete mix outline's primary objectives can thus be launched immediately, which concrete could.

- Satisfying the prerequisites of new concrete (Workability).
- Satisfying the properties of solidified concrete (Strength and Durability).
- Most practical for the craved particulars and given materials at a given site.
- Performing most ideally in the given structure under given states of environment.

3.2.3 TYPE OF MIXES

In the past, information on concrete's fine and coarse aggregates was included among its endorsements. The phrase "ostensible mix" is used to describe combinations of settled bond total proportion that guarantee adequate quality. These provide convenience and, in most cases, superior quality to the specified option. However, due to variations in mix fixes, the apparent quality of concrete for a given workability varies widely.

3.2.3.1 STANDARD MIXES

The quality of apparent mixes of set concrete total percentage (by volume) varies widely and can result in an inadequate or excessive mixture of cement. As a result, multiple nuances now reflect the fundamental compressive quality. Standard mixes refer to these combinations.

3.2.3.2 DESIGNED MIXES

Except for the underlying concrete ingredient, the designer of these mixes has little say in the mix proportions beyond indicating how well the concrete will perform. Given that some materials have somewhat exceptional qualities, this is the most prudent approach to deciding on the mix extents. The methodology results in the economical production of concrete with the desired characteristics. However, the composed mix is of no use because it does not guarantee the appropriate mix extents for the approved execution.

In cases where the 28-day strength of concrete does not exceed 30 N/mm2, ostensible or standard mixes can be employed as per code specifications. These standard mixes are defined by the prescribed amounts of dry ingredients per cubic meter and the desired slump value. However, it is important to note that no controlled experiments were conducted as these standard mixes primarily rely on predetermined ingredient quantities.

3.2.4 FACTORS INFLUENCING THE DECISION OF MIX EXTENTS

The different variables influencing the mix configuration are:

3.2.4.1. COMPRESSIVE QUALITY

It has a major effect on the other measurable characteristics of the cured concrete and is therefore one of the most important. The apparent water-bond proportion of the mix is determined by the mean compressive quality required at a specific age, often 28 days. The degree of compaction is another factor that affects the quality of concrete after it has aged and been cured at the ideal temperature. Completely compacted concrete quality, as stated by Abraham's law, is inversely proportional to the water-bond ratio.

3.2.4.2WORKABILITY

The required level of practicality depends on three factors: the area size, reinforcement strength, and compaction method. These factors must be considered when determining the appropriate concrete workability. In narrow or complex regions with corners and difficult-to-reach areas, it is crucial to have highly workable concrete to achieve full compaction with reasonable effort. This is especially important when dealing with surgically placed steel anchors. The ease of handling and compaction is also influenced by the availability of suitable compacting machinery at the construction site.

3.2.4.3. SOLIDNESS

Concrete's strength lies in its resistance to the harshness of natural environments. Superior concrete is far more reliable than its inferior counterpart. Toughness need will concentrate the water-concrete ratio to be used in cases where the high quality is a little excessive yet the states of presentation are such that high solidness is needed.

3.2.5 Grading and Kind of Total

The mix proportions for a certain workability and water-concrete ratio are affected by the overall evaluation. The coarser the blend, the more accurate the evaluation. Extremely steep mix is unappealing because it lacks the better substance necessary to make the concrete long-lasting.

The type of aggregate has a decisive effect on the total concrete percentage for the desired workability and required water bond percentage. Mixing parts of varying sizes allows for more reliable assessments, which is crucial to achieving a respectable sum.

3.2.6. QUALITY CONTROL

Variation in test results provides a quantitative measure of the degree of control. Inaccurate quality controls during the bunching, mixing, setting, curing, and testing processes contribute to the wide range of outcomes. The smaller the gap between the median and minimum mix characteristics, the less concrete will be required. We now have a name for the variable that determines whether.

3.2.7 MIX PROPORTION ASSIGNMENTS

Parts, proportions, and fine and coarse aggregate totals are the standard measures for describing the quantities of ingredients in a concrete mix. Volumetric or mass-based limits are used. In most cases, the water-bond fraction is expressed as a mass.

3.2.8 FACTORS TO BE CONSIDERED FOR MIX PLAN

- The evaluation assignment giving the trademark quality necessity of concrete.
- The sort of concrete impacts the rate of advancement of compressive quality of concrete.
- It may now be possible to use aggregates of up to their maximum apparent size in concrete while yet staying within the limits prescribed by IS 456:2000.
- Shrinkage, cracking, and web blanketing of the binding substance must be limited.
- The size and shape of the area, the number of reinforcements and how they are placed, and the way the concrete is moved all affect its workability.

3.2.9 MIX DESIGN ACCORDING TO IS 10262: 2009

The mix design for M50 grade concrete was carried out following the guidelines of the Indian Standard Recommended Method IS 10262-1982. The specifications and proportions of the various ingredients were determined in accordance with this method to achieve the desired strength and performance characteristics for M50 grade concrete.

