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Effect of Mechanical Properties of Concrete Using Nano Titanium Dioxide and Partial Replacement of Fly Ash in Cementitious Material

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ABSTRACT:

This study aims to evaluate the mechanical properties of concrete by simultaneously utilizing nano titanium dioxide and replacing a portion of fly ash in the cementitious material. The incorporation of nano titanium dioxide as a supplementary cementitious material, coupled with strategically replacing a segment of conventional fly ash in the cement blend, presents the prospect of noteworthy enhancements. The study delves into a comprehensive exploration of the impacts of nano titanium dioxide and fly ash replacement on the concrete's mechanical properties. Our goal is to identify the optimal dosage for fly ash replacement and nano titanium dioxide addition, while also investigating the dispersion solution and method to ensure the effective dispersion of nano titanium dioxide in the concrete mix.

Keywords: Nano Titanium Dioxide, Fly Ash Replacement, Mechanical Properties, Optimal Dosage, Dispersion Solution

1. INTRODUCTION

The study at hand is dedicated to pushing the boundaries of concrete performance within the construction industry. It intricately investigates the combined impact of nano titanium dioxide and fly ash replacement on concrete, with a keen focus on unlocking their potential synergy to enhance both strength and durability. Notably, the deliberate choice of OPC 53 grade cement, class F fly ash, and M-Sand reflects a commitment to contemporary construction practices that prioritize sustainability while aiming for optimal performance in infrastructure projects. This research aims to contribute valuable insights to the ongoing quest for innovative methods to elevate the mechanical properties of concrete in a manner that aligns with the evolving standards of the construction landscape.

1.1 Concrete

Concrete is a versatile and widely used construction material composed of a mixture of cement, water, aggregates (such as sand and gravel), and sometimes additives or admixtures. It is known for its strength, durability, and ability to take on various shapes and forms.

Fig. 1 Concrete

1.1.1 Ingredients of concrete

- Cement: The binding agent in concrete, typically Portland cement, which reacts with water to form a solid matrix.
- Water: Activates the cement and facilitates the mixing process.

- Aggregates: Include fine aggregates (like sand) and coarse aggregates (such as gravel or crushed stone). Aggregates provide volume and stability to the concrete.

1.1.2 Mixing and Placement

- The process involves combining the dry ingredients (cement and aggregates) and then adding water to create a workable mixture.
- Once mixed, concrete is transported to the construction site and placed in molds or formwork to achieve the desired shape.

1.1.3 Curing

- The curing process involves maintaining adequate moisture and temperature conditions for the concrete to achieve its optimal strength and durability.
- Proper curing is crucial to prevent cracks and ensure long-term durability.

1.1.4 Properties

- Strength: Concrete's compressive strength is a critical parameter, and it can be tailored for specific applications.
- Durability: Concrete is resistant to weathering, chemical attack, and abrasion.
- Workability: A balance must be struck between a mix that is easy to work with and one that provides the required strength.

1.1.5 Applications

- Buildings: Foundations, walls, columns, beams, and floors.
- Infrastructure: Bridges, highways, dams, tunnels, and retaining walls.
- Decorative and Architectural: Stamped concrete, exposed aggregate, and polished concrete for aesthetic purposes.
- Overall, concrete is a fundamental building material with a wide range of applications, and its properties can be adjusted to meet specific project requirements.

1.2 Cement

Fig 2. Cement

Cement is a key component in concrete, acting as a binding agent. Typically composed of finely ground clinker mixed with gypsum, it forms a paste when combined with water. This paste solidifies over time, providing strength and cohesion to concrete structures. Varieties such as Ordinary Portland Cement (OPC) are widely used in construction for their ability to create durable and resilient concrete.“Portland cement,” it’s a common type used in construction. It’s composed of clinker, gypsum, and other additives, binding together when mixed with water. This results in a durable material used in concrete. Portland cement is named after Portland, England, due to its resemblance to a limestone found there. It plays a crucial role in various construction projects, providing strength and stability to structures.Cement is the magical binder that transforms loose ingredients into a solid masterpiece.Cement acts as the mighty glue, binding together the coarse and fine aggregates (sand and gravel) in concrete. This binding power comes from a chemical reaction called hydration, where cement and water form a sticky paste that hardens and locks everything in place.

