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Using Microsilica and Nano copper oxide to improve mechanical properties and permeability in concrete channels and pressurized water and sewage pipes

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ABSTRACT

Since corrosion of longitudinal and transverse rebars in concrete sewage pipes is a major. In this research, experiments were conducted by changing different percentages of nano copper oxide and microsilica in the original concrete plan. Therefore, in 14 different plans, compressive strength, and permeability were performed on 15 x 15 cm cubic samples at ages 7, 28, and 42, and then compressive strength tests were performed using the BS method. In the case of nano copper oxide up to 3%, we see an improvement in strength, but after that the strength results of the samples decrease. It was also found that the strength of samples containing 7% microsilica at the age of 42 days with a grade of 300 kg/m^3 has better strength than other grades tested, and increasing cement and increasing the age of concrete significantly improves the permeability of concrete. According to the results, increasing the cement content of concrete caused an acceptable level of permeability, so 7% microsilica with a cement content of 350 kg/cm^3 had the best performance. According to the results of nano copper oxide and microsilica, microsilica was able to perform better than nano copper oxide in improving the permeability characteristics at a cement content of 350 kg/cm^3, at an amount of 7% of the weight of cement at the age of 42 days. Nano copper oxide and microsilica can reduce cement consumption in concrete while maintaining the required strength and

1. Introduction

According to research, corrosion in sewage facilities costs more than $1 billion per year, which translates to $50 per person per year [1]. The first study of corrosion of concrete sewer pipes was conducted in Los Angeles in 1895, and studies showed that sulfuric acid was the main cause of corrosion [2]. Today, the destruction of concrete sewer pipes by biological attack by sulfuric acid is among the most common mechanisms of destruction of such structures and is one of the most important concerns in cities around the world [3, 4]. For example, in Los Angeles, 10% of the sewage pipelines are affected by microbial corrosion, and the cost of renovating these lines is estimated at $400 million [3]. Sulfur is an essential element for microorganisms 1 and is included in the composition of amino acids, cofactors and ferroxins and enzymes. The basis of the phenomenon of microbial corrosion by hydrogen sulfide gas in sewage collection networks is based on the presence of sulfur. This sulfur is either in the form of organic sulfur, which is formed from protein materials, or in the form of inorganic sulfur, which is caused by sulfates in flowing waters. Another form of sulfur present in the sewage network is in the form of sulfates caused by cleaning and detergents [4].

Studies show that the most important and major type of biological attack on concrete is the attack of sulfur-acting bacteria. These bacteria include two groups: the first group is sulfate-reducing bacteria, the product of the reduction process by these bacteria is hydrogen sulfide, and the second group is sulfide-oxidizing bacteria, the metabolic product of these bacteria is sulfuric acid. It should be noted that the pH range for the growth of sulfate-reducing bacteria is 4.2-10.4, and the optimal pH for their growth is 7.2-7.5 [5].

Concrete is an indispensable part of highways, ports, sewage treatment facilities, water supply projects and other types of structures. That is why concrete has

become the most suitable material for most of the world's infrastructure. The use of concrete as a strong and inexpensive material in the construction of concrete structures in sewage facilities such as canals and water and sewage pipes has been widely used. Along with the development of concrete, strengthening the strength of concrete structures with the help of steel bars and protecting it against chemical corrosive agents has been considered. High temperature and humidity conditions in water structures provide a suitable environment for the biochemical activities of various bacteria. Therefore, increasing the durability of concrete channels against high temperature and humidity conditions and biochemical activities of various bacteria in water with the help of appropriate coating has been one of the most important issues in water transmission facilities and lines in recent years.
The main phases are the ability of natural repair, swelling and hydration of cement paste, which continue with the deposition of calcium carbonate (CaCO3) and ultimately block the flow paths and deposition of water impurities or the movement of some concrete particles separated during the cracking process.
Researchers' efforts to increase the strength and useful life of concrete have led to the concept of self-healing concrete making its way into the construction industry. There are two main areas of research for this type of concrete; One is the natural hydrate-based way to seal cracks over time and the other is the artificial way to seal cracks that require human intervention. The main purpose of this work is to increase the durability of concrete, which will have a great positive impact on the environment and the economy.