For this study, we made 17 different types of concrete. One of the mixtures was just regular Portland cement with no additional additives like silica fume or steel fibers. The remaining 16 batches were made by adding steel fibers (0.5 %, 1%, 1.5%, and 2 %) and silica fume (5%, 7%, 10%, and 15%) to the cement in different ratios. Round crimped steel fibers (25 mm in length and 0.55 mm in diameter) were employed. The aspect ratio was 45.45. For each mix type, the precise amounts of water, coarse aggregate, and fine aggregate needed were determined.

The steel fibers used in the mix design are of the round crimped type, with an aspect ratio of 45.45 (length of 25mm and diameter of 0.55mm). The details of the mix design can be found in Table 3.4 (silica fume percentages), Table 3.5 (steel fiber percentages), and Table 3.6 (combined mix design).

Table 3.6: Mixture proportions of SF and SF blended concretes.

Mix	Silica Fume %	Steel Fiber %	Quantity (Kg/m^3)						
			Cement	Silica Fume	Steel Fiber	Coarse Aggregate	Fine Aggregates	Super Plasticizer	Water
M1	0	0	504.21	0	0	1108.13	683.24	4.6681	141.61
M2	5	0.5	479	25.21	30	1108.13	683.24	4.6681	141.61
M3	7		468.92	35.29	30	1108.13	683.24	4.6681	141.61
M4	10		453.79	50.42	30	1108.13	683.24	4.6681	141.61
M5	15		428.58	75.63	30	1108.13	683.24	4.6681	141.61
M6	5	1	479	25.21	60	1108.13	683.24	4.6681	141.61
M7	7		468.92	35.29	60	1108.13	683.24	4.6681	141.61
M8	10		453.79	50.42	60	1108.13	683.24	4.6681	141.61
M9	15		428.58	75.63	60	1108.13	683.24	4.6681	141.61
M10	5	1.5	479	25.21	90	1108.13	683.24	4.6681	141.61
M11	7		468.92	35.29	90	1108.13	683.24	4.6681	141.61

M12	10		453.79	50.42	90	1108.13	683.24	4.6681	141.61
M13	15		428.58	75.63	90	1108.13	683.24	4.6681	141.61
M14	5	2	479	25.21	120	1108.13	683.24	4.6681	141.61
M15	7		468.92	35.29	120	1108.13	683.24	4.6681	141.61
M16	10		453.79	50.42	120	1108.13	683.24	4.6681	141.61
M17	15		428.58	75.63	120	1108.13	683.24	4.6681	141.61

3.3 EXPERIMENTAL PLAN

The experimental investigation focuses on studying the characteristics of M50 grade concrete. Different combinations of silica fume (at percentages of 5%, 7%, 10%, and 15%) and crimped steel fibers (at percentages of 0.55%, 1%, 1.5%, and 2%) were incorporated into the concrete mix. For testing purposes, beams measuring 100 x 100 x 500 mm and cubes measuring 150 x 150 x 150 mm were cast. Compressive and flexural strength experiments were conducted at ages of 7, 21, and 28 days using the varied proportions of silica fume and steel fibers. The aim of the experiments was to evaluate the impact of these additives on the strength properties of the M50 grade concrete.

3.3.1 BATCHING

Weighing scales were used for the concrete mixing process. With a precision of 0.5 grams, we measured out all the ingredients for the concrete mix exactly as needed.

3.3.2MIXING

Hand-mixing of the concrete took place on the dry deck. Before adding the sand, the cement and silica fume were properly blended in the dry condition. After another thorough mixing, the mixture was spread out over the coarse aggregate. Fiber reinforced concrete uses steel strands that are dispersed throughout the mixture. Then, during the mixing process, water was cautiously introduced along with the chemical admixture. A workable combination was achieved after extensive mixing.

3.3.3 CASTING

Three separate pours of concrete were used to fill the molds. The concrete cubes in each stratum will be compacted 25 times. The table vibrator was used to vibrate the cube molds. To guarantee even compaction, the vibrations lasted for a full minute. After 24 hours, the specimens were removed from the mold and cured for 7 or 28 days.

Fig. 3.7: Casting of Cubes

Fig. 3.8: Curing of cubes and Beams

3.3.4 FLEXURAL STRENGTH TEST

Beam specimens were tested for flexural strength in accordance with the standards laid out in I.S.516-1959. Two-point loading was applied to the beams over a total effective span of 600 mm, which was then subdivided into three equal sections. Based on the flexural loads at failure, the average ultimate flexural tensile stress was calculated. For the flexural strength test, specimen beams were produced with dimensions of 150 millimeters (mm) x 150 millimeters (mm) x 150 millimeters (mm). After 28 days of curing, we put it through its paces in the lab. The test involved applying a growing load to a beam specimen until it cracked, at which point the failure load was recorded. Flexural strength was determined by applying the proper formulas to the test findings.

“Flexural strength (MPa) = (P x L) / (b x d) Where, P = Failure load, L = Centre to centre distance between the support = 600 mm, b = width of Specimen=150 mm, d = depth of specimen= 150 mm”.

Fig.3.9: Flexural Test

3.4 Properties of Metakaolin and Silica fume

Metakaolin and silica fume are two pozzolanic materials commonly used in concrete to improve its properties. While they share some similarities, they also have distinct properties that make them suitable for different applications.

Properties of Metakaolin:

Chemical composition: Metakaolin is composed mainly of amorphous silica and alumina, with minor amounts of iron oxide and other minerals.

Particle size and surface area: Metakaolin has a small particle size and a high surface area, typically ranging from 15,000 to 25,000 m^2/kg.

Reactivity: Metakaolin is highly reactive and can react with calcium hydroxide to form additional cementitious materials, mainly calcium silicate hydrate (C-S-H) gel.

Pozzolanic activity: Metakaolin has a high pozzolanic activity, which means that it can contribute significantly to the strength and durability of concrete.

Workability: The addition of metakaolin to concrete can enhance its workability by reducing the water demand and increasing the cohesion of the mix.

Sustainability: Metakaolin is a sustainable material as it is a by-product of the production of kaolin clay, a natural resource.

Physical Properties

The physical properties of metakaolin play a crucial role in its application in concrete. Metakaolin is a fine white powder that is mainly composed of amorphous silica and alumina. Its physical properties can vary depending on the source material and the production process. However, some general physical properties of metakaolin are:

Particle size: The particle size of metakaolin is small, typically ranging from 1 to 10 microns. This small particle size allows for improved bonding between the metakaolin particles and the surrounding cement paste, resulting in enhanced mechanical properties of the concrete.

Specific gravity: The specific gravity of metakaolin is around 2.5. This property can be used to determine the dosage of metakaolin required to achieve the desired mechanical properties in concrete.

Surface area: The surface area of metakaolin is high, typically ranging from 15,000 to 25,000 m^2/kg. This high surface area allows for improved reactivity between metakaolin and the surrounding cement paste, resulting in enhanced mechanical properties of the concrete.

Color: Metakaolin is typically white or off-white in color. This property makes it an attractive material for use in applications where the color of the concrete is important.

Density: The density of metakaolin is typically around 2.4 g/cm^3. This property can be used to determine the dosage of metakaolin required to achieve the desired mechanical properties in concrete.

pH: The pH of metakaolin is generally neutral, ranging from 6 to 7. This property makes it compatible with the alkaline environment of concrete.

The small particle size and high surface area of metakaolin make it an ideal material for use in concrete. These properties allow it to fill the gaps between cement particles and react with calcium hydroxide to form additional cementitious materials. The high surface area also allows for improved bonding between the metakaolin particles and the surrounding cement paste, resulting in enhanced mechanical properties of the concrete.

In addition to its use in concrete, metakaolin is also used in the production of ceramics, refractories, and other materials that require high levels of purity and reactivity. Its physical properties make it an attractive alternative to other pozzolanic materials such as fly ash and slag. However, its high cost and limited availability can be limiting factors in some applications.

The particle size and surface area of metakaolin are particularly important in determining its effectiveness in concrete. The small particle size allows for improved dispersion in the cement paste, resulting in enhanced reactivity and bonding. The high surface area allows for improved interaction with the surrounding cement paste, resulting in enhanced strength and durability.

The color of metakaolin can also be important in some applications. For example, in architectural concrete, the color of the concrete can play an important role in the aesthetic appeal of the structure. The use of metakaolin can help to achieve a consistent color in the concrete, resulting in an attractive finished product.

The density and specific gravity of metakaolin are also important in determining the dosage required to achieve the desired mechanical properties in concrete. The dosage of metakaolin can vary depending on factors such as the water-to-cement ratio and the curing conditions. The density and specific gravity can be used to determine the optimal dosage for a given application.

The physical properties of metakaolin play a crucial role in its application in concrete. Its small particle size, high surface area, and neutral pH make it an ideal material for use in concrete. These properties allow for improved bonding and reactivity, resulting in enhanced mechanical properties of the concrete. The color, density, and specific gravity of metakaolin can also be important in determining its effectiveness in concrete.

Mechanical Properties

Adding the highly reactive pozzolanic substance metakaolin to concrete can boost its mechanical qualities. Pure amorphous silica and alumina form the bulk of metakaolin, a fine white powder. Calcium hydroxide is a byproduct of cement hydration, and when metakaolin is added to concrete, it combines with the hydroxide to generate additional cementitious materials, primarily calcium silicate hydrate (C-S-H) gel. As a result of this reaction, the concrete matrix becomes denser, increasing the material's strength and endurance.

Compressive strength is a fundamental mechanical property that can be enhanced by using metakaolin. The resistance of a substance to deformation when subjected to compressive loads is its compressive strength. In structural applications, it is arguably the most crucial feature of concrete. Concrete's compressive strength is mostly governed by the cohesiveness of the cement paste used as a binder between the particles. By eliminating air pockets in the cement paste, metakaolin boosts concrete's density and thus its compressive strength.

The effect of metakaolin on the compressive strength of concrete has been the subject of a number of investigations. Ganesan et al. (2008) compared the compressive strength of regular concrete to that of concrete with metakaolin. According to the findings, adding 10% metakaolin to the concrete mixture increased its compressive strength by around 15%. When comparing the compressive strength of concrete built with metakaolin and fly ash, Mehta et al. (2012) ran a similar experiment. Metakaolin-containing concrete had a higher compressive strength than fly ash-containing concrete, according to the tests.

The inclusion of metakaolin can also increase flexural strength, which is a significant mechanical attribute. The resistance of a material to deformation under bending stresses is known as its flexural strength. Beams, slabs, and other structural elements that experience bending loads are places where this property shines. By increasing the density of the concrete matrix and strengthening the bonds between the cement paste and the aggregates, metakaolin can boost the flexural strength of concrete.

Several investigations have examined how metakaolin modifies the flexural strength of concrete. Mehta et al. (2012) compared the flexural strength of concrete with metakaolin to that of concrete containing fly ash. The results showed that when the concrete was bent, the concrete with metakaolin was more durable than the concrete with fly ash. The bending strength of high-performance concrete with metakaolin was compared to that of regular concrete in a study by Sahu et al. (2019). When metakaolin was added, the data showed that the concrete's bending strength went up by about 35%.

Properties of Silica Fume:

Chemical composition: Silica fume is composed mainly of amorphous silica, with minor amounts of alumina, iron oxide, and other minerals.

Particle size and surface area: Silica fume has a very small particle size and a high surface area, typically ranging from 15,000 to 30,000 m^2/kg.

Reactivity: Silica fume is highly reactive and can react with calcium hydroxide to form additional cementitious materials, mainly calcium silicate hydrate (C-S-H) gel.

Pozzolanic activity: Silica fume has a high pozzolanic activity, which means that it can contribute significantly to the strength and durability of concrete.

Workability: The addition of silica fume to concrete can enhance its workability by reducing the water demand and increasing the viscosity of the mix.

Sustainability: Silica fume is a by-product of the production of silicon and ferrosilicon alloys, and its use in concrete can reduce the carbon footprint of the material.

In summary, both metakaolin and silica fume are highly reactive and pozzolanic materials that can enhance the properties of concrete. They have similar particle size and surface area, but metakaolin is mainly composed of silica and alumina, while silica fume is mainly composed of silica. The addition of these materials to concrete can improve its strength, durability, and workability, while also reducing its carbon footprint.

CHAPTER 4

RESULTS AND ANALYSIS

4.1 MECHANICAL PROPERTIES

Mechanical properties such as compressive strength and flexural strength tests are evaluated.

4.1.1 COMPRESSIVE STRENGTH TEST

The compressive strength of concrete is an excellent indicator of its overall quality since it is proportional to the crystalline structure of the hydrated cement paste. Compressive strength testing was performed on cube samples at 7, 21, and 28 days of age.

4.1.2EFFECT OF SILICA FUME WITH STEEL FIBERS

4.1.2.1 FOR 7 DAYS OF CURING

When silica fume and steel fibers are mixed together in concrete, it changes the way the material works and what it can do. Silica dust, which is also called microsilica, is made when silicon metal and ferrosilicon alloys are made. It is very reactive and made up of small particles that can fill the spaces between cement grains. This makes the concrete matrix more dense and tougher. Steel fibers act as reinforcement and enhance the strength and ductility of the concrete when they are added to the mix. A three-dimensional network is formed by the uniform dispersion of steel fibers throughout the mixture, which increases crack resistance and stops crack spread. This type of reinforcement is especially good at preventing shrinkage cracks and making the concrete last longer.

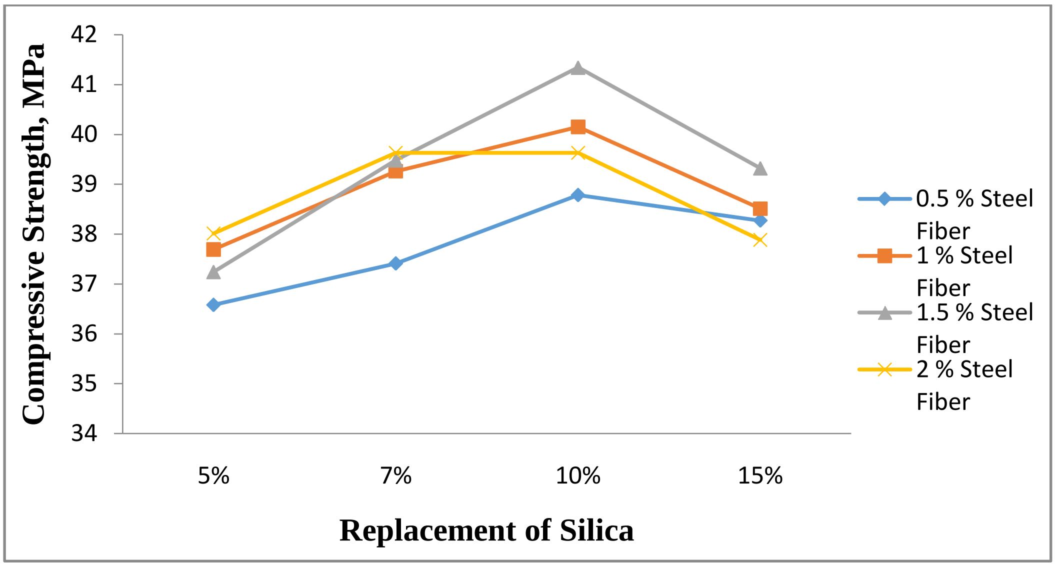

Fig. 4.1 Compressive Strength of M60 grade concrete at 7 days curing

Table 4.1: Compressive Strength of M50 grade at 7 days curing

Mix	Silica Fume %	Steel Fiber %	Compressive Strength (Mpa)
M1	0	0	29.80
M2	5	0.5	36.58
M3		1	37.69
M4		1.5	37.24
M5		2	38.01
M6	7	0.5	37.41
M7		1	39.26
M8		1.5	39.48
M9		2	39.63
M10	10	0.5	38.78
M11		1	40.15
M12		1.5	41.34
M13		2	39.63
M14	15	0.5	38.27
M15		1	38.51
M16		1.5	39.32
M17		2	37.88

4.1.2.2 FOR 21 DAYS OF CURING

Having silica fume and steel fibers in concrete during its 21-day curing time can change the way its features develop in a number of ways. The concrete can gain strength and toughness over time thanks to the crucial process of curing. The early strength growth of concrete can be aided by silica fume, which is a highly reactive material. It combines with calcium hydroxide, which is a byproduct of hydration, to make more cement-like compounds. This makes the process of cement hydration more efficient and speeds up the strength gain in the early stages of curing. When steel fibers are mixed into the concrete, they add extra strength. During the curing time, the steel fibers help to spread out the loads and keep shrinkage cracks from forming too much. This is especially important in the early stages, when the concrete is still starting to gain strength and is more prone to breaking.

The combination of silica fume and steel fibers can result in a denser and more compact concrete matrix. Silica fume particles fill the voids between cement grains, while steel fibers create a three-dimensional network. This densification enhances the concrete's resistance to water penetration and improves its durability over time.

Table 4.2: Compressive Strength of M50 grade at 21 days curing

Mix	Silica Fume %	Steel Fiber %	Compressive Strength (Mpa)
M1	0	0	32.20
M2	5	0.5	40.18
M3		1	42.37
M4		1.5	44.10
M5		2	42.55
M6	7	0.5	41.88
M7		1	44.62
M8		1.5	45.06
M9		2	44.77
M10	10	0.5	43.28
M11		1	46.52
M12		1.5	47.18
M13		2	43.21
M14	15	0.5	42.48
M15		1	44.63
M16		1.5	45.10
M17		2	42.18

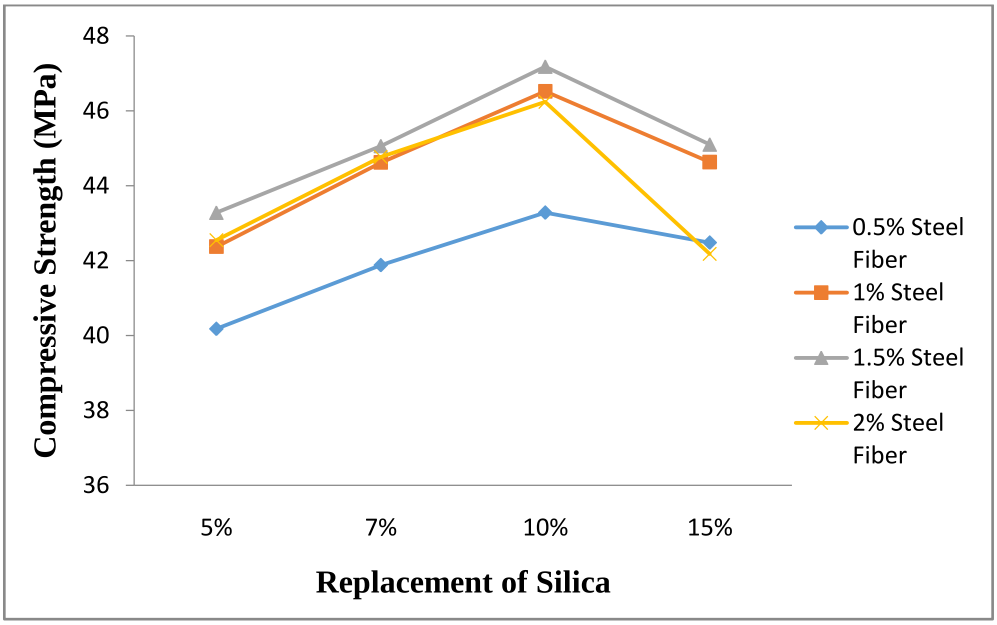

Fig. 4.2: Compressive Strength of M50 grade concrete at 21 days curing

4.1.2.3 FOR 28 DAYS OF CURING

Table 4.3 Compressive Strength of M50 grade at 28 days curing

Mix	Silica Fume %	Steel Fiber %	Compressive Strength (Mpa)
M1	0	0	48.21
M2	5	0.5	53.46
M3		1	53.18
M4		1.5	52.33
M5		2	54.56
M6	7	0.5	53.78
M7		1	54.88
M8		1.5	54.32
M9		2	54.76
M10	10	1	54.55
M11		1.5	56.74
M12		2	55.31
M13		0.5	57.67
M14	15	0.5	51.68
M15		1	54.42
M16		1.5	53.65
M17		2	56.24

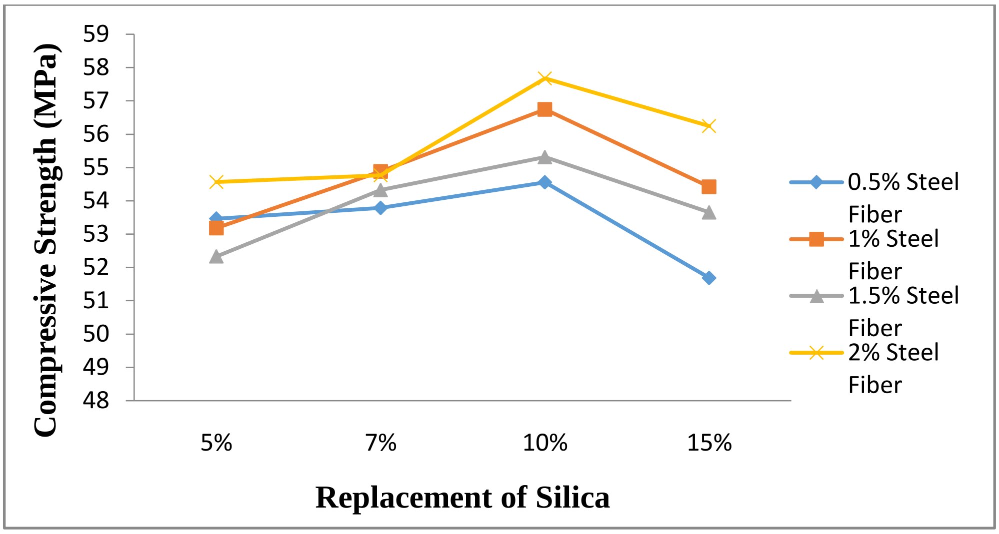

Fig. 4.3:Compressive Strength of M50 grade concrete at 28 days curing

M50 grade concrete is a high-strength mix of concrete that is often used in building projects that require high compressive strength. Usually, the compressive strength of M50 grade concrete after 28 days of curing is specified to meet certain design standards and requirements. Concrete's ability to withstand compressive loads without cracking is measured by its compressive strength. Compressive forces are applied to concrete samples, and the maximum load they can withstand before breaking is measured. Most of the time, the curing time of 28 days is used as a standard to measure the compressive strength of concrete. The goal compressive strength for M50 grade concrete is typically specified to be around 50 megapascals (MPa) or higher after 28 days of curing. This means that the concrete should be able to withstand a 50 MPa compressive load without breaking. Carefully choosing high-quality materials, using the right amounts in the mix design, and using the right curing techniques are necessary to achieve this strength.

4.2 FLEXURAL STRENGTH TEST

The ability of a material, such as concrete, to prevent bending or deformation under applied loads is evaluated using a technique called flexural strength testing. In this test, a specimen in the shape of a beam is loaded from three or four points, which causes a bending moment. The load is slowly put on the specimen until it breaks, and the highest load at failure is written down. Flexural strength shows how well a material can handle bending stresses and is an important measure for judging how well a material performs structurally. It is often used to evaluate the quality and suitability of concrete for beams, slabs, and other structural elements.

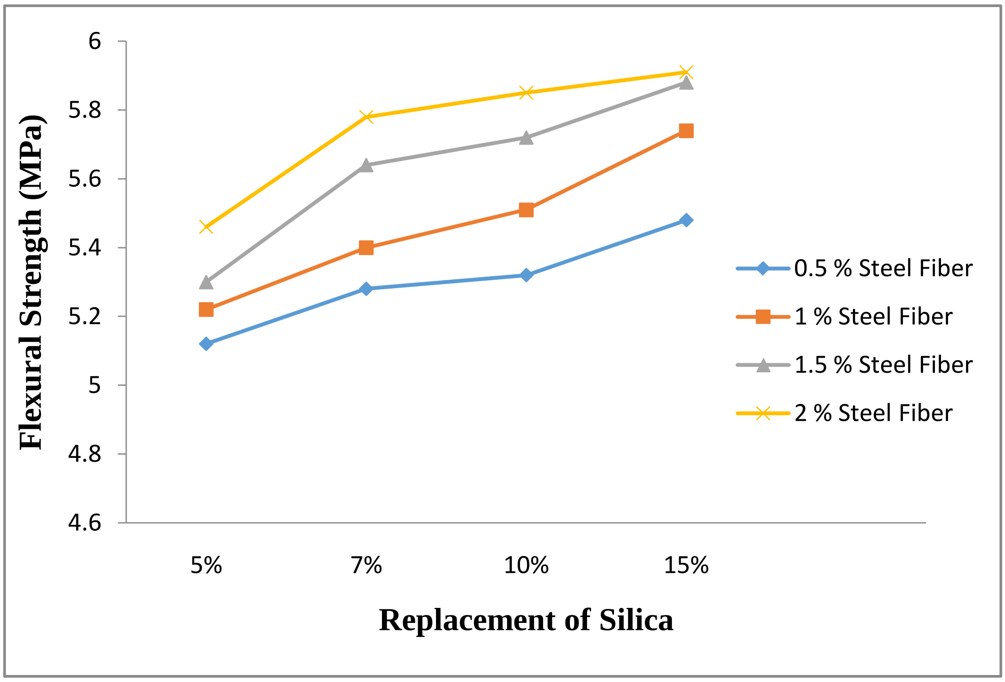

Fig. 4.4: Flexural Strength of M50 grade concrete at 28 days curing

Table 4.4 Flexural Strength of M50 grade at 28 days curing

Mix	Silica Fume %	Steel Fiber %	Flexural Strength (Mpa)
M1	0	0	4.98
M2	5	0.5	5.12
M3		1	5.22
M4		1.5	5.30
M5		2	5.46
M6	7	0.5	5.28
M7		1	5.40
M8		1.5	5.64
M9		2	5.78
M10	10	0.5	5.32
M11		1	5.51
M12		1.5	5.72
M13		2	5.85
M14	15	0.5	5.48

M15		1	5.74
M16		1.5	5.88
M17		2	5.91

CHAPTER 6

CONCLUSION AND FUTURE SCOPE

6.1 CONCLUSION

In conclusion, substituting silica fume and metakaolin for cement in concrete has a number of advantages and can significantly improve the material's performance. Silica fume and metakaolin are both pozzolanic materials that interact with the calcium hydroxide in cement to make new cementitious compounds with improved strength, durability, and other desirable properties. The total strength of the concrete can be enhanced by adding silica fume and metakaolin. These materials help to make the matrix denser and thicker, which lowers the number of holes and strengthens the links between cement granules. This strengthens the concrete's compressive and bending properties, making it less prone to crack or deform while under pressure. By adding metakaolin and silica fume to the concrete, you can also make it live longer. They limit the amount of water, chloride ions, and sulfates that can get into the concrete by making it less permeable. This makes the concrete stronger against weathering, alkali-aggregate reactions, and chemical attacks, which makes it last longer. The fact that silica fume and metakaolin can reduce the heat of hydration is another important benefit of using them. These materials have a pozzolanic effect, which lowers the amount of heat made during the cement hydration process. This is especially helpful in large cement structures or when it's important to keep the temperature from rising, like in big buildings or in hot areas. Also, adding silica fume and metakaolin can make concrete last longer. They are byproducts of industrial processes and can be utilized as supplementary cementitious materials, reducing the need for primary cement production and the related carbon emissions. This adds to the environmental impact of the concrete as a whole.

6.2 FUTURE SCOPE

Environmental Impact Assessment: Although the study highlighted the sustainability aspect of incorporating silica fume and metakaolin, a comprehensive assessment of the environmental impact is warranted. Future research can analyze the life cycle assessment (LCA) of this concrete, considering factors such as carbon footprint, energy consumption, and waste generation. This will provide a holistic understanding of its environmental benefits and contribute to sustainable construction practices.

Field Applications and Performance Monitoring: Further studies can focus on the practical implementation of silica fume fiber reinforced concrete in real-world construction projects. Monitoring the performance of these structures over time will provide valuable data on the long-term behavior, durability, and maintenance requirements. This field performance data can validate the laboratory findings and serve as a basis for wider adoption of this concrete in the industry.

Economic Viability and Cost Analysis: Future research should also include a detailed economic analysis to evaluate the cost-effectiveness of using silica fume and metakaolin-based concrete in construction projects. This analysis should consider the availability and cost of these materials, their impact on the overall project budget, and potential savings in terms of maintenance and life cycle costs. Such information will assist in decision-making by stakeholders and promote the wider implementation of this concrete.

Exploring the optimization of mix proportions, investigating performance under dynamic loading, assessing long-term durability, conducting environmental impact assessments, monitoring field applications, and analyzing economic viability will further enhance our understanding of this concrete and its practical application in the construction industry.

6.3 RECOMMENDATION

Variation of Replacement Levels: Specific levels of silica fume and metakaolin replacement were the focus of the study. Further research can look at a wider variety of replacement levels to better understand how they affect the performance of the concrete. This will aid in determining the ideal combination of strength, sturdiness, and workability for the replacement percentages.

Fiber Selection and Optimization: Although the type and dosage of fibers were not thoroughly studied in the current study, they were added to the concrete mixture. Future research can look into different types of fibers, like steel, polypropylene, or glass, and optimize their dosage to improve the concrete's mechanical properties and crack resistance.

Rheological Properties: More research can be done on the workability and flow of silica fume fiber reinforced concrete. With varying amounts of silica fume and metakaolin, rheological studies can shed light on the flow behavior, viscosity resistance, and segregation of concrete mixtures. This knowledge will aid in the creation of concrete mixtures with superior workability and ease of placement and compacting.

Combined Effects of Supplementary Materials: The study looked at the effects of silica fume and metakaolin separately. Future research can look into the combined effects of various components in the same concrete mixture. Examining the combined effects of silica fume and metakaolin on strength, durability, and other qualities can provide an in-depth understanding of their synergistic potential.

Field Applications and Case Studies: Real-world applications of silica fume fiber reinforced concrete should be tracked and documented. Case studies on structures constructed using these materials will provide valuable information on their functioning, toughness, and long-term behavior under a variety of environmental and loading conditions. This will facilitate the application and validation of study findings in practice.

Standardization and Guidelines: To encourage the broader adoption of silica fume fiber reinforced concrete with silica fume and metakaolin, it is important to develop standardization and guidelines for its use. Collaborative efforts involving researchers, industry professionals, and regulatory bodies can help establish standards, specifications, and recommended practices for the production, testing, and application of this concrete.

Comparative Studies: Comparative studies between silica fume reinforced fiber reinforced concrete and other types of concrete mixtures can give light on how well they operate in terms of relative strength. The precise benefits and cons of this particular mixture can be assessed by comparing it to regular concrete as well as various supplemental cementitious materials.

Following these recommendations will allow us to make even more progress in our understanding of the properties and potential applications of silica fume fiber reinforced concrete, which uses metakaolin and silica fume as partial cement substitutes. Continuous research and development will help to improve mix designs, building processes, and standards, ultimately encouraging a wider acceptance of this high-performance and sustainable concrete solution.

6.4 LIMITATION

Generalizability: The study's findings and conclusions are specific to the experimental conditions, including the materials used, mix proportions, curing conditions, and testing methods. The applicability of the results to different scenarios and variations in materials and conditions should be carefully considered.

Time Dependency: The study may have focused on short-term performance evaluations of the concrete. Long-term effects, such as creep, shrinkage, and aging, were not thoroughly investigated. It is important to recognize that the behavior and properties of the concrete may evolve over time, which could impact its long-term performance.

Material Variability: The properties of supplementary cementitious materials, such as silica fume and metakaolin, can vary significantly based on their source, production method, and composition. The study may have used specific batches of these materials, and the findings may not be directly transferable to other sources or variations of silica fume and metakaolin.

Compatibility with Admixtures: The study may not have examined the compatibility of silica fume and metakaolin-based concrete with various chemical admixtures commonly used in construction. The interaction between these supplementary materials and admixtures, such as superplasticizers or air-entraining agents, could affect the workability, setting time, and overall performance of the concrete.

Cost Considerations: Given the availability, pricing, and regional variations in the cost of silica fume and metakaolin, the study may not have performed a thorough cost analysis. The cost-effectiveness and economic viability of using these materials in real-world building projects could be affected by things like transportation costs, the supply of these materials on the market, and local building codes.

Limited Scope of Properties: It's probable that the study was primarily interested in mechanical properties such as compressive and flexural strength. Other critical properties, such as thermal conductivity, fire resistance, and durability under specific environmental conditions, were not adequately investigated. More research is needed to understand how this concrete responds under different conditions.

Lack of Comparative Analysis: The study may not have included a complete comparative analysis with different types of concrete mixtures or alternative cementitious materials. Comparative studies can aid in a better understanding of the specific benefits and limitations of silica fume fiber reinforced concrete employing silica fume and metakaolin in compared to other market alternatives.Acknowledging these limitations is crucial to interpreting and applying the study's findings appropriately.

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