1.2.1 Composition of Cement

This study delves into the chemical composition of cement, specifically focusing on the primary compounds present in clinker, which can be accurately depicted through chemical equations. The pivotal constituents in cement clinker encompass calcium silicates (C3S and C2S), tricalcium aluminate (C3A), and tetracalciumaluminoferrite (C4AF). The formation of these compounds during the cement manufacturing process is elucidated through the following chemical equations:

1. Formation of Tricalcium Silicate (C3S)

$$3CaO + SiO_2 \xrightarrow{Heat} 3CaO\ .\ SiO_2$$

2. Formation of Dicalcium Silicate (C2S)

$$2CaO + SiO_2 \xrightarrow{Heat} 2CaO\ .\ SiO_2$$

3. Formation of Tricalcium Aluminate (C3A)

$$3CaO + Al_2O_3 \xrightarrow{Heat} 3CaO\ .\ Al_2O_3$$

4. Formation of TetracalciumAluminoferrite (C4AF)

$$4CaO + Al_2O_3 + Fe_2O_3 \xrightarrow{Heat} 4CaO\ .\ Al_2O_3\ .Fe_2O_3$$

These equations represent the key chemical reactions that occur during the high-temperature processing of raw materials in the cement kiln, leading to the formation of clinker. The clinker is then ground to produce the final cement product. Additionally, gypsum ($CaSO4 \cdot 2H2O$) is often added during the grinding stage to control the setting time of the cement:

$$Clinker + 2CaSO_4 \xrightarrow{Grinding} Cement$$

These equations provide a simplified representation of the chemical transformations involved in cement production. The actual process involves multiple reactions and intermediate compounds, but the equations above capture the essence of the main reactions leading to the formation of the key cementitious compounds.

1.2.2 Types of Cement

- Ordinary Portland Cement (OPC): Used in general construction.
- Portland Pozzolana Cement (PPC): Have pozzolanic materials like fly ash.
- Rapid Hardening Cement: Sets quickly and gains strength early.
- Portland Slag Cement (PSC): Includes granulated blast furnace slag.
- White Cement: Produced from raw materials low in iron and manganese.

1.2.3 Properties of cement

- Setting Time: Time taken for the cement to set.
- Strength: Determines the load-bearing capacity.
- Fineness: Particle size affects the surface area.
- Heat of Hydration: The heat produced during the curing process.

1.3 Fine Aggregate

Fine aggregate is a granular material that passes through a 4.75 mm (No. 4) sieve. It is typically composed of natural sand or crushed stone with particles smaller than 5 mm.

Fig. 3 Fine Aggregate

1.3.1 Properties of fine aggregate

- Particle Size: The particles are smaller than those of coarse aggregate, usually ranging from 0.075 mm to 4.75 mm.
- Shape: It should have a rounded shape to ensure good workability and bonding with cement particles.

- Surface Texture: Fine aggregates often have a smoother surface compared to coarse aggregates.

1.3.2 Functions

- Workability: Fine aggregate contributes to the workability of concrete, making it easier to mix, transport, and place.
- Surface Area: It increases the surface area for the bonding of cement paste, enhancing the strength and durability of the concrete.

1.3.3 Sources

- Natural sources include riverbeds, beaches, and sand quarries.
- Manufactured sources include crushed stone, manufactured sand, and recycled materials.

1.4 Coarse Aggregate

Coarse aggregate is a granular material that remains on a 4.75 mm (No. 4) sieve. It consists of particles larger than 5 mm.

Fig. 4 Coarse Aggregate

1.4.2 Properties

- Particle Size: The particles range from 4.75 mm to 20 mm or more.
- Shape: Coarse aggregates can be rounded, irregular, or angular in shape, depending on the source.
- Surface Texture: They may have a rougher surface compared to fine aggregates.

1.4.3 Functions

- Strength: Coarse aggregate provides strength to concrete by bonding with the cement paste.
- Volume Stability: It helps in reducing the shrinkage and cracking of concrete.
- Resistance to Wear and Erosion: Coarse aggregates contribute to the durability of concrete in harsh conditions.

1.4.4 Sources

- Natural sources include crushed stone, gravel, and sand and gravel deposits.
- Recycled concrete and other materials can also be used as coarse aggregates.

1.5 Chemical Admixtures

Fig. 5 Admixtures

Chemical admixtures are substances added to concrete to modify its properties. They can enhance workability, reduce water requirements, control setting time, and improve durability. Admixtures provide flexibility in adjusting concrete characteristics, ensuring optimal performance for specific construction needs.Chemical admixtures play a crucial role in modern concrete construction, significantly enhancing the properties of both fresh and hardened concrete. Among these admixtures, superplasticizers (SPs) are particularly noteworthy for their impressive effects on workability and strength.SPs are chemical admixtures that dramatically increase the workability of concrete without adding more water. This is achieved by dispersing and deflocculating cement particles, preventing them from clumping together and reducing internal friction within the mix. Imagine SPs as tiny molecular magnets that repel cement particles, allowing them to move more freely and creating a smoother, more fluid concrete.Superplasticizers are powerful tools that revolutionized concrete technology. Their ability to enhance workability, strength, and durability makes them invaluable for modern construction projects, contributing to safer, more efficient, and longer-lasting structures.

1.5.1 Applications of SPs

SPs are widely used in various concrete applications, including:

- High-strength concrete: For buildings, bridges, and other structures requiring exceptional strength.
- Self-compacting concrete: For intricate formwork or congested reinforcement, where excellent flowability is essential.
- Precast concrete: For prefabricated elements requiring high early strength and ease of handling.
- Shotcrete: For spraying concrete onto surfaces, such as tunnel walls or rock slopes, where pumpability and adhesion are crucial.

1.6 Fly Ash

Flyash is a by-product of coal combustion, often used as a supplementary cementitious material in concrete production. Its incorporation improves workability, reduces water demand, and enhances long-term strength. This sustainable approach to waste utilization minimizes environmental impact.Overall, fly ash is a valuable mineral admixture for concrete offering numerous benefits. Its use leads to more sustainable, durable, and cost-effective construction.Mineral admixtures, also known as supplementary cementitious materials (SCMs), are finely ground materials added to concrete mixtures to improve their performance and sustainability. Fly ash, a by-product of coal burning in power plants, is one of the most common and versatile mineral admixtures.

Fig. 6 Fly ash

1.6.1 Benefits of using fly ash in concrete

- Fly ash can partially replace Portland cement, typically by 20-40%, decreasing the need for this energy-intensive and CO_2-emitting material. This contributes to environmental sustainability and resource conservation.
- Fly ash possesses fine particles that act as fillers, enhancing the consistency and workability of fresh concrete, making it easier to mix, place, and finish.
- Fly ash reacts with calcium hydroxide, a hydration product of cement, leading to additional strength development over time. It also improves density and reduces permeability, enhancing durability against chemical attack, abrasion, and freezing-thawing cycles.
- The slower hydration of fly ash compared to cement generates less heat during the curing process. This minimizes shrinkage cracks and improves dimensional stability, especially beneficial in mass concrete structures.
- Fly ash is often considerably cheaper than Portland cement, leading to cost savings in concrete production.

1.7 Nano Particles

Nanoparticles, such as silica fume or titanium dioxide, are added to concrete to enhance its mechanical and durability properties. These materials function at the nanoscale, filling voids and improving the overall strength and performance of the concrete matrix. Nanoparticles contribute to advanced concrete technologies, offering innovative solutions for high-performance construction materials.

Nanoparticles are being increasingly explored for use in concrete, offering exciting possibilities for enhancing its properties and performance. These tiny particles, measuring less than 100 nanometers (about 100,000 times smaller than the width of a human hair!), can significantly impact the behaviour of concrete at the microscopic level.

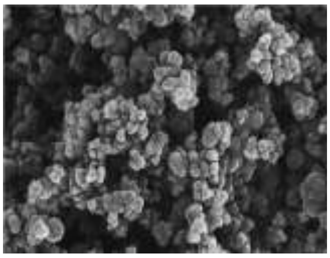

Fig. 7 Nano particle

1.7.1 Ways nanoparticles are being used in concrete

- Nanoparticles can fill pores and micro-cracks in concrete, leading to a denser and more robust material. This can significantly improve the concrete's strength, compressive resistance, and resistance to wear and tear.
- Some nanoparticles can react with water to form a gel that fills cracks in concrete, promoting self-healing and reducing the need for maintenance.
- Nanoparticles can be used to create concrete that is more resistant to corrosion, acids, and fire. This can be especially beneficial for infrastructure projects exposed to harsh environments.
- Nanoparticles can make concrete less permeable to water and other liquids, preventing corrosion of reinforcing steel and improving the overall durability of the structure.

1.7.2 Common types of nanoparticles used in concrete

- Nano-silica: These nanoparticles are very effective at improving the strength and durability of concrete.
- Titanium dioxide (TiO2): Nanoparticles of TiO2 can give concrete self-cleaning properties by breaking down dirt and pollutants under UV light.

1.8 OPC 53 Grade Cement

OPC refers to Ordinary Portland Cement, which is the most commonly used type of cement in construction. It is typically used for general purposes, such as making concrete, mortar, and plaster.

Fig. 6 OPC 53 grade cement

OPC 53 Grade cement is one of the various types of OPC available, and it refers to the compressive strength of the cement after 28 days of curing. It means that this grade of cement will achieve a minimum compressive strength of 53 megapascal (MPa) in 28 days. OPC 53 Grade cement is known for its high strength, making it suitable for applications where high-strength concrete is required.In summary, OPC 53 Grade cement is a type of Ordinary Portland Cement that offers high compressive strength after 28 days of curing. It has a specific chemical composition, physical properties, and chemical properties that make it suitable for applications where high-strength concrete is desired. While it has several advantages, such as high strength and durability, it also has limitations regarding heat of hydration and sulphate resistance. Overall, OPC 53 Grade cement is widely used in the construction industry for a range of projects that require strong and reliable concrete structure.This type of cement is widely used in the construction of buildings, bridges, and other infrastructure projects. The higher compressive strength makes OPC 53 Grade cement preferable in scenarios where structures need to withstand heavy loads or harsh environmental conditions.

1.8.1 Major components

Table 1

Name of compound	Values
Lime (CaO)	60% - 67%
Silica (SiO_2)	21% - 25%
Alumina (Al_2O_3)	4% - 7%
Iron Oxide (Fe_2O_3)	2% - 6%
Magnesia (MgO)	< 6%

1.9 Significance of Fly Ash in Concrete

Class F fly ash, a by-product of coal combustion, has gained prominence as a supplementary cementitious material in concrete production. Its pozzolanic properties contribute to improved workability, reduced heat of hydration, and enhanced long-term strength. The decision to replace 35% of the cement with fly ash in this study aligns with sustainable construction practices, aiming to mitigate environmental impact while enhancing concrete performance.

1.10 M-sand (Manufactured Sand)

M-sand is an artificial alternative to natural sand, produced by crushing rocks. It addresses environmental concerns related to excessive sand mining. M-sand enhances workability and strength in concrete mixes, making it a sustainable and effective choice for construction projects.

Manufactured Sand (M-sand) is a substitute for river sand in construction activities. It is produced by crushing rocks and stones to create fine aggregates. M-sand has gained popularity due to its consistent quality, gradation, and reduced environmental impact compared to traditional river sand extraction. It is commonly used in concrete production, plastering, and other construction applications.

1.10.1 Properties of M-sand

- **Angular and rough texture:** Unlike the smooth, rounded grains of natural sand, M-sand particles are angular and have a rougher texture. This provides better bonding with cement and improves the strength of concrete.
- **Consistent quality:** M-sand is produced under controlled conditions, ensuring consistent quality and gradation, unlike natural sand, which can vary significantly depending on the source.
- **Reduced impurities:** M-sand is washed during the production process, removing most impurities like clay, silt, and organic matter, which can weaken concrete.

1.10.2 Advantages of using M-sand

- **Improved concrete strength:** The angular shape and rough texture of M-sand particles provide better bonding with cement, leading to stronger and more durable concrete.
- **Reduced permeability:** M-sand concrete has lower permeability, making it more resistant to water infiltration and improving the durability of structures.
- **Reduced shrinkage cracks:** M-sand concrete exhibits less shrinkage compared to natural sand concrete, minimizing the formation of cracks.
- **Improved workability:** M-sand is easier to mix and work with, leading to faster and more efficient construction processes.

1.10.3 Disadvantages of M-sand

- **Higher cost:** Manufacturing M-sand often comes at a higher cost compared to natural sand, although the long-term benefits in terms of quality and durability may offset this cost.
- **Regulation:** Depending on the region, specific regulations and standards may apply to the use of M-sand in construction.

1.10.4 Applications of M-sand

- **Concrete production:** M-sand is the preferred choice for making high-strength concrete for buildings, bridges, roads, and other structures.
- **Mortar and plastering:** M-sand is used in mortar mixes for brickwork and blockwork, as well as in plastering walls and ceilings.
- **Landfill construction:** M-sand is used as a cover material in landfills due to its good drainage properties.
- **Road construction:** M-sand is used in asphalt mixes for road construction due to its strength and durability.

1.11 Poly-Carboxylic Ether Solution

Polycarboxylate ether (PCE) is a high-performance polymer widely used in various industries, particularly in construction. It's a type of polycarboxylate, a family of polymers characterized by the presence of multiple carboxylate groups along their backbone. These groups give PCE unique properties that make it valuable for different applications. Polycarboxylate ether is a versatile polymer with a wide range of applications. Its unique properties, particularly its high water reducing capacity and excellent dispersing ability, make it a valuable material in various industries.

Fig. 9 Poly-Carboxylic Ether Solution

1.11.1 Chemical Composition

PCEs are typically copolymers, meaning they are formed from multiple monomer units. The main monomers used in PCE synthesis are:

- **Acrylic acid:** This monomer provides the carboxylate groups responsible for PCE's key properties.
- **Maleic acid**: This monomer can be used to create side chains that influence the polymer's performance.
- **Polyethylene glycol (PEG):** This ether group introduces flexibility and water solubility to the polymer chain.
- **Physical and Chemical Properties:**
- **Appearance:** PCEs are typically light yellow to colourless viscous liquids or white powders.
- **Molecular weight:** PCEs have high molecular weights ranging from 10,000 to 100,000 g/mol.
- **Water solubility:** PCEs are highly soluble in water due to the presence of PEG groups.
- **Thermal stability:** PCEs are stable at moderate temperatures but can decompose at high temperatures.
- **Acid-base properties:** The carboxylate groups make PCEs weak acids.

1.11.2 Advantages

- **High water reducing capacity:** PCEs can significantly reduce the water required for concrete mixes while maintaining workability. This leads to stronger concrete with improved durability.
- **Excellent dispersing ability:** PCEs effectively disperse cement particles in concrete mixes, preventing lumps and improving flowability.
- **Enhanced workability:** PCEs improve the workability of concrete mixes, making them easier to place and finish.
- **Increased strength:** PCEs can lead to higher concrete strength due to improved compaction and reduced water content.
- **Durability:** PCEs can improve the durability of concrete by reducing shrinkage and cracking.

1.11.3 Disadvantages

- **Higher cost:** PCEs are more expensive than traditional concrete admixtures.
- **Sensitive to temperature:** PCEs can lose their effectiveness at high temperatures.

- **Compatibility issues:** PCEs may not be compatible with all types of cement.

1.11.4 Applications

- Detergents: PCEs act as builders in detergents, aiding in the removal of dirt and grime.
- Textile dyeing: PCEs can be used as dispersing agents for dyes in textile applications.
- Papermaking: PCEs can improve the retention of fillers and pigments in paper production.
- Water treatment: PCEs can be used as flocculants for water clarification.

1.12 Magnetic Stirring for Nano Titanium Dispersion

Achieving a homogeneous dispersion of nano titanium dioxide is crucial for realizing its benefits in concrete. Magnetic stirring has been recognized as an effective method for dispersing nanomaterials in cementitious matrices. This section reviews studies showcasing the advantages of magnetic stirring in achieving uniform distribution and improved properties in nano-enhanced concrete.

Fig. 10 Magnetic stirrer

1.13 Nano Titanium DioxideNanoparticle

Nano Titanium dioxide, with its ultrafine particle size, is known for its pozzolanic and pozzolanic-hydraulic properties. Its addition to concrete has shown promising results in enhancing strength, durability, and impermeability. The study incorporates 0.8% nano Titanium dioxide to explore its synergistic effects with fly ash, aiming to unlock the full potential of these supplementary materials in improving concrete properties.

1.13.1 Features

- High refractive index
- Biocompatible
- Non-toxic
- Lightweight
- Strong corrosion resistance
- High thermal stability
- Minimal ion release
- Non-magnetic
- Molar Mass of 79.9378 g/mol
- Melting Point of 1843 °C
- Boiling Point of 2972 °C
- Density of 4.23 g/cm3

1.13.2 Description and Specification of Titanium Dioxide Nanoparticles

Titanium dioxide is a molecule comprising one titanium atom and two oxygen atoms. It is famous for ultrafine titanium dioxide (TiO2) particles, nano-crystalline titanium dioxide, or microcrystalline titanium dioxide. It has a diameter smaller than 100 nm and is white in color.Titanium dioxide nanoparticles are formed by titanium dioxide molecules joining together to create a cylinder's surface. Each oxygen atom bonds to another titanium atom, resulting in a cylindrical lattice with each oxygen atom connected to two titanium atoms. Placing oxygen atoms among titanium atoms resulted in a significantly more complex nanoparticle structure. It is ideal for glass, optics, and ceramics since it is not electrically conductive. It consists of at least one oxygen anion and one metallic cation. It does not dissolve easily in aqueous solutions. It is exceptionally stable in applications ranging from clay bowl production to complex electronics in lightweight structural parts in aircraft and electrochemical applications such as fuel. Because oxide compounds are basic anhydrides, they can induce redox to react with acids and act as potent reducing agents.

1.13.3 Synthesis

Researchers use sulfate, chloride, or sol-gel processes to produce the majority of manufactured titanium dioxide nanopowder. We use digesting ilmenite (FeTiO3) (titanium slag) with sulfuric acid to manufacture Anatase or rutile TiO2. The ultrafine anatase phase involves the use of sulfate solution. The ultrafine rutile form is a result of chloride solution.

To manufacture Natural or rutile nanoparticles, we follow the chlorination process at temperatures ranging from 850 to 1000 °C in the chloride process. Moreover, we follow vapor-phase oxidization of the titanium tetrachloride to generate ultrafine anatase.

Researchers cannot use Grinding to transform pigmentary TiO2 to ultrafine TiO2. Ultrafine titanium dioxide may be produced using various methods, including precipitation, gas-phase reaction, sol-gel, and atomic layer deposition.

1.13.4 Properties of Titanium Dioxide Nanoparticles

- This product has a high refractive index.
- It is biocompatible, non-toxic, and lightweight.
- It has strong corrosion resistance, high thermal stability, minimal ion release, and is non-magnetic.
- It has a Molar Mass of 79.9378 g/mol.
- It has a Melting Point of 1843 °C and a Boiling Point of 2972 °C.
- It exhibits a Density of 4.23 g/cm3.

1.13.5 Applications of Titanium Dioxide Nanoparticles

Titanium Dioxide Nanopowder is part of a film that uses light energy to initiate a chemical reaction that kills micro-organisms on surfaces. Because it reflects all hues in the visible light spectrum, the light reflected from it is white. This feature makes it suitable as a white pigment in paintings and may result in a white residue on the skin when you apply sunscreen. It can also help in eliminating eliminate cancer tumors. It helps remove environmental pollutants, such as NO2, from flue gases and other sources. Furthermore, it may break down SOx, a hazardous inorganic molecule in the atmosphere.

Because of its capacity to disrupt cell membranes, harden viral proteins, regulate virus activity, and catch infectious particles, it frequently uses sterilization and virus restraint medicines. It can eradicate micro-organisms and is perfect for wastewater treatment due to its low cost, corrosion resistance, and general stability. It is used as packing material in solid-phase extraction (SPE) to preconcentrate and remove contaminants from water for surface water treatment. It involves the removal of the ripening hormone ethylene from storage facilities for perishable fruits, vegetables, and cut flowers. It is a long-term dental implant success as it helps manage the infection and acquire new implant insertion technologies in bone.

1.13.6 How to Use it?

Titanium dioxide is not generally soluble in water. Mix one part of the product with three pieces of warm water or carrier oil. Water is typically quicker and easier to mix than oil. It takes a long time to dissolve in water. Some titanium dioxide nanoparticle forms can only be dispersed in oil, but researchers can use water or oil for others.

1.13.7 Safety Measures

Avoid direct contact with moisture at all costs.The pigment's characteristics should not diminish over time if properly stored. However, it is advised that the product be utilized on a first-in, first-out basis from arrival to guarantee maximum effectiveness. The pigment should not be kept in open, weather-exposed regions. One of the critical problems is that it can cause issues with inhalation. Titanium dioxide inhalation can be carcinogenic (cause cancer) and promote cell malfunction or chronic inflammation. Therefore, while performing experiments, ensure that researchers wear respirators instead of safety masks. Similarly, use industrial safety equipment as well as keep them handy. Always use Nitrile gloves while performing experiments to avoid direct skin contact. We recommend, as it states in the safety acts, that the researchers must take a monthly checkup to track their wellbeing.

1.14 Mechanical Properties of Concrete

1.14.1 Compressive Strength

Compressive strength, denoting concrete's resistance to axial forces seeking to compress it, is a critical property. Typically determined through tests on cylindrical specimens, the process involves applying a load until failure. Various factors, including water-cement ratio, curing conditions, aggregate properties, and mix design, significantly influence the compressive strength.

1.14.2 Tensile Strength

Tensile strength, indicative of concrete's ability to resist forces attempting to pull it apart, poses challenges in direct testing. Instead, flexural tests are often conducted to indirectly estimate tensile strength. Factors such as aggregate quality, curing conditions, and the presence of reinforcing materials play pivotal roles in determining tensile strength, which is notably lower than compressive strength in concrete.

1.14.3 Flexural Strength

Flexural strength, also known as modulus of rupture, characterizes concrete's resistance to bending. Testing involves subjecting beams to a bending load and measuring the maximum stress in the extreme fibers of the specimen. Similar to tensile strength, mix design, curing conditions, and the use of reinforcing materials are key influencers of flexural strength.

1.14.4 Elastic Modulus

Elastic modulus, representing concrete stiffness and deformation under load, is derived from stress-strain curves during compressive testing. Aggregate type, water-cement ratio, and curing conditions are pivotal factors influencing the elastic modulus, providing insights into how much deformation occurs under a given load.

1.14.5 Poisson's Ratio

Poisson's ratio, describing the ratio of lateral strain to axial strain, reflects how a material tends to contract laterally when compressed. Determined experimentally or estimated through empirical relationships, Poisson's ratio is influenced by the composition and proportions of concrete components.

1.14.6 Shear Strength

Concrete's ability to resist forces acting parallel to its surface is known as shear strength. Determined through shear tests like direct shear or punching shear tests, factors such as aggregate type, size, shape, and the presence of shear reinforcement significantly influence shear strength.

1.14.7 Creep and Shrinkage

Creep, the time-dependent deformation of concrete under sustained load, and shrinkage, the reduction in volume due to drying and chemical changes, are crucial for long-term structural performance. Influenced by factors such as humidity, temperature, mix design, and curing conditions, engineers carefully consider these aspects to ensure the durability and safety of concrete structures over time.

2. LITERATURE REVIEW

AnjezaAlaj’s 2023 research affirms the viability of sustainable concrete by replacing 30% of cement with low CaO content class F fly ash, showcasing positive environmental and quality outcomes over 600 days of testing. In Ashwini’s 2023 study, concrete properties were compared after replacing 20% of cement with fly ash and incorporating Multiwalled Carbon Nanotubes (MWCNTs) at 0.025%, 0.050%, and 0.075%, revealing variations in compressive strength, flexural strength, and split tensile strength among five different mixes, including conventional concrete and fly ash replaced concrete. Surface decoration using magnetic stirring in Poly Carboxylate Ether facilitated MWCNT dispersion.In 2022, C. R. Mahesha explored the impact of nanotitanium oxide fillers on the mechanical properties of hybrid jute-hemp composites, revealing enhanced strength at 6 wt.% TiO_2 and optimal contributions from the E-type specimen in the study of organic fiber-based biocomposites. In 2021, B. Ashwini and Vidiveli’s research demonstrated enhanced durability properties in concrete through partial cement replacement with fly ash (20%) and incorporation of Multi-Walled Carbon Nanotubes (0.025%, 0.05%, 0.075%), analyzed via acid, chloride, and sulphate resistance tests. In 2021, Kanta Rao’s research explores the utilization of fly ash as a cost-effective alternative to cement in concrete, revealing that a 30% replacement enhances compressive, split tensile, and flexural strengths by 13%, 9%, and 13%, respectively, with finer particles and pozzolanic action contributing to increased strength even after optimal replacement. In 2020,

B. Ashwini and Vidiveli conducted research on incorporating Multi-Walled Carbon Nanotubes (0.025%, 0.050%, 0.075%) and partial cement replacement with fly ash (20%) in concrete, assessing mechanical properties through compression, split tensile, and flexural tests. In 2020, B. Ashwini and Vidiveli investigated the combined effects of Multiwalled Carbon Nanotube incorporation (0.025%, 0.05%, 0.075%) and 20% cement replacement with Class-F fly ash in concrete, emphasizing the importance of dispersion for enhanced mechanical properties, specifically focusing on the elastic modulus after 28 days of curing. Arun Kumar's 2020 study innovates with Photocatalytic Concrete, incorporating Titanium Dioxide, sinicon PP, and Rice Husk Ash to enhance mechanical properties and reduce emissions. In 2020, Ramganesh explores corrosion resistance in reinforced concrete through nano-TiO2-epoxy coatings, scrutinized in 3.5% NaCl and 1M H2SO4, while also investigating the reinforcement effects of micro-silica on mechanical properties, providing valuable insights for corrosion mitigation and concrete improvement. The study suggests that using activated fly ash as a partial replacement for cement in concrete can be a viable option for improving the strength and sustainability of concrete structures by B.Tipraj at 2019. Sumit Sharma's 2019 research focuses on enhancing concrete compressive strength by partially replacing cement with fly ash (0%, 10%, 20%, 30%) and Nano-titanium dioxide (0%, 1%, 1.5%, 2%), addressing early-age strength loss and improving durability through nanomaterials. Umamaheshwari (2019) found that adding 1.5% TiO2 to concrete maximized strength and durability, exceeding standard concrete.Jay Sorathiya (2018) studied adding Anatase Nano Titanium Dioxide to M20 concrete, finding 1.25% mix optimal for workability and strength. In Srikanthan's 2018 study, concrete strength is optimized by using 1% nano titanium dioxide and 0.7% Dewflo SP101, achieving a compressive strength of 44.09 N/mm² at 28 days. Similarly, 5% black carbon powder with the same admixture ratio yields a significant strength increase to 40.84 N/mm², demonstrating the synergistic effect of these materials.Suryanash Sharma (2018) explored using nano-TiO2 and Fe2O3 to improve concrete strength and durability, finding 1.5% TiO2 and 1% Fe2O3 optimal.Srikanthan (2018) found adding 1% nano-TiO2 and 1% PEG 600 to M25 concrete with M-sand maximized compressive strength (38.75 N/mm2) after 28 days, surpassing both conventional and other self-curing concrete mixes. In his 2017 review paper, Rishab Joshi investigated the impact of partial cement replacement with fly ash (0%, 10%, 20%, and 30%) on M20 grade concrete, finding that while workability and durability increased with fly ash content, there was a corresponding reduction in compressive strength, with the optimal replacement identified as 30%. This research by R.D. Padhye (2016) investigated the optimal use of fly ash as a partial cement replacement in high-grade concrete. They tested various percentages of fly ash in different concrete grades and curing periods, finding the best balance between strength, cost, and applicability for each grade.In 2016, Jayanta Chakraborty's research extensively analyzes the effects of Fly Ash as a partial replacement for cement in high-grade concrete, investigating compressive strength variations at different Fly Ash percentages and curing periods to determine optimum, acceptable, and economical usage. In 2003, Rafat Siddique's study reveals that incorporating high volumes of Class F fly ash (40%, 45%, and 50% replacement) in concrete initially reduces short-term strength but exhibits significant improvement in compressive, tensile, and flexural strengths, modulus of elasticity, and abrasion resistance after 91 and 365 days, suggesting suitability for up to 50% cement replacement in precast elements and reinforced concrete construction.

3. CONCLUSION

In conclusion, this study focused on improving the mechanical properties of concrete by simultaneously incorporating nano titanium dioxide and replacing a portion of fly ash in the cementitious material. The study identified an optimal dosage of 0.8% for nano titanium dioxide, highlighting OPC 53 grade cement as the most effective in providing enhanced strength for the concrete mix. A 35% replacement of cement with fly ash emerged as a judicious choice, striking a balance between performance and cost-effectiveness. The recommendation of M-sand as a fine aggregate further contributes to an economical and suitable mix. To ensure the effective dispersion of nano titanium dioxide within the concrete matrix, the study endorsed the use of Poly-carboxylic Ether solution and magnetic stirring as the most efficient methods. These findings collectively offer valuable insights into concrete mix design, presenting a promising strategy for the development of sustainable and high-performance concrete formulations across diverse construction applications. The integration of nano materials and strategic replacement of traditional components represent a step forward in advancing the durability and mechanical strength of concrete structures, contributing to the overall sustainability of construction practices.

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