Figure (1) An example of concrete corrosion

Since corrosion of longitudinal and transverse rebars in concrete channels and pressure pipes for water transmission and sewage pipes is a major problem and one of the main causes of their destruction, the ultimate goal of the project is to investigate the stability and permeability to prevent this type of complications. By increasing stability, the destructive corrosion process can be prevented and, consequently, the useful life of the structure can be significantly increased.

The concrete used in the various parts of the reinforced concrete pipes is of the C25 class with a characteristic strength of fc = 25Ma and above. The use of concrete with lower strength is not permitted. The concrete used must have the necessary efficiency to fit into the corners and edges of the mold and surround the reinforcement and create compaction, especially around the expansion joints. In order to prevent the creation of a suitable place for the reproduction of algae and parasites, the surface of the concrete in contact with water must be as smooth and as close to a screed as possible. Due to the high heat of dehydration of cement-rich concrete, which increases the expansion of the concrete during setting and creates cracks during cooling, the maximum amount of cement in the reinforced concrete of concrete channels is limited to 480 kg/m3. The maximum water-cement ratio of the concrete used in channels is 0.45. For corrosive environmental conditions such as coastal areas, this value is limited to 0.35.

Soluble sulfates such as magnesium, calcium, etc. are naturally present in soil and water everywhere. Usually, soil or water containing such sulfates is called alkaline. Sulfates attack various combinations of hydrated cement:
1- They attack the aluminate of cement, which increases the volume and destroys the concrete. The conversion of calcium hydroxide to a water-soluble salt causes the surface of the concrete to decompose and ultimately causes the concrete to become porous.
2- In general, the cement environment is an alkaline environment, and for this reason, materials made with cement, such as concrete, are highly corrosive in an acidic environment.

- Concrete permeability

In any concrete structure, it is necessary to maintain the function for which it is intended, that is, its resistance and performance, over a certain life. It follows that concrete must be able to withstand the decomposition processes that it is expected to encounter. Water is the most important substance on earth. Among the most important properties of water is its remarkable capacity to penetrate small pores or cracks and dissolve large amounts of material in itself. The presence of water in cement causes hydration and causes concrete to harden. However, the presence of water after concrete hardens and after the hydration reaction has decreased or stopped may cause concrete to deteriorate.
Concrete permeability or sealing is the resistance of concrete to any external factors that attack the surface of the concrete to penetrate it, such as water, air, chemicals, etc. Sealed concrete must be free of surface corrosion of capillary channels inside to a low or zero extent and have negligible pores that minimize the penetration of any external factors into the concrete and

so-called sealed concrete. Concrete permeability depends on several factors, including the type of aggregate and its granulation, cement, water-cement ratio, curing time, the presence of cracks and storage conditions in the environment, etc. Given the sensitivity of concrete permeability, especially in water supply channels and water and sewage pipes, much research has been conducted in this regard, especially in the field of using additives, some of which are mentioned in this section. It is important to note that the purpose of this thesis is to investigate the permeability of concrete used in the construction of concrete channels. Water is as an agent with chloride ions, sulfate ions, acid ions, etc. can activate or accelerate many harmful reactions that cause destruction or significant reduction in the durability and life of concrete. According to many researchers, the water permeability is the most important factor in determining the durability and strength of a concrete. Therefore, by reducing the porosity of concrete, this permeability should be reduced to increase the durability and life of concrete and concrete structures, which requires controlling the composition of concrete, the ratio of water to cement, and the method of mixing.

In their research, they have addressed the requirements for making durable concrete in marine environments and have provided the necessary recommendations in the field of constituent materials, implementation methods, and dealing with subsequent cracking. In addition, since in very severe environmental conditions, in addition to the measures taken to reduce the permeability of concrete, there is a need for greater protection of the reinforcement against corrosion, they have also discussed methods for protecting the reinforcement, including cathodic protection, the use of chemical inhibitors, the use of organic and inorganic coatings, and the use of corrosion-resistant alloys for the reinforcement [6].

Research has been conducted on the effect of various coarse-grained materials, which shows that the type, size, and saturated or unsaturated conditions of the stone materials have a significant effect on the permeability of concrete. Regardless of the type of stone materials, concrete mixtures produced from coarser-grained materials have higher water absorption and permeability than concrete mixtures using smaller stone materials. Also, concrete mixtures using stone materials saturated before mixing have lower permeability than mixtures containing relatively dry materials [7].
Concrete permeability is not just a simple function of its porosity and in addition it depends on the size, distribution, shape, tortuosity and continuity of pores. Research has shown that the presence of stress in reinforced concrete structures causes cracks in concrete, which causes harmful substances to penetrate into the concrete, so that under the applied stresses, the permeability of concrete first decreases until a threshold is reached, and if the stress exceeds this limit, then this downward trend becomes an upward trend. The depth of water penetration can be used as a qualitative evaluation of concrete. So that a depth of less than 50 mm puts concrete in the category of impervious under destructive conditions [8].
Concrete is a very heterogeneous material produced by a combination of cement powder and aggregate of different sizes and water, with natural physical, mechanical and chemical properties [9]. The reaction between cement and water produces calcium hydrate silicate, which causes the strength of concrete and other mechanical properties of concrete, as well as some by-products such as calcium hydroxide CH, gel pores, and so on. Despite hydrated cement and by-products everywhere in concrete, it is difficult to control the reaction in concrete after molding and hardening, and this is a major problem in the concrete industry. The important issue, in the fresh and hard state of concrete, is the cracks and the resulting problems. Cracks in concrete structures and premature erosion occur due to alkaline silica reactions, which is a chemical reaction. Apart from the above, the permeability of gases through pores and micro-cracks in concrete has led to the problem of corrosion, which in concrete repairs causes further deterioration. In addition to the expansion and contraction of concrete, which causes cracks in concrete at older ages, sulfate attack causes the concrete to decompose and leach chemicals, both of which are due to excess calcium hydroxide CH [10]. The by-product during cement hydration is according to the following equation:

$$2C3S+6H \rightarrow C3S2H3 + 3CH \quad (1)$$
$$2C2S + 4H \rightarrow C3S2H3 + CH \quad (2)$$

C=Cement, S=SiO_2 and H=H_2O (3)

According to the above equation, CSH is the resistance phase, while the CH by-product has no cementitious properties and is easily washed away by chemical attack. By adding suitable siliceous or aluminum cementitious materials to the cement which react with CH. Production of excess CSH and replacement with CH improves the pore structure, reduces the permeability of gases and water in concrete. Reducing the amount of CH during hydration of cement reduces the chance of sulfate attack and leaching with chemicals. Will cope to some extent. To solve the above problem, various methods such as pozzolanic reaction of cement using cementitious materials for chemical reaction with lateral CH to obtain the amount of excess CSH or the use of cementitious materials such as abrasive fly ash, pozzolanic granules to fill pores To reduce CH and gain extra CSH has been investigated. Addition of cementitious materials in concrete not only

improves the mechanical properties of concrete, but also affects its efficiency, changing the formability time and its durability [10].

The white masses in the electron microscope images are the same as the calcium hydroxide crystals. According to Figure (2), it can be said that the addition of silica fume and nanosilica to the combination of cement and water in the cement paste can reduce The amount and size of calcium hydroxide crystals in the transition area between the dough and the aggregate and thus strengthen this area [10].

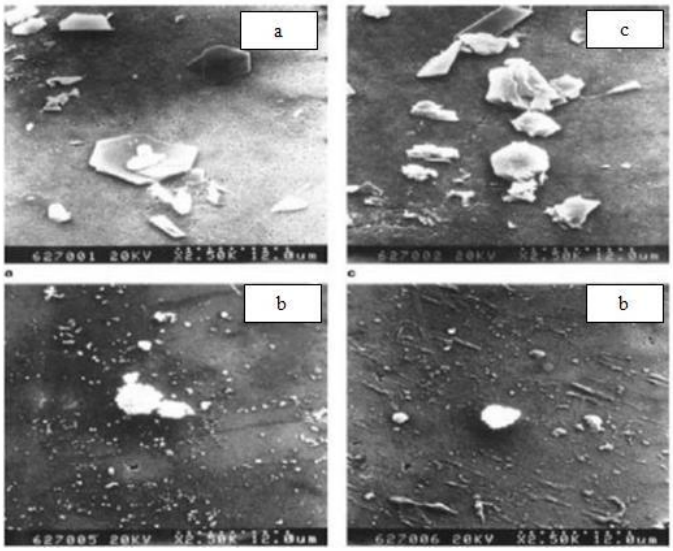


Figure (2) SEM images of calcium hydroxide crystals in 28-day aggregate and cement paste area a) without the use of nanosilica b) using 3% nanosilica c) using 3% microsilica [10].

Copper oxide nanoparticles (CuO NPs) can improve concrete's permeability properties by reducing porosity and enhancing the microstructure. The addition of CuO NPs to concrete can lead to a denser microstructure, minimizing interconnected pores that facilitate the passage of water and harmful substances. This results in increased resistance to water and chloride ion penetration, improving the long-term durability of concrete structures.

Here's a more detailed explanation:

1. Reduction of Porosity:
   - CuO NPs, due to their small size and high surface area, can act as a filler material, filling voids and pores within the concrete matrix.
   - This filling effect leads to a reduction in the overall porosity of the concrete, making it less permeable to liquids and gases.
2. Improved Microstructure:
   - CuO NPs can promote the hydration of cement, leading to a denser and more refined microstructure.
   - The nanoparticles can act as nucleation sites for hydration products, such as calcium silicate hydrate (C-S-H), resulting in a more compact and less porous structure.
3. Enhanced Durability:
   - By reducing permeability, CuO NPs enhance the concrete's resistance to the ingress of water, chloride ions, and other harmful substances.
   - This improved resistance helps prevent issues like corrosion of steel reinforcement, freeze-thaw damage, and other forms of deterioration, ultimately increasing the lifespan of concrete structures.
4. Optimal Dosage:
   - The effectiveness of CuO NPs in enhancing concrete properties, including permeability, is dependent on the optimal dosage.
   - While some studies show significant improvements with low dosages (e.g., 1-2%), excessive amounts of CuO NPs can sometimes lead to a decrease in strength and an increase in porosity.
5. Combined Effects:
   - Research has also explored the combined effects of CuO NPs with other nanomaterials, such as nano-silica (nSiO2), to further optimize concrete properties.
   - The synergistic effect of different nanomaterials can lead to enhanced strength, durability, and resistance to various forms of degradation.

b) In summary, the addition of CuO nanoparticles in concrete can be a promising strategy for improving permeability and enhancing the overall durability of concrete structures. However, careful consideration of the optimal dosage and potential interactions with other materials is crucial for achieving desired results. CuO nanoparticle as a partial replacement of cement up to 3.0 wt. (%) could accelerate C-S-H gel formation as a result of increased crystalline $Ca(OH)_2$ amount at the early age of hydration and hence increase strength and improve the resistance to water permeability of concrete specimens [6].

Nazari et al. (2011) investigated strength assessments and percentage of water absorption of high performance self compacting concrete containing different amounts of ground granulated blast furnace slag and CuO nanoparticles as binder. Portland cement was replaced by different amounts of ground granulated blast furnace slag and the properties of concrete specimens were investigated. Although it negatively impacts the physical and mechanical properties of concrete at early age of curing, ground granulated blast furnace slag was found to improve the physical and mechanical properties of concrete up to 45

wt.(%) at later ages. CuO nanoparticles with the average particle size of 15 nm were partially added to concrete with the optimum content of ground granulated blast furnace slag and physical and mechanical properties of the specimens were measured. CuO nanoparticle as a partial replacement of cement up to 3.0 wt.(%) could accelerate C-S-H gel formation as a result of increased crystalline $Ca(OH)_2$ amount at the early age of hydration and hence increase strength and improve the resistance to water permeability of concrete specimens. The increased the CuO nanoparticles' content more than 3.0 wt.(%), causes the reduced the split tensile strength because of the decreased crystalline $Ca(OH)_2$ content required for C-S-H gel formation. Several empirical relationships have been presented to predict flexural and split tensile strength of the specimens by means of the corresponding compressive strength at a certain age of curing. More rapid appearance of the peaks related to hydrated products in X-ray diffraction results, all indicate that CuO nanoparticles could improve mechanical and physical properties of the concrete specimens[11].

Naari and Riahi (2011) measured the compressive strength, thermal properties and microstructure of self-compacting concrete with different amounts of CuO nanoparticles have been investigated. CuO nanoparticles with an average particle size of 15 nm were added to self-compacting concrete and various properties of the specimens. The results indicate that CuO nanoparticles are able to improve the compressive strength of self-compacting concrete and reverse the negative effects of superplasticizer on compressive strength of the specimens. CuO nanoparticles as a partial replacement of cement up to 4 wt.% could accelerate C–S–H gel formation as a result of the increased crystalline $Ca(OH)_2$ amount at the early ages of hydration. Increasing CuO nanoparticle content to more than 4 wt.%, causes reduced compressive strength because of unsuitable dispersion of nanoparticles in the concrete matrix. Accelerated peak appearance in conduction calorimetry tests, more weight loss in thermogravimetric analysis and more rapid appearance of peaks related to hydrated products in X-ray diffraction results, all indicate that CuO nanoparticles up to 4 wt.% could improve the mechanical and physical properties of the specimens. Finally, CuO nanoparticles improved the pore structure of concrete and caused shifting of the distributed pores from harmless to low harm [12].

Hashemi et al. (2024) investigated effect of magnesium oxide and copper oxide nanoparticles on UHPC properties under different curing conditions.

In this study was evaluated the impact of different content of slag 2.5, 5 and 10% and as well nano-particles of 0.5, 1 and 2% as replacement by weight of cement materials (without addition) and two different curing conditions—standard and accelerated—on the compressive strength, ultrasonic pulse velocity (UPV), electrical resistivity, and drying shrinkage of UHPC. The UHPC used in the study contained varying amounts of slag, nano magnesium oxide (MgO**)**, nano copper oxide (CuO), and a combination of slag and nanoparticles for different ages [13]. The results indicated that the optimal amount of slag did not have high effect on the physical and mechanical properties of UHPC. After 90 days, for each of the specimens containing 1% nano-MgO and Nano-CuO, approximately 37% increase in compressive strength was obtained compared to the 7-day specimen[13].

Yu et al.(2014) [14] investigated Effect of nano-silica on the hydration and microstructure development of Ultra-High Performance Concrete (UHPC) with a low binder amount.

They investigated the influence of incorporating nano-silica (1–5%) on the mechanical properties and the evolution of the microstructure of UHPC. The findings highlighted a uniform composition with reduced binder content upon the addition of nano-silica. Moreover, an optimal quantity of nano-silica can result in minimized porosity. As such, the optimal nano-silica content for superior mechanical properties is reported to be 4%.

Wu et al. (2018) [15] investigated Effect of SCM and nano-particles on static and dynamic mechanical properties of UHPC. They explored the effects of supplementary cementitious materials (SCMs - including slag (SL), fly ash (FA), and their combinations) and nanoparticles (nano-calcium carbonate $CaCO_3$ and nano-silica SiO_2) on the mechanical properties of a UHPC matrix containing 20% silica fume and 2% steel fibers. The findings revealed that incorporating 20% silica fume with any type of SCMs or nanoparticles results in enhanced fiber-matrix bonding and improved mechanical characteristics of the UHPC.

Wu et al. (2021) [16] investigated mechanisms underlying the strength enhancement of UHPC modified with nano-SiO2 and nano-CaCO3.

They reported that the fiber-matrix bond strength and mechanical resilience of UHPC improved with the inclusion of both CaCO3 and SiO2 nano-particles up to limited concentrations of 1% and 3.2%, respectively.

Chunping (2018) [17] studied effect of nano-TiO_2 on the durability of ultra-high performance concrete with and without a flexural load.

He tested the mechanical strength and durability of UHPC containing various concentrations of nano-TiO2 (ranging from 0.5% to 5%). Their results revealed that the inclusion of nano-TiO2 improved strength, with 1% content delivering optimal mechanical properties. However, exceeding this concentration had adverse effