

# **Sustainable concrete structure with silica nanoparticles**

**A thesis Submitted by**

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**Master of Philosophy in Chemistry**

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I Maria Ajmal Regd. No. SU92-MSCHW-F22-011 declare that the contents of my research thesis entitled "Sustainable concrete structure with silica nano-particles" are based on my own research findings and have not been taken from any other work except the references and has not been published before.

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I Shaukat Ali certify that the contents and the form of research thesis submitted by Maria Ajmal Regd. No. SU92-MSCHW-F22-011 have been found satisfactory. I hereby accept the full responsibility of the supervisorship of mentioned above student and recommend it for the award of the degree of Master of Philosophy.

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## **CERTIFICATE OF APPROVAL**

This is to certify that the research work presented in this thesis, titled “**Sustainable concrete structure with silica nanoparticles**” was conducted by “**Maria Ajmal**” under the supervision of “**Dr. Shaukat Ali**” No part of this thesis has been submitted anywhere else for any other degree. This thesis is submitted to the ‘**Faculty of Science**’, The Superior University, Lahore in partial fulfillment of the requirements for the degree of Master of Philosophy in the field of “**Chemistry**” in Faculty of Sciences at The Superior University, Lahore.

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Designation

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***DEDICATION***

TO

PROPHET MUHAMMAD (Peace Be Upon Him)

Blessing on whole Mankind

***MY LOVING PARENTS***

Whom

Prayers, love and guidance lightens my whole life

and are sources of inspiration for me

**&*****MY FAMILY***

Without whom my life is incomplete

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All praises thanks for **Allah Almighty**, who bestowed us with the heart to feel and brain to think, so that we know, what we don't indeed. He is the best knower, the wisest, peace and blessing of **Allah** be upon **His Holy prophet Hazrat Muhammad (S.A.W.W)** who is the real role model for the mankind.

I feel highly indebted to my intellectual supervisor **Dr. Shaukat Ali** for their kind and affectionate attitude, guidance and keen interest throughout my research work. Their support has been instrumental in my success, I appreciate their mentorship and the opportunity they have provided. Thank you for believing in me and pushing me to excel. Their leadership has made significant impact on our teams' achievements. And I am thankful for the trust they have placed in me and for their continued support.

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I dedicate my research work to my beloved and respectful father **Rana Muhammad Ajmal** for his countless prayers, salutary advices and emboldening attitude that kept my spirit alive. I am unable to show my gratitude to my loving and encouraging **Mother, Sister** and my whole family. They are symbol of love for me, prayers, support, and encouragement provided by my whole family.

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## LIST OF ABBREVIATIONS

SCMs	Supplementary Cementitious Materials
RCA	Recycled Coarse Aggregates
RAC	Recycled Aggregate Concrete
XRD	X-Ray Diffraction
TGA	Thermal Gravimetric Analysis
SEM	Scanning Electron Microscopy
MK	Metakaolin
TG-DSC	Thermogravimetric -Differential Scanning Calorimetry
AS	Autogenous Shrinkage
ASTM	American Society for Testing and Materials
BS	British Standards
IO	Iron Oxide
RA	Rubber Aggregate
NA	Nano Aluminum
GD	Granite Dust
MD	Marble Dust
UHPC	Ultra High Performance Concrete
SiO <sub>2</sub>	Silicon Dioxide
CNT	Carbon Nano Tubes
MgO	Magnesium Oxide
ZnO	Zinc Oxide
OPC	Ordinary Portland Cement

$\text{CaCO}_3$	Calcium Carbonate
$\text{Al}_2\text{O}_3$	Aluminum Oxide
$\text{TiO}_2$	Titanium Dioxide
$\text{Fe}_2\text{O}_3$	Ferric Oxide

## ABSTRACT

The mechanical strength of nano-silica-containing concrete composites was investigated in order to manufacture more flexible and strong concrete, which is required for long-term concrete structures. Seven batches of concrete composites were created for this study, with nano-silica powder added in amounts ranging from 0.5% to 3%. A total of 126 concrete specimens were produced, with 63 cubes and 63 cylinders. The compressive strength of these samples was determined using a CTM at 7, 14, and 28 days. Morphological analysis was carried out utilizing SEM. The results revealed that adding nano-silica increased compressive strength significantly. Notably, concrete samples containing 2% nano-silica had a remarkable average compressive strength of 3246 psi at 28 days, compared to 3006 psi in reference samples, representing an approximate 2.3% gain. SEM images also demonstrated that adding nano-silica to the concrete considerably improved the interfacial transition zone between cement particles



# CHAPTER 1

## INTRODUCTION

The construction industry uses a substantial amount of concrete, which is essential for sustainable development. A single estimate states that about 14 billion tons of concrete were utilized in 2007 [1]. On the other hand, concrete which is composed of granulated components in varying sizes, is utilized in constructions and infrastructure. Additionally, concrete has been noted to be a global man-made material. As a result, 3.97 billion tons of cement were produced globally in 2013, according to estimates. Another estimate puts the annual production of concrete at around one ton per person on earth [2]. In comparison to other building materials such as plastics, steel, aluminum, and wood, concrete is used twice as much worldwide. Because, in the current world, naturally occurring water has surpassed the use of concrete. Therefore, sustainable development is a big concern. Incorporating sustainable development ideas into building design and communities is urgently needed for economic and environmental benefits [3].

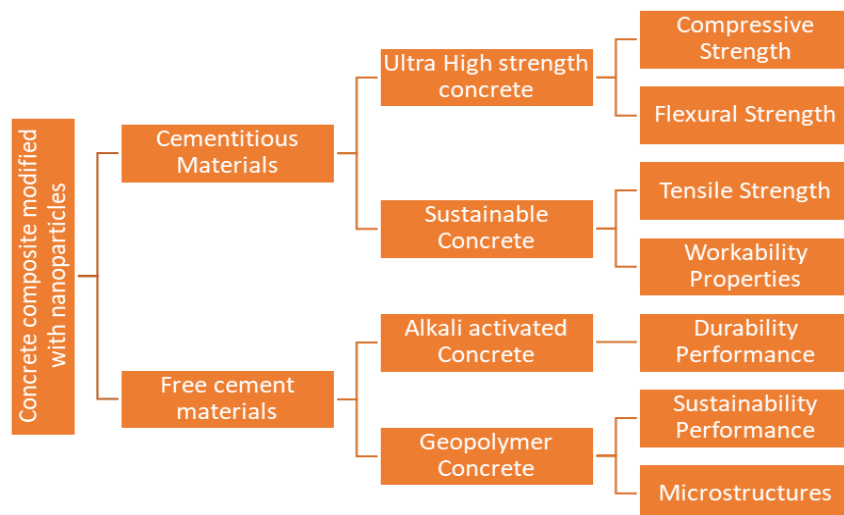
More recently, attempts have been undertaken to manufacture environmentally friendly materials. And they have been devoted toward enhancing existing procedures rather than developing whole new products or approaches. Typically, to manufacture concrete, the cement and aggregates are blended, and the material is pushed into steel molds [4]. However, to strengthen the concrete, manufacturing processes are employed to generate common building materials with a substantial environmental impact. Specifically, cement, which is a fundamental component of concrete, emits a significant amount of greenhouse gases, including carbon dioxide (CO<sub>2</sub>). And it is the main source of climate change and global warming [5].

Nanotechnology has long been focused on producing and manipulating molecules with structural sizes ranging from 1 nm to 100 nm [6]. Nanomaterials are used in many industries, including biomedical sciences, paints, transparent sunscreens, automotive technologies, nanowires, nanorods, optical sensors, medication delivery systems, cosmetics, robotics, electrical energy, food and textiles, and environmental remediation. Similarly, research into nanotechnology's potential to improve concrete qualities has become an increasingly active field of study. Nano titanium dioxide, nano

aluminum dioxide, nano iron oxide, nano clay, nano ferric oxide, nanotubes, and nano zirconium dioxide are examples of nanoparticles used in concrete compositions today [7].

However, with concrete, a range of synthetic and natural compounds are put into the mixture to boost its strength [8]. Nanomaterials are utilized to increase concrete's surface area and improve its resistance to loading. Incorporating nanoparticles into concrete is a rising concept in concrete technology that aims to improve performance. Numerous studies have found that adding nanoparticles to concrete improves its mechanical qualities, including strength and durability [9].

Furthermore, dense microstructural concrete is formed when nanomaterials fill the micropores, hastening the hydration reaction. The main benefits of nanoparticles are commonly seen in modified concretes and mortars, where they act as pore fillers in the concrete matrix, making mortars more compact. Nanoparticles also act as pore fillers, improving uniformity and making the network more compact than standard cement-based concretes. Nanoparticles also collect micropores and begin a process of microcrack refinement early on, improving the microstructures of concrete matrices. As a result, nanoparticles have a high reactivity, which enhances strength and accelerates chemical reactions in concrete, including setting and durability [10]. The concrete composite modified with nanoparticles is shown in figure 1.



**Figure 1.** Concrete composite modified with nanoparticles

The use of nano-sized additives enhances concrete quality more efficiently than standard approaches, propelling advances in nanotechnology. The hydration kinetics of cement paste are greatly influenced by the exceedingly small particle sizes of its constituents. The enhanced cement paste has a higher specific surface area, allowing it to set and solidify more quickly. Because of their strong reactivity, the nano-material particles accelerate the hydration of cement, like the Ferric oxide [11].

Nanoparticles are also used in the production of smart cement, which has significantly boosted its sensitivity in practical applications. Furthermore, adding a little amount of nanoparticles to the cement improves its workability [12].

Adding a modest amount of nanoparticles to cement increases the material's resilience to stress and failure while also boosting concrete durability [13]. However, for infrastructure development, new raw materials are used as supplemental cementitious materials. These measures improve concrete durability, extend the service life of structures, and expedite cement manufacturing [14].

## **1. 1 Types of nanoparticles**

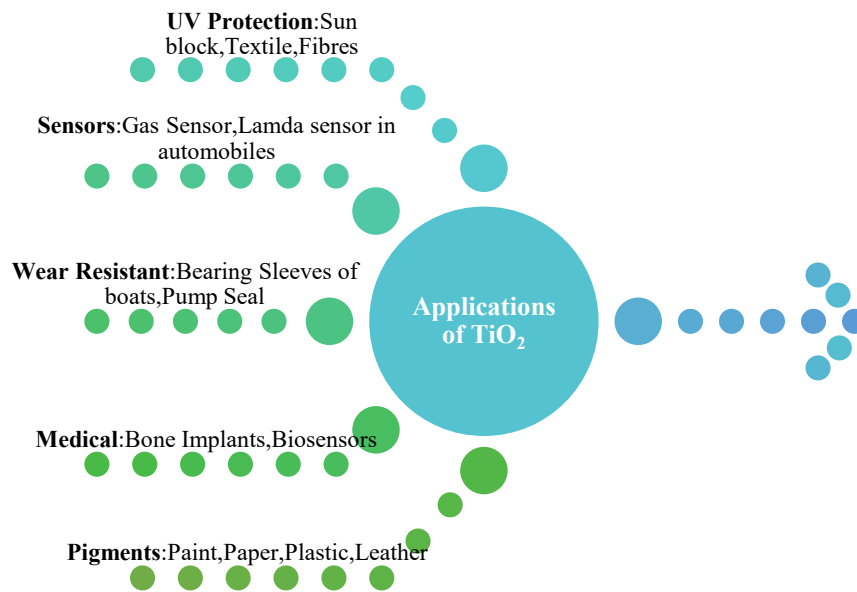
The detail of different types of nanoparticles using in concrete are following that:

### **1. 1.1 Nano-Titanium dioxide**

Nanomaterials, such as nano titanium dioxide, used in concrete have exceptional thermal and chemical resilience. It has also been shown that using nano titanium dioxide improves the compressive strength and overall mechanical qualities of concrete. Nano-titanium dioxide is also employed as a coating material in the building industry [15].

Titanium dioxide is the basic ingredient used to produce nano-titanium oxide. Furthermore, the crystalline form of titanium oxide is known as nano-titanium oxide. Paints, plastics, cement, and other materials all contain nano titanium oxide as a supplement. Incorporating nano  $\text{TiO}_2$  into concrete decreases calcium hydroxide levels in the C-S-H gel. However, titanium can induce irritation and cancer, thus

caution should be exercised when adding it to concrete mixtures. Some applications of  $\text{TiO}_2$  are shown in figure 1.1.1.



**Figure 1.1.1** Applications of titanium dioxide

### 1.1.2 Fly ash

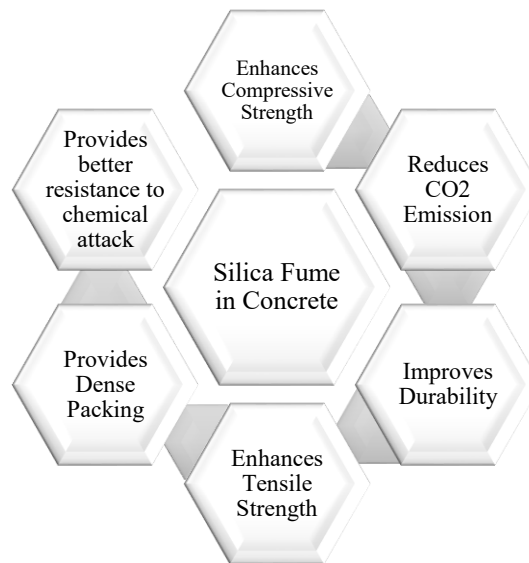
Fly ash, a byproduct of coal combustion in thermal power plants, is utilized as an additional cementitious material in concrete to increase its strength. Incorporating fly ash into the concrete improves its compressive strength, durability, and consistency while reducing its carbon footprint, shrinkage, hydration, and heat rate and improving resistance [16]. Some applications of fly ash are in figure 1.1.2.



**Figure 1.1.2** Applications of fly ash

### **1.1.3 Silica fume**

Silicon and ferrosilicon are the origins of silica fume. It begins the hydration process in high-performance concrete as a pozzolanic component. Adding silica fume to concrete reduces mass loss at elevated temperatures. Furthermore, when concrete is mixed at high temperatures, the silica fume enhances the concrete's impact and compressive strengths [17]. Some applications of silica fume in concrete are shown in figure 1.1.3.



**Figure 1.1.3** Silica fume in concrete

#### **1.1.4 Nano iron oxide**

It addresses the nanoscale hydration products of concrete. Nano iron oxide, due to its paramagnetic nature, acts as a blocking agent to shield buildings from ultraviolet radiations, increasing the durability of the building structure [18]. Nano iron oxides are the most widely used manmade and naturally occurring nanostructures. Increased exposure to these nanostructures has prompted worries about their possible biotoxicity [19].

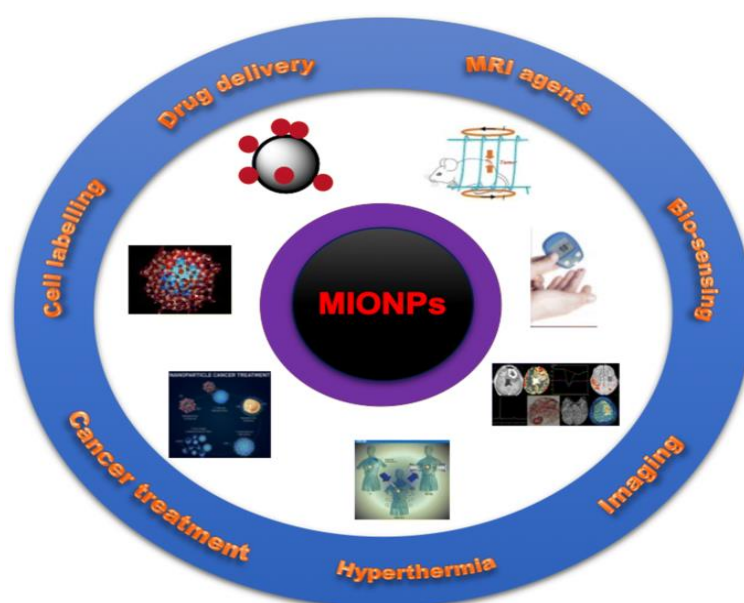
One of the most remarkable aspects of IONPs is their superparamagnetic behavior, which happens when the particle size goes below a particular threshold. The wide range of applications for IONPs demonstrates their adaptability. In the biomedical industry, they are used for targeted medication administration, magnetic hyperthermia (where they selectively heat and destroy cancer cells), and as MRI contrast agents [20].

Their biocompatibility and functionalization make them more successful in these roles. Beyond biomedicine, IONPs are used to remove heavy metals from wastewater and act as catalysts in a variety of chemical processes, including the degradation of environmental pollutants. IONPs are employed in the industrial sector as magnetic

recording media, pigments, and catalysts in chemical processes, leveraging their magnetic characteristics and reactivity [21].

Iron oxide nanoparticles are a flexible and exciting family of materials that have the potential to change a variety of sectors, including biomedicine, environmental remediation, and industrial uses [22].

IONPs are a prospective contender for future technological breakthroughs due to their unique features, such as superparamagnetic and enormous surface area, and the ability to customize their capabilities through synthesis and modification procedures [23]. Biomedical applications of nano iron oxides are shown in figure 1.1.4.



**Figure 1.1.4** Biomedical applications of nano iron oxide

### 1.1.5 Nano clay

Incorporating nano clay into concrete improves its performance., increases flexural strength, and also the durability, such as temperature and resistance [24]. Nano clay also reduces permeability and water adsorption because it functions as nano

reinforcement nucleation sites, which helps to promote hydration and also boosts the properties of materials.

Some composites of nano clay are shown in figure 1.1.5.

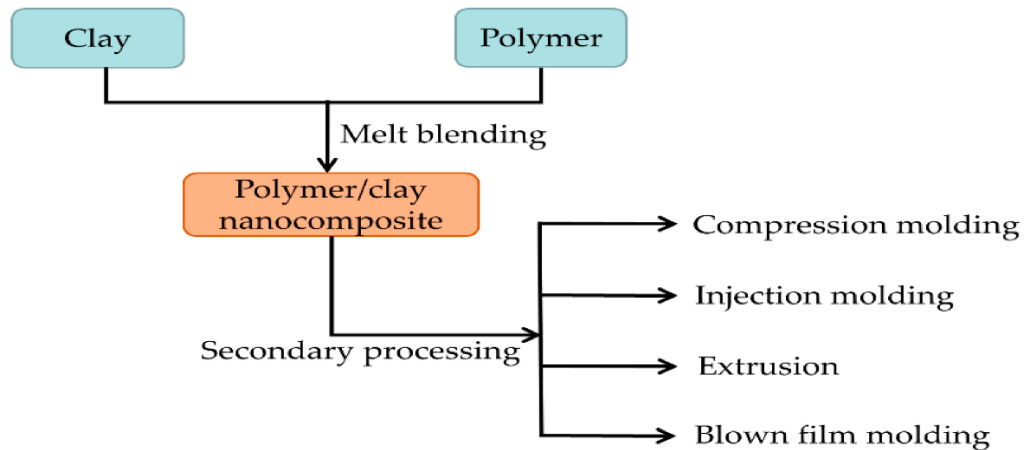


Figure 1.1.5 Composites of nano clay

### 1.1.6 Nano Al<sub>2</sub>O<sub>3</sub>

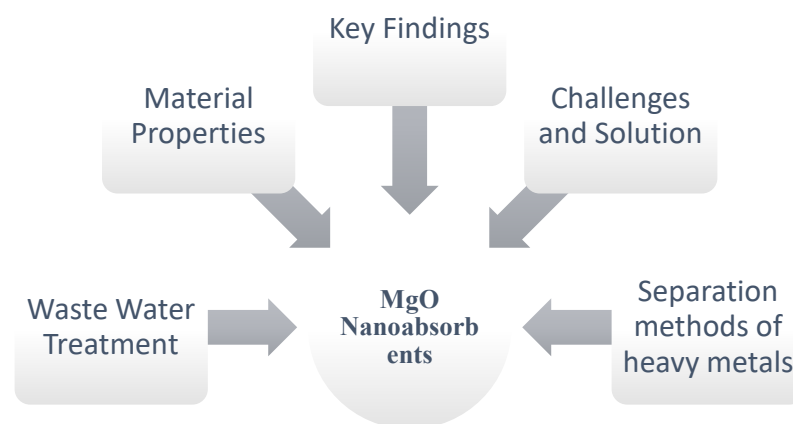
Adding nano aluminum oxide (Al<sub>2</sub>O<sub>3</sub>) to concrete improves its durability and mechanical qualities. Incorporating nano-sized components into concrete formulations is a modern and novel approach to improving the performance of typical concrete mixtures. Adding nano aluminum oxide to concrete considerably boosts its compressive strength by filling vacancies in the matrix, resulting in a denser and more durable construction [25].

### 1.1.7 Nano Magnesium Oxide

Nano-MgO acts as an expansion agent in cement-based composites, which reduces shrinkage in large-volume concrete. Its presence in concrete improves mechanical qualities such as flexural and compressive strength while also improving the microstructure of the cement paste. This improves the long-term stability and strength of the concrete [26].

However, Nano-MgO affects the hydration process by encouraging the creation of magnesium hydroxide crystals, which aid in slurry expansion. Prolonged curing permits the hydration process to progress, resulting in greater stability over time. This enhanced stability is particularly useful for applications that require long-term performance [27].

Some absorbents of MgO are in figure 1.1.7



**Figure 1.1.7** Nano absorbents of MgO

### 1.1.8 Carbon nano tubes (CNT)

Carbon nanotubes (CNTs) in concrete improve its mechanical qualities, such as compressive, tensile, and flexural strength. CNTs also improve the ductility of concrete beams by bridging micro and nano cracks, strengthening the composite. Their high modulus of elasticity and tensile strength result in strain constructed of CNTs. Hence, a promising reinforcing material. CNTs improve the electrical characteristics of concrete, making it suitable for structural health monitoring [28].

Furthermore, CNTs diminish concrete permeability, resulting in a fall in the permeability coefficient. However, there were obstacles with employing CNTs in concrete [29]. However, establishing appropriate dispersion of CNTs in cement paste is critical and difficult, necessitating procedures such as sonication and high-shear

mixing to avoid agglomeration. Furthermore, handling CNTs entails health hazards that must be addressed properly. Whether CNTs provide mechanical benefits and typical reinforcements such as fibers or mineral/chemical admixtures [30].

Some applications of carbon nanotubes are in figure 1.1.8.

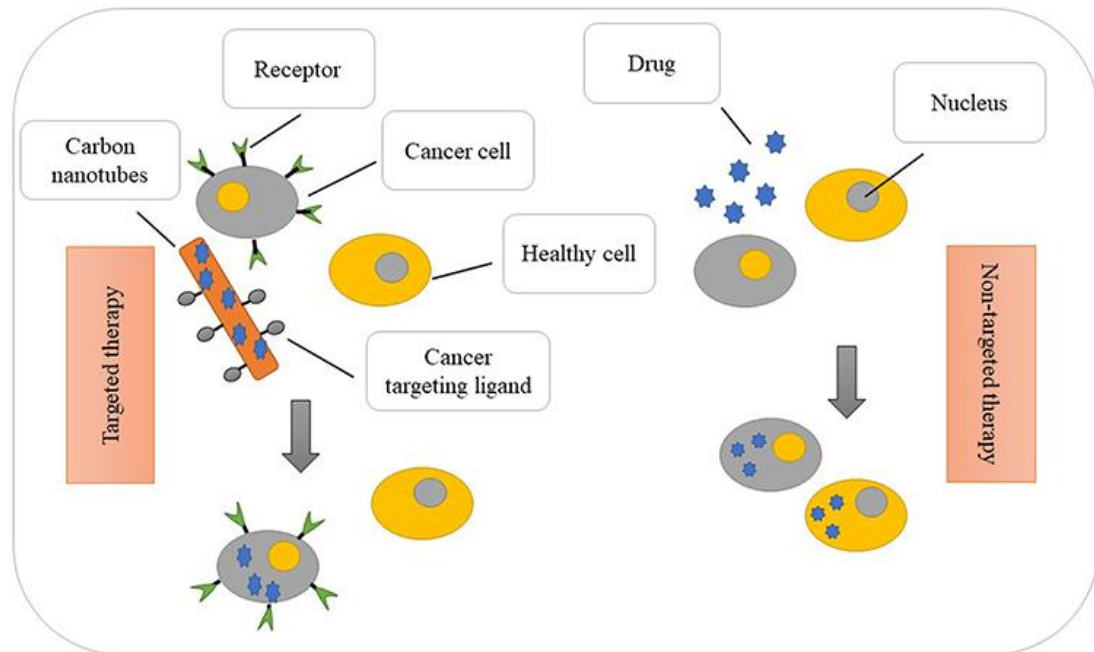


Figure 1.1.8 Applications of carbon nanotubes

### 1.1.9 Nano Copper Oxide

When CuO nanoparticles are utilized as a partial cement replacement in concrete, they increase compressive strength and hasten cement hydration, resulting in higher early strength. However, exceeding CuO tends to decrease these gains due to less area for  $\text{Ca(OH)}_2$  crystal formation. In terms of microstructure and porosity, CuO nanoparticles operate as fillers, increasing concrete density and decreasing porosity [31].

It also speeds cement hydration while reducing the size and orientation of  $\text{Ca(OH)}_2$  crystals. Composites containing CuO have the finest mechanical, structural, and durability qualities. In contrast, increased CuO levels led to a modest increase in

micropores and bigger pores, primarily due to agglomeration and slower hydration. Furthermore, the CuO nanoparticles increase tensile strength by encouraging the synthesis of additional hydration products [32].

They also limit water absorption while increasing abrasion resistance in concrete. CuO nanoparticles improved grain structure and densified microstructure of cement composites demonstrate a substantial potential for increasing the strength and thermal properties of cementitious materials [33].

The main component of concrete is cement, which has a high unit cost. As a result, selecting the right cement and using it correctly is critical to achieving the necessary qualities of economically feasible concrete. However, the over use of cement is a major source of carbon dioxide emissions. One new approach to addressing this issue is to incorporate nanomaterials into concrete mixtures to minimize cement content [34].

As a result, whereas several nanomaterials have been used to substitute cement and improve concrete characteristics, fused silica nanoparticles have gotten less attention. This study explores the use of SiO<sub>2</sub> as a cementitious ingredient to improve the compressive strength of concrete, resulting in more lasting and cost-effective constructions [35]. Nano silica has excellent compressive strength and endurance, and it is an essential component of concrete structures. Adding nano silica to cement helps limit deterioration and increase durability. By using superplasticizer, nano silica enhances strength and properties. Cement quality improves as its strength increases [36].

## **AIM AND OBJECTIVES**

Some important aims and objectives regarding above thesis are below:

- Using fused silica nano particle in concrete is to increase its strength.
- To enhance mechanical properties of concrete by using fused silica nano particle.
- Analysis about the impact of silica nanoparticles at the micro structure level.
- Also to identify the right amount of silica nanoparticle for the better results.

## CHAPTER 2

### LITERATURE REVIEW

Phushap and colleagues (2024) highlighted that nanotechnology-based engineering is fast progressing over the world. As infrastructure demand grows in both emerging and industrialized countries, so does cement usage, which has a severe impact on the environment and human health. This results in greenhouse gas emissions and severe respiratory illnesses including asthma and silicosis. To address these concerns, it is critical to limit cement use in construction materials. Recently, novel additional ingredients have been introduced to improve mortar performance. Nano-titanium dioxide has gained popularity in green building construction because of its capacity to breakdown air pollutants, provide self-cleaning capabilities, and improve the mechanical, microstructural, and durability features of cement mortar [37].

Summit (2022) revealed that recent advances in nanotechnology have significant potential for addressing a variety of difficulties. Nanotechnology has proven useful at improving the performance of traditional building materials such as concrete. The use of various nanoparticles, including nano-titanium dioxide, has considerably increased the efficiency, durability, and sustainability of concrete. Conventional plain or blended cement systems usually have minimal water absorption and permeability [38].

According to Chahuhan *et al.*, (2024) demonstrated that UHPC is a particular type of concrete with compressive strengths above 120 N/mm<sup>2</sup>. It is composed of a unique cementitious composite that comprises fine sand, silica fume, fly ash, and other ingredients. UHPC's remarkable strength makes it an excellent choice for sustainable, long-term building applications. Because of their endurance, high-strength and high-performance concretes have been widely employed in the construction of nuclear power plants, bridges, tunnels, water resource projects, and high-rise structures. However, UHPC was less frequently used, mostly because to its high cost, lack of specialized contractors, and the absence of standardized standards [39].

Imran and colleagues (2024) explained that using rubber aggregates produced from waste rubber tires in concrete was a novel technique to replace natural aggregate and furthering sustainable construction practices. This solution addressed the issue of

accumulating waste rubber tires while also providing a more sustainable option to decreasing the need of natural aggregate[40].

However, because crumb rubber reduces concrete strength, introducing titanium dioxide as a nanomaterial mitigates this strength loss in crumb rubber concrete. Furthermore, the addition of  $\text{TiO}_2$  reduced drying shrinkage in rubberized concrete, with significant reductions occurring at increasing  $\text{TiO}_2$  concentration. Incorporating  $\text{TiO}_2$  improved pore structure and strengthened the contact between cement matrix and aggregate in cured rubberized concrete. As a result, rubberized concrete with  $\text{TiO}_2$  demonstrated impressive compressive strength, similar with that of normal concrete [41].

Mohamed and colleagues (2024) investigated the effect of marble dust (MD), granite dust (GD), and nano alumina (NA), both individually and in combination, on the performance of Portland cement concrete. MD and GD were used to replace cement in varying percentages, and NA was added to each combination in different amounts. The physical characteristics, workability, mechanical properties, and microstructure of the individual and combined mixtures, as well as a control mix, were assessed using scanning electron microscopy and energy-dispersive X-ray analysis [42].

Their findings revealed that when the concentrations of GD and NA increased, more water was required to achieve standard homogeneity, but both the initial and final setting times reduced. Variations in MD content had only a minor impact on uniformity and setting time when compared to the control mixture. Workability decreased consistently across all blends, which was associated with the surface area of the materials used. The most significant decrease in workability was observed with NA, which had the greatest surface area, followed by GD and MD, which had the least influence. The substitution of samples enhanced the strength of hardened concrete at all curing ages [43].

Al-Madani *et al.*, (2014) demonstrated that the decrease of compressive strength was linked to an increase in porosity within the mortar as the aluminum oxide level increased. They claimed that mixing aluminum oxide into a cement-based matrix decreases its mechanical properties, particularly compressive strength. This was useful in learning how increasing aluminum oxide content affects the compressive strength of cement mortar and emphasizes the need of staying within defined limitations [44].

Ismail (2023) explained that nano aluminum oxide (nano  $\text{Al}_2\text{O}_3$ ), with its excellent electrical conductivity, is a recent invention in construction materials. Nano  $\text{Al}_2\text{O}_3$ , like other nanomaterials, enhances the physical characteristics and mechanical strength of cementitious composites by uniform dispersion. The study looked at the mechanical and physical properties of mortar, as well as its microstructure. Mortars treated with nano  $\text{Al}_2\text{O}_3$  showed enhanced mechanical strength after 7 days of cure [45].

Beilin and his coworker (2024) demonstrated that geopolymers are a novel material and a promising alternative to traditional Portland cement in the building industry due to their ease of manufacturing, low energy consumption, and wide range of raw components from which they were synthesized. The use of geopolymers in civil engineering was a highly promising technique for reducing the environmental impact and significant energy consumption associated with Portland cement production [46].

Geopolymers were mostly made from industrial waste, which resulted in lower carbon emissions and energy consumption than traditional cement products. However, geopolymers faced issues such as low strength, breaking susceptibility, and limited manufacturing efficiency, limiting its use in engineering. Nanoscience advancements have had a huge impact on construction materials, and it has been shown that adding nanoparticles into a geopolymer matrix significantly improves its properties [47].

Telem and his colleague (2024) stated that cement manufacture, combined with deforestation and the use of petroleum derivatives, was a significant source of carbon dioxide emissions. The incorporation of glass into concrete was a promising way to reduce waste disposal costs while also enhancing sustainability. Glass, a nontoxic material, was regularly recycled without affecting its chemical composition. Fly ash was regularly used to glass concrete to make it more environmentally friendly [48].

Cracking resistance metrics such as fracture toughness and fracture energy were assessed for warm mix asphalt mixes with high levels of reclaimed asphalt pavement and variable concentrations of nano calcium carbonate as a modifier. The study discovered that adding calcium carbonate improved both fracture toughness and fracture energy, regardless of the mix type used. The addition of Nano calcium carbonates significantly improved cracking resistance and increased the brittleness of the material, resulting in a fall in the flexibility index [49].

Deng and his colleagues (2024) explained that recycling building and demolition debris into recycled coarse aggregate (RCA) increased the value of the resources. The practical application of recycled aggregate concrete is limited due to its inferior material qualities. Improving the performance of recycled concrete aggregates is critical in engineering applications [50].

This entails evaluating the performance of several types of concrete, such as natural aggregate concrete, recycled aggregate concrete (RAC), RAC enhanced with nano-calcium carbonate, and natural aggregate concrete with nano-calcium carbonate. They discovered that replacing natural coarse aggregate (NCA) with RCA considerably degraded concrete's mechanical and fatigue properties, with the negative impacts worsening as the RCA replacement rate increased. However, adding nano-CaCO<sub>3</sub> to RAC increased overall performance by boosting compressive strength, flexural strength, elastic modulus, and fatigue life [51].

Omer and coworkers (2024) demonstrated the creation of ecologically acceptable slag-based mixes required the use of solid sodium carbonate as an alkali activator and reactive magnesium oxide (MgO) as a component. MgO was added in varied concentrations to improve the reaction mechanism and strength growth. The effects of integrating calcium carbonates into binary mixes were also investigated, with emphasis on strength development and microstructure. It was discovered that a tiny amount of reactive MgO improved the reaction mechanism, resulting in faster setting periods and considerable increases in early-age and final compressive strength. Additionally, the addition of calcium carbonate improved compressive strength at all ages, resulting in a denser matrix [52].

Zaid and his colleagues (2024) investigated the concrete that introduced a new form of coating: nanoparticle mixes. The performance of these coatings required to be thoroughly evaluated, particularly in concrete combinations with significant amounts of supplementary cementitious materials (SCMs), as decreasing carbon footprints is an important industry goal [53].

They tested concrete mixtures to determine the effectiveness of nano-clays in concrete. Physical, thermal, and microstructural investigations revealed that concretes with a high water-to-binder ratio and considerable SCM content were especially sensitive to harsh exposure conditions. Incorporating nano-clay into these polymers considerably

increased protection over neat coatings. Nanocomposites provided comprehensive protection, achieving up to 100% improvement with low surface scaling, especially with nano-clay [54].

Asadabadee *et al.*, (2024) illustrated that by focusing on creating eco-friendly concrete with building waste as aggregates, nano clay was used both individually and in combination to improve the physical and mechanical qualities of the concrete. At ideal levels, nano clay outperformed the reference sample in compressive and tensile strength, indicating the greatest improvement in mechanical qualities. They also proved that using Nano Clay considerably increased the physical qualities of concrete prepared from waste aggregates [55].

Elaf and his coworkers (2024) explained the increased emphasis on the usage of nanoparticles in different types of concrete. They also describe how nano clay is used in both traditional and self-compacting concrete, as well as the impact it has on these types. The insertion of nano clay provided various benefits, the most notable of which were reduced cement content by partial replacement and the reduction of microspore development [56].

Sena and coworkers (2024) demonstrated that nano-modification is a promising approach for improving the mechanical properties of concrete by using different nanoparticles. Studies have demonstrated that these nanoparticles not only increase the mechanical and durability performance of concrete, but they also influence how nanoparticle-enhanced concrete responds to stress, particularly through progressive failure mechanisms. Research on the effect of nano clay on the mechanical properties and failure behaviors of concrete indicated that adding nano clay considerably boosted the load-bearing capacity and ductility of the concrete samples [57].

Yasien and colleagues (2024) illustrated that nano clay, with its enormous surface area and high reactivity, has been shown to improve the hydration process and overall performance of concrete. This makes them very beneficial in reducing the impact of cold temperatures on concrete. Nano clay powders loaded with phase change elements were used to create internal curing nanocomposites [58].

The performance of the combinations was evaluated using a variety of tests, including setting times, compressive strengths, fluid absorption, and frost resistance in both water and salt solutions. They demonstrated that nano clay considerably increased the

performance of concrete. Notably, nano clay powder improved the concrete's overall characteristics [59].

Muhd *et al.*, (2024) illustrated the use of nanoparticles in Ultra High-Performance Concrete was a cutting-edge technique, notably for attaining slender designs, reducing the requirement for steel reinforcement, and improving compressive strength. They investigated the impact of nano clay on the physical characteristics, elemental composition, workability, strength, and morphology of UHPC and compared them to normal UHPC. The findings showed that while nanomaterials increased the surface area of UHPC, they also shortened the setting time. The chemical investigation found high levels of nano clay, which contributed to their pozzolanic properties. The addition of nanoparticles considerably increased the strength properties of UHPC [60].

Srinivasan *et al.*, (2024) demonstrated that the development and evaluation of nano-modified concrete focused on its microstructural features. The addition of nano clay not only enhanced concrete characteristics, but also helped to reduce soil pollution. The study uses these nanoparticles as supplementary cementitious materials to examine the structural integrity of nano-modified concrete utilizing sophisticated methodologies [61]. Compared to normal concrete, nano-modified concrete demonstrated significant increases in microstructural qualities without sacrificing critical attributes. The inclusion of nano clay boosted slump values, suggested improved workability, and produced smoother concrete surfaces. The nano-modified concrete shows great promise as an innovative building material [62].

Additionally, ZnO nanoparticles increased concrete density, reduced pore size, and improved concrete strength. They have practical implications for construction engineering and management, affecting areas such as buildings, roads, tunnels, bridges, airports, railways, dams, and utilities [63].

Thanongsak and coworkers (2015) illustrated that Zinc oxide nanoparticles show great promise as nano photocatalysts for self-cleaning concrete construction. However, their effect on cement hydration, setting time, and compressive strength is critical for practical applications. The study examined the impact of adding ZnO nanoparticles into cement-based products, namely the setting time, compressive strength, and porosity of mortars. Experimental data showed that when colloidal ZnO nanoparticles

were dispersed ultrasonically, the mortar's strength increased more than that of control samples [64].

Isothermal calorimetry and electrical resistance experiments revealed that nano-ZnO lengthened the induction period of cement hydration and influenced the hydration rate during acceleration [65].

X-ray diffraction (XRD), thermogravimetric-differential scanning calorimetry (TG-DSC), and scanning electron microscopy (SEM), which corroborated in these findings [66].

CNTs improve the abrasion resistance, service life, strength, durability, and self-sensing properties of concrete. CNTs are revolutionary nanoscale materials with extraordinary properties such as superior mechanical behavior, high tensile strength, corrosion resistance, chemical stability, and thermal performance. CNTs, even in modest concentrations, can increase fracture energy and toughness [67].

The inclusion of steel fibers greatly improves ductility under tensile loads, with packing density being critical in enhancing the bond strength between steel fibers and the UHPC matrix. Multiwalled carbon nanotubes (MWNTs) were chosen for their superior physical and mechanical qualities, such as ultimate strength, stiffness, and ductility. Because nanotubes tend to agglomerate, substantial study was done to optimize their dispersion in concrete mixing fluids [68]. The study looked at how MWNTs, relative to cement weight, affected the bonding behavior of two types of high-strength steel fibers. Mechanical experiments demonstrated that even at low concentrations, MWNTs significantly enhanced the bonding behavior of high-strength steel fibers in pull-out tests [69].

Pravithra and coworkers (2013) demonstrated MWCNTs considerably increase the strength and durability of concrete. The sonication process involves combining MWCNTs, surfactants, and water in proportion to the cement weight [70].

CNTs showed significant potential for enhancing crack resistance and fracture toughness, particularly in pre-peak performance phase of concrete. Concrete containing greater doses of CNTs with lower aspect ratios had the largest gain in mechanical strength, which was attributed to reduced structural damage and improved dispersion in high pH settings. Higher aspect ratio CNTs, on the other hand, were more successful in increasing fracture energy due to their superior bridging capabilities [71].

## **CHAPTER 3**

### **METHODOLOGY**

All the experimental work was done with Dr. Shaukat's research group in Building Research Station, Lahore, Communication and Works Department, Government of the Punjab and in the office of Geological Survey of Pakistan at Lahore. This chapter comprises of three portions i.e. selection of material, experimental section and methodology for evaluation of engineering properties.

#### **3.1 Materials**

The materials utilized in this research are mentioned below.

##### **3.1.1 Cement**

This investigation used ordinary Portland cement. Ordinary Portland Cement (OPC) of Pioneer manufacturing company having grade 46 was gifted by BRS which satisfied the standards of the ASTM C1-50. The term "grade 46" relates with compressive strength of cement having at least 46 MPa.

##### **3.1.2 Coarse aggregates**

The coarse aggregate of was obtained from project executing with the name of Multi Storey Flate/Suits in the primacies of Building Research Station, Lahore. The coarse aggregate used in concrete was strong, workable, durable and appropriate grading which ensured that the aggregate fit together to reduce voids. Moreover, the grading of coarse aggregate for concrete was in accordance with specification as mentioned in various standards such as ASTM C39 and BS 882 [72].

##### **3.1.3 Fine aggregates**

The selection of fine aggregates is a critical step in ensuring the necessary performance characteristics of the concrete and environmental sustainability in sustainable concrete constructions employing silica nanoparticles. We took the fine aggregates from river Ravi. Fine aggregate (sand) was collected from river Ravi near Ravi Toll Plaza Lahore.

##### **3.1.4 Water**

Clean, potable water free from impurities was used.

### **3.1.5 Nano silica**

Nano silica particles were purchased from XFANO (Lahore , Pakistan) with purity of 99.%

## **3.2 Apparatus**

Followings apparatus was being used during performing of experiment which are mentioned below:-

- (1) Iron moulds having dimension 6X6X6
- (2) Mechanical full load mixture machine
- (3) Water curing tank
- (4) Compression Testing machine
- (5) Weighing Balance

### **3.2.1 Procedure for preparation of concrete cubes**

Stepwise procedure for preparation of concrete cube is described as below.

The concrete cubes and cylinder were prepared according to literature protocol like ASTM C39 and British Standard BS 1881: Part 225 [73]. Seven concrete combinations were made, each combination contain 3 cubes, all based on the same control mixtures, in order to fulfill the objectives. As a percentage of the total cementitious material content nano-silica was added. Various percentages of colloidal nano-silica were tested and compared to the reference mix to see how they affected both fresh and cured concrete qualities. The prepared samples were tested after three distinct ages like 7,14,28 days.

### **3.2.2 Preparation of mixture**

All components used in this investigation, including regular Portland cement, fine and coarse aggregates, water, and nano silica, were mixed automatically using a mechanical full-load mixer. The seven concrete mixtures were created as follows: Mixture No. 1, which served as the reference, had 50 kg of cement, 100 kg of fine aggregate, and 200 kg of coarse aggregate. Mixture #2 had 50 kilogram of cement,

100 kg of fine aggregate, 200 kg of coarse aggregate, and 0.5 kg of nano silica. Mixture No. 3 contained 50 kg of cement, 100 kg of fine aggregate, 200 kg of coarse aggregate, and 1 kg of nano silica. Mixture No. 4 was created using 50 kg of cement, 100 kg of fine aggregate, and 200 kg of coarse aggregate and 1.5 kilograms of nano silica. Mixture No. 5 consisted of 50 kg cement, 100 kg fine aggregate, 200 kg coarse aggregate, and 2 kg nano silica. Mixtures No. 6 and No. 7 contained 50 kg of cement, 100 kg of fine aggregate, 200 kg of coarse aggregate, and 2.5 kilogram and 3 kg of nano silica, respectively. Each mixture was completely mixed for 10 minutes in a mechanical drum-type full-load mixing machine, with water supplied as needed to obtain the required homogeneity and workability of the concrete paste.

### **3.3 Casting of concrete cubes**

36 No iron mould of sizes 6X6X6 were used to cast concrete cubes. 21 No of concrete cubes were casted from each freshly prepared mixture. For this purpose, iron moulds were filled with reference concrete mixture and blended nano silica particle concrete mixture in the laboratory. The poured concrete cube in iron mould were left at room temperature for 24 hours for early setting.

### **3.4 Curing of concrete cubes and cylinders**

All the casted concrete cubes and cylinders were separated from iron mould after passing the 24 hours and placed them in fresh water curing tank for 7, 14 and 28 days. Curing was carried out by using normal curing method at room temperature.

### **3.5 Collection of concrete cubes and cylinders**

From water curing tank, the cured concrete cubes and cylinders were collected after specified time period. In order to avoid any damage that could affect the test results, extra care was taken to handle them.

### **3.6 Testing and analyzing**

#### **3.6.1 Compressive strength test**

The concrete cubes and cylinders were tested after 7, 14, and 28 days curing by using two steel bearing plates covering the specimens' top and lower bearing areas to determine their compressive strength.

## CHAPTER 4

### RESULTS

**Table 4.1** Determined compressive strength of concrete Cubes against specified compressive strength 2000 psi after 07 days as BS 1881: Part 225

Cube No.	Mix Ratio Cement: Sand: Aggregate	Use of additive in %age	Area in inches	Load applied in lbs.	Determined compressive strength in psi
1	1:2:4	-	36	70700	1964
2	1:2:4	-	36	72500	2014
3	1:2:4	-	36	71800	1994
4	1:2:4	0.5%	36	71900	1997
5	1:2:4	0.5%	36	74800	2078
6	1:2:4	0.5%	36	72900	2025
7	1:2:4	1%	36	72600	2017
8	1:2:4	1%	36	71600	1989
9	1:2:4	1%	36	75500	2097
10	1:2:4	1.5%	36	72200	2006
11	1:2:4	1.5%	36	75200	2089
12	1:2:4	1.5%	36	73300	2036
13	1:2:4	2%	36	70900	1989
14	1:2:4	2%	36	73800	2050
15	1:2:4	2%	36	74600	2072
16	1:2:4	2.5%	36	71950	1999
17	1:2:4	2.5%	36	72400	2011
18	1:2:4	2.5%	36	70800	1966
19	1:2:4	3%	36	72800	2022
20	1:2:4	3%	36	71500	1986
21	1:2:4	3%	36	73900	2053

**Table 4.2** Determined compressive strength of concrete cylinders against specified compressive strength 1750 psi after 07 days as ASTM C39

<b>Cylinder No.</b>	<b>Mix Ratio Cement :Sand: Aggregate</b>	<b>Use of additive in %age</b>	<b>Area in inches</b>	<b>Load applied in lbs.</b>	<b>Determined compressive strength in psi</b>
1	1:2:4	-	28.3	49600	1753
2	1:2:4	-	28.3	47200	1668
3	1:2:4	-	28.3	49900	1763
4	1:2:4	0.5%	28.3	48800	1724
5	1:2:4	0.5%	28.3	50100	1770
6	1:2:4	0.5%	28.3	47600	1682
7	1:2:4	1%	28.3	49700	1756
8	1:2:4	1%	28.3	50900	1798
9	1:2:4	1%	28.3	48300	1706
10	1:2:4	1.5%	28.3	49500	1749
11	1:2:4	1.5%	28.3	51200	1809
12	1:2:4	1.5%	28.3	50100	1770
13	1:2:4	2%	28.3	49600	1753
14	1:2:4	2%	28.3	50200	1774
15	1:2:4	2%	28.3	49300	1742
16	1:2:4	2.5%	28.3	48800	1724
17	1:2:4	2.5%	28.3	50400	1781
18	1:2:4	2.5%	28.3	49700	1756
19	1:2:4	3%	28.3	49800	1760
20	1:2:4	3%	28.3	48900	1728
21	1:2:4	3%	28.3	50600	1788

**Table 4.3** Determined compressive strength of concrete cubes against specified compressive strength  
2400 psi after 14 days as BS 1881: Part 225

<b>Cube No</b>	<b>Mix Ratio Cement :Sand: Aggregate</b>	<b>Use of additive in %age</b>	<b>Area in inches</b>	<b>Load applied in lbs.</b>	<b>Determined compressive strength in psi</b>
1	1:2:4	-	36	86600	2406
2	1:2:4	-	36	87600	2433
3	1:2:4	-	36	85900	2386
4	1:2:4	0.5%	36	87300	2425
5	1:2:4	0.5%	36	86500	2403
6	1:2:4	0.5%	36	85800	2383
7	1:2:4	1%	36	86800	2411
8	1:2:4	1%	36	88100	2447
9	1:2:4	1%	36	89700	2492
10	1:2:4	1.5%	36	86700	2408
11	1:2:4	1.5%	36	89400	2483
12	1:2:4	1.5%	36	87500	2431
13	1:2:4	2%	36	90800	2528
14	1:2:4	2%	36	88200	2450
15	1:2:4	2%	36	91600	2544
16	1:2:4	2.5%	36	89400	2483
17	1:2:4	2.5%	36	86400	2400
18	1:2:4	2.5%	36	88300	2453
19	1:2:4	3%	36	87200	2422
20	1:2:4	3%	36	85900	2386
21	1:2:4	3%	36	86300	2397

**Table 4.4** Determined compressive strength of concrete cylinders against specified compressive strength 2000 psi after 14 days as ASTM C39

<b>Cylinder NO</b>	<b>Mix Ratio Cement :Sand: Aggregate</b>	<b>Use of additive in %age</b>	<b>Area in inches</b>	<b>Load applied in lbs.</b>	<b>Determined compressive strength in psi</b>
1	1:2:4	-	28.3	55600	1965
2	1:2:4	-	28.3	56900	2046
3	1:2:4	-	28.3	56700	2004
4	1:2:4	0.5%	28.3	57300	2025
5	1:2:4	0.5%	28.3	59100	2088
6	1:2:4	0.5%	28.3	56500	1996
7	1:2:4	1%	28.3	57600	2035
8	1:2:4	1%	28.3	56700	2004
9	1:2:4	1%	28.3	59400	2099
10	1:2:4	1.5%	28.3	57700	2039
11	1:2:4	1.5%	28.3	56900	2011
12	1:2:4	1.5%	28.3	58800	2078
13	1:2:4	2%	28.3	62300	2201
14	1:2:4	2%	28.3	59400	2099
15	1:2:4	2%	28.3	60300	2131
16	1:2:4	2.5%	28.3	59200	2092
17	1:2:4	2.5%	28.3	57800	2039
18	1:2:4	2.5%	28.3	57200	2021
19	1:2:4	3%	28.3	56800	2007
20	1:2:4	3%	28.3	58200	2057
21	1:2:4	3%	28.3	57100	2018

**Table 4.5** Determined compressive strength of concrete Cubes against specified compressive strength 3000 psi after 28 days as BS 1881: Part 225

<b>Cube No</b>	<b>Mix ratio Cement :Sand :Aggregate</b>	<b>Use of additive in %age</b>	<b>Area in inches</b>	<b>Load applied in lbs.</b>	<b>Determined compressive strength in psi</b>
1	1:2:4	-	36	108400	3011
2	1:2:4	-	36	109200	3033
3	1:2:4	-	36	107100	2975
4	1:2:4	0.5%	36	110300	3064
5	1:2:4	0.5%	36	111200	3089
6	1:2:4	0.5%	36	108100	3003
7	1:2:4	1%	36	109500	3042
8	1:2:4	1%	36	108800	3022
9	1:2:4	1%	36	110200	3061
10	1:2:4	1.5%	36	109600	3044
11	1:2:4	1.5%	36	110900	3081
12	1:2:4	1.5%	36	112500	3125
13	1:2:4	2%	36	111500	3097
14	1:2:4	2%	36	120200	3339
15	1:2:4	2%	36	118400	3289
16	1:2:4	2.5%	36	115700	3213
17	1:2:4	2.5%	36	109900	3053
18	1:2:4	2.5%	36	112300	3119
19	1:2:4	3%	36	108200	3006
20	1:2:4	3%	36	105600	2933
21	1:2:4	3%	36	110100	3058

**Table 4.6** Determined compressive strength of concrete cylinders against specified compressive strength 2400 psi after 28 days as ASTM C39

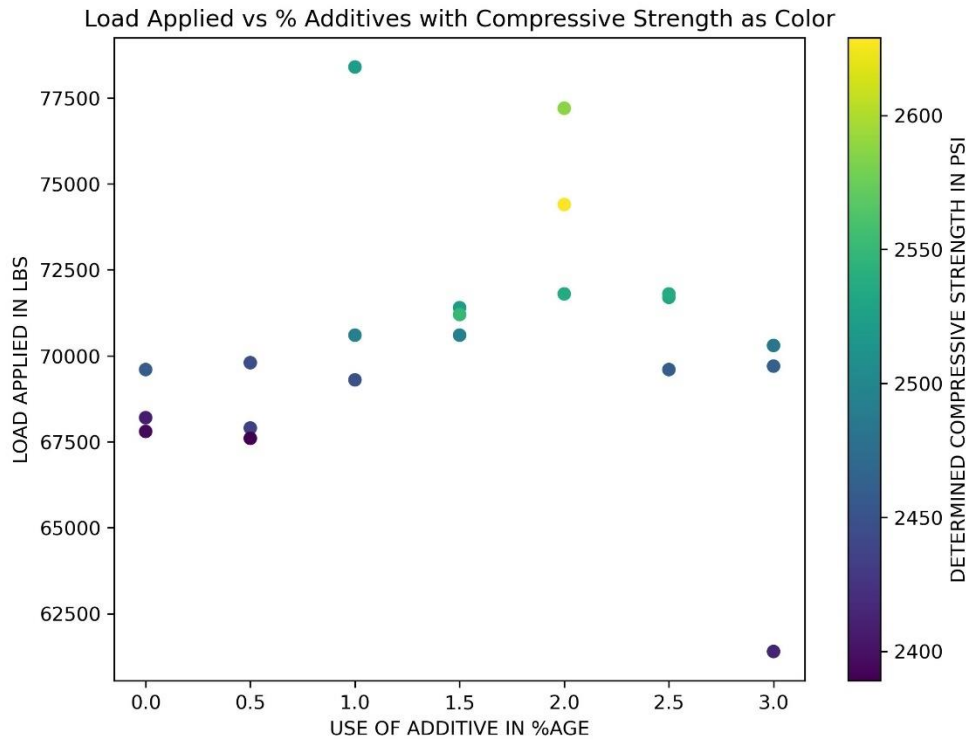
<b>Cylinder No</b>	<b>Mix ratio Cement :Sand :Aggregate</b>	<b>Use of additive in %age</b>	<b>Area in inches</b>	<b>Load applied in lbs.</b>	<b>Determined compressive strength in psi</b>
1	1:2:4	-	28.3	68200	2409
2	1:2:4	-	28.3	67800	2396
3	1:2:4	-	28.3	69600	2459
4	1:2:4	0.5%	28.3	67900	2435
5	1:2:4	0.5%	28.3	67600	2389
6	1:2:4	0.5%	28.3	69800	2446
7	1:2:4	1%	28.3	70600	2495
8	1:2:4	1%	28.3	78400	2523
9	1:2:4	1%	28.3	69300	2449
10	1:2:4	1.5%	28.3	71400	2523
11	1:2:4	1.5%	28.3	71200	2551
12	1:2:4	1.5%	28.3	70600	2495
13	1:2:4	2%	28.3	77200	2587
14	1:2:4	2%	28.3	71800	2537
15	1:2:4	2%	28.3	74400	2629
16	1:2:4	2.5%	28.3	71700	2533
17	1:2:4	2.5%	28.3	69600	2459
18	1:2:4	2.5%	28.3	71800	2537
19	1:2:4	3%	28.3	70300	2484
20	1:2:4	3%	28.3	61400	2415
21	1:2:4	3%	28.3	69700	2463

## CHAPTER 5

### DISCUSSION

The total 126 concrete specimens were prepared to evaluate the influence of nano silica on the mechanical properties of concrete. Therefore, various batches of concrete composites were made by mixing cement, sand, and aggregate in a ratio of 1:2:4 along with nano silica content ranging from 0% to 3%. Concrete cubes and cylinders were produced to determine their compressive strength after 7, 14, and 28 days. After seven days, 42 specimens, including 21 concrete cubes and 21 cylinders, were examined for compressive strength. Table 4.1 shows the results. Concrete cubes 1, 2, and 3 served as reference specimens, while cubes 4–21 were test specimens. The compressive strengths of the test specimens were compared to those of the reference specimens.

Three reference concrete cubes no 1,2 3 revealed compressive strength 1964 psi,2014 psi, and 1994 psi respectively against the specified 2000 psi compressive strength as per BS:1881 (part 225).The concrete cube for 4,5 and 6 along with 0.5% by weight nano silica as an additive exhibited compressive strength 1997 psi ,2078 psi and 2025 psi respectively .Moreover, prepared concrete cubes 7,8 and 9 having 1% of nano silica showed 2017psi ,1989 psi and 2097 psi respectively. Furthermore, cube no 10-12 with 1.5% of nano silica gave compressive strength 2006 psi ,2089 psi and 2036 psi respectively. Whereas 2% nano silica blended concrete cube 13,14 and 15 revealed 1979 psi ,2058 psi and 2072 psi compressive strength respectively .While concrete cube 16,17 and 18 having 2.5% nano silica additive provided compressive strength 1999 psi ,2011 psi and 1966 psi respectively. Whereas 3% nano silica blended concrete cube 19,20 and 21 exhibited 2022 psi ,1986 psi and 2053 psi compressive strength. As shown in figure 2.

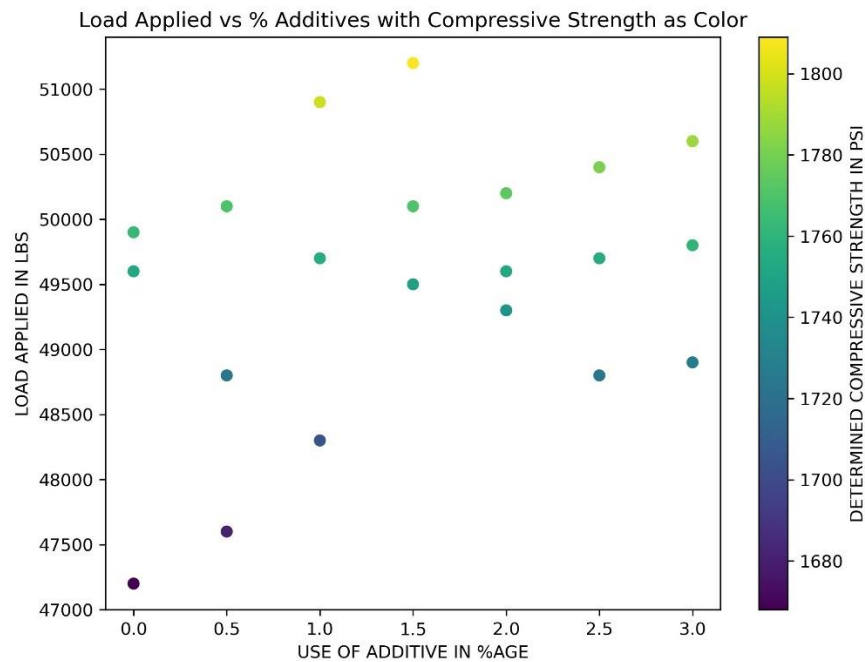


**Figure 2.** 3D scattered plot of cube specimens after 7 days between additive %age ,load applied and compressive strength

Similarly 21 concrete cylinder were tested at the age of 7 days in order to determine their compressive strength against specified compressive strength 1750 psi as per ASTM C39. The test results are depicted in table 4.2. Almost all the concrete cylinders gave compressive strength in range 1668 psi .The cylinder no 1 to 3 are considered as reference concrete specimen whereas cylinder no 4 to 21 are considered as test concrete specimen and their determined compressive strength is compared with reference concrete specimen.

The reference concrete cylinders numbered 1, 2, and 3 had compressive strengths of 1753 psi, 1668 psi, and 1763 psi, respectively, against the specified 1750 psi as per BS:1881 (part 225). Concrete cylinders 4, 5, and 6, incorporating 0.5% nano silica by weight as an additive, showed compressive strengths of 1724 psi, 1770 psi, and 1682 psi, respectively. Cylinders 7, 8, and 9, containing 1% nano silica, demonstrated compressive strengths of 1756 psi, 1798 psi, and 1706 psi. Cylinders 10, 11, and 12, with 1.5% nano silica, achieved compressive strengths of 1749 psi, 1809 psi, and 1770 psi. Concrete cylinders 13, 14, and 15, which had 2% nano silica, exhibited strengths of 1753 psi, 1774 psi, and 1742 psi respectively. Cylinders 16, 17, and 18, containing

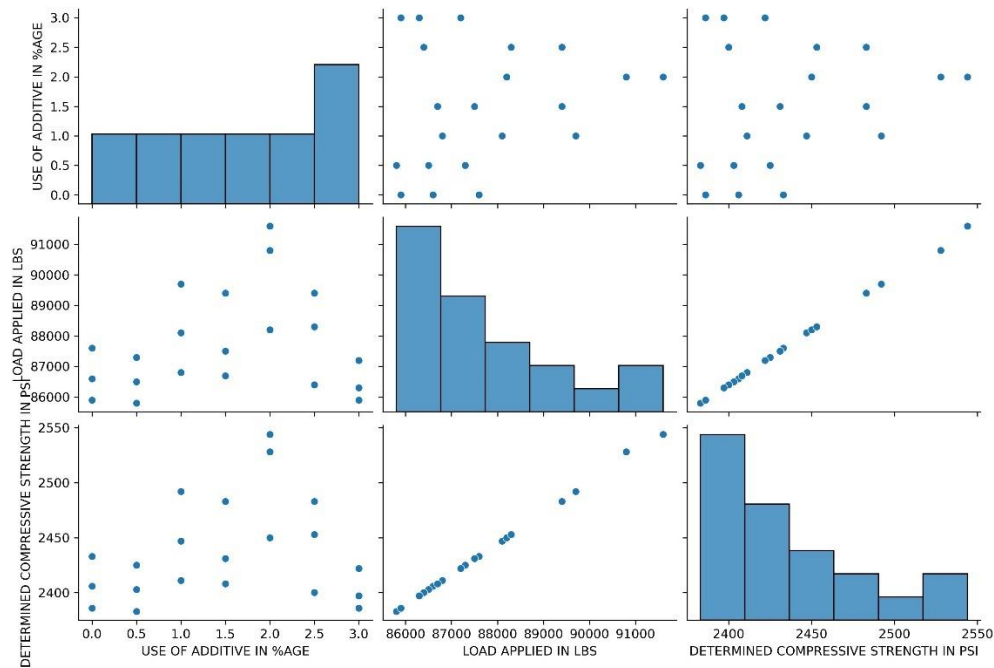
2.5% nano silica, provided compressive strengths of 1724 psi, 1781 psi, and 11756 psi respectively. Finally, cylinders 19, 20, and 21, with 3% nano silica, showed compressive strengths of 1760 psi, 1728 psi, and 1788 psi, respectively. As shown in figure 3.



**Figure 3.** 3D scattered plot of cylinders specimens after 7 days between additive %age, load applied and compressive strength

Secondly, at the age of 14 days, 42 concrete specimens comprising of 21 concrete cubes and 21 concrete cylinders were again tested to determine their compressive strength. The reference concrete cubes numbered 1, 2, and 3 had compressive strengths of 2406 psi, 2433 psi, and 2386 psi, respectively, compared to the specified 2400 psi as per BS:1881 (part 225). Concrete cubes 4, 5, and 6, with 0.5% nano silica by weight as an additive, showed compressive strengths of 2425 psi, 2403 psi, and 2383 psi. Cubes 7, 8, and 9, containing 1% nano silica, demonstrated compressive strengths of 2411 psi, 2447 psi, and 2492 psi. Cubes 10, 11, and 12, with 1.5% nano silica, achieved compressive strengths of 2408 psi, 2483 psi, and 2431 psi.

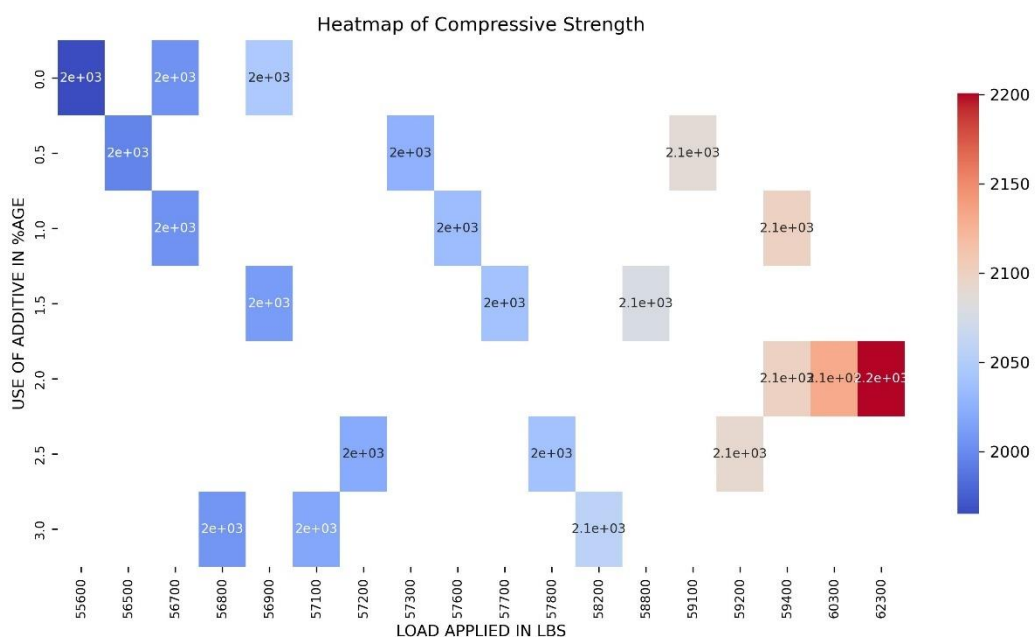
Concrete cubes 13, 14, and 15, incorporating 2% nano silica, exhibited strengths of 2528 psi, 2450 psi, and 2544 psi. Cubes 16, 17, and 18, with 2.5% nano silica, provided compressive strengths of 2483 psi, 2400 psi, and 2453 psi. Finally, cubes 19, 20, and 21, containing 3% nano silica, showed compressive strengths of 2422 psi, 2386 psi, and 2397 psi, as shown in figure 4.



**Figure 4.** 3D scattered plot of cubes specimens after 14 days between additive %age, load applied and compressive strength

Similarly, for concrete cylinders, the reference concrete cylinders numbered 1, 2, and 3 had compressive strengths of 1965 psi, 2046 psi, and 2004 psi, respectively, compared to the specified 2000 psi according to BS:1881 (part 225). Concrete cylinders 4, 5, and 6, with 0.5% nano silica by weight as an additive, demonstrated compressive strengths of 2025 psi, 2088 psi, and 1996 psi. Cylinders 7, 8, and 9, containing 1% nano silica, showed compressive strengths of 2035 psi, 2004 psi, and 2099 psi.

Cylinders 10, 11, and 12, incorporating 1.5% nano silica, achieved compressive strengths of 2039 psi, 2011 psi, and 2078 psi. Concrete cylinders 13, 14, and 15, with 2% nano silica, exhibited strengths of 2201 psi, 2099 psi, and 2131 psi. Cylinders 16, 17, and 18, containing 2.5% nano silica, provided compressive strengths of 2092 psi, 2039 psi, and 2021 psi. Lastly, cylinders 19, 20, and 21, incorporating 3% nano silica, showed compressive strengths of 2007 psi, 2057 psi, and 2018 psi which is shown in figure 5.

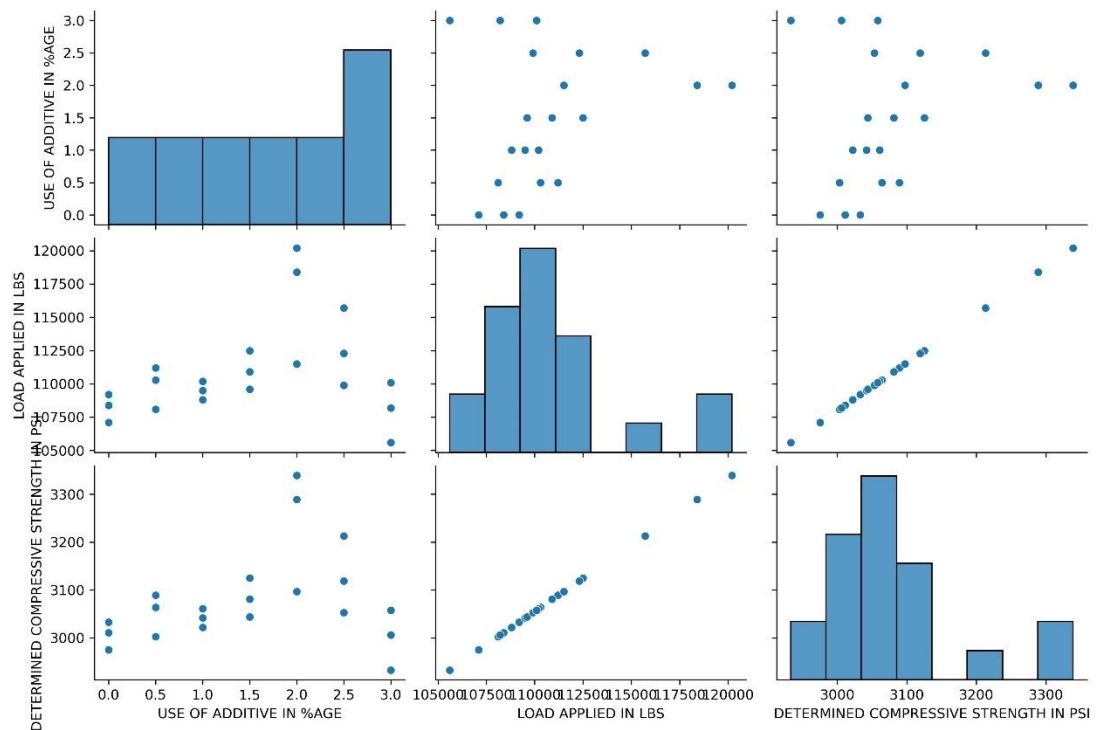


**Figure 5.** 3D scattered plot of cylinders specimens after 14 days between additive %age, load applied and compressive strength

At last, at the age of 28 days ,42 concrete specimens comprising of 21 concrete cubes and 21 concrete cylinders were lastly tested to determine their compressive strength. The reference concrete cubes numbered 1, 2, and 3 exhibited compressive strengths of 3011 psi, 3033 psi, and 2975 psi, respectively, compared to the specified 3000 psi according to BS:1881 (part 225). Concrete cubes 4, 5, and 6, with 0.5% nano silica by weight as an additive, showed compressive strengths of 3064 psi, 3089 psi, and 3003 psi. Cubes 7, 8, and 9, containing 1% nano silica, demonstrated compressive strengths

of 3042 psi, 3022 psi, and 3061 psi. Cubes 10, 11, and 12, incorporating 1.5% nano silica, achieved compressive strengths of 3044 psi, 3081 psi, and 3125 psi.

Concrete cubes 13, 14, and 15, with 2% nano silica, exhibited strengths of 3097 psi, 3339 psi, and 3289 psi. Cubes 16, 17, and 18, containing 2.5% nano silica, provided compressive strengths of 3213 psi, 3053 psi, and 3119 psi. Finally, cubes 19, 20, and 21, with 3% nano silica, showed compressive strengths of 3006 psi, 2933 psi, and 3058 psi as shown in fig 6.

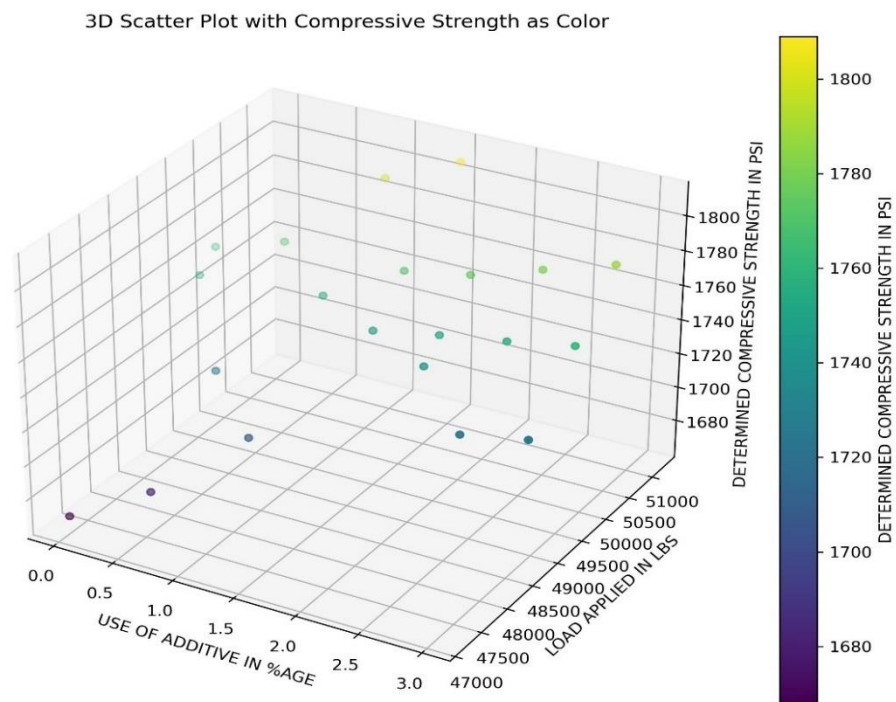


**Figure 6.** 3D scattered plot of cubes specimens after 28 days between additive %age, load applied and compressive strength

At 28 days of age, the reference concrete cylinders numbered 1, 2, and 3 had compressive strengths of 2409 psi, 2396 psi, and 2459 psi, respectively, compared to the specified 2400 psi according to BS:1881 (part 225). Concrete cylinders 4, 5, and 6, with 0.5% nano silica by weight as an additive, showed compressive strengths of 2435 psi, 2389 psi, and 2446 psi. Cylinders 7, 8, and 9, containing 1% nano silica,

demonstrated strengths of 2495 psi, 2523 psi, and 2449 psi. Cylinders 10, 11, and 12, incorporating 1.5% nano silica, achieved compressive strengths of 2523 psi, 2551 psi, and 2495 psi.

Concrete cylinders 13, 14, and 15, with 2% nano silica, exhibited strengths of 2587 psi, 2537 psi, and 2629 psi. Cylinders 16, 17, and 18, containing 2.5% nano silica, provided compressive strengths of 2533 psi, 2459 psi, and 2537 psi. Finally, cylinders 19, 20, and 21, with 3% nano silica, showed compressive strength of 2484 psi, 2415 psi, and 2463 psi which is shown in figure 7.



**Figure 7.** 3D scattered plot of cylinders specimens after 28 days between additive %age, load applied and compressive strength

Variety of SEM images demonstrates that particles of nano silica are strictly attached to the concrete specimens that enhance the concrete bonding and strength. Nano silica is in under loaded situation of concrete sample.

## CHAPTER 6

### CONCLUSION

The performance of concrete with micro silica particles was investigated by comparing its compressive strength to that of normal concrete. Seven distinct batches of concrete composites were mixed to form various concrete cubes and cylinders. These specimens' compressive strength was measured using a Compression Testing Machine (CTM) at 7, 14, and 28 days. Furthermore, the morphology of the samples was examined using Scanning Electron Microscopy (SEM).

The results showed that using silica nanoparticles greatly boosted compressive strength. The study looked at various concentrations of nano silica, ranging from 0.5% to 3% by weight, at different curing ages. Both cube and cylinder specimens demonstrated similar trends in strength increase with varying nano silica concentrations. Consistent performance across different specimen types demonstrated the uniform efficiency of nano silica in increasing the mechanical properties of concrete.

The observation is that compressive strength is increased by the addition of nano silica particles. One of the greatest improvements is on the addition of 2% silica nanoparticles. Because of that the compressive strength improved at 28 days, which was recorded as 3097 to 3289 psi and it is the best result for any nanoparticle. Same thing notices in the cylinder which also have 2% nano silica particles Because of that it showed that nano silica particles improve in development of strength and its performance .

The slow addition of nano silica particles showed that the compressive strength increased in the percentage of 0.5% to 1% , 1.5% and also 2% .It was also noticeable that the strength of concrete suddenly decreased as the percentage of nano silica particles increased above the 2% . Scanning Electron Microscopy (SEM) showed that nano silica particles enhance the structure of paste of concrete and also the aggregates.

It was also noticeable that due to the nano silica particles the mechanical strength was also increased and it also optimize the concrete for the proper distribution .Nano silica particles improves the life cycle of the structures of concrete.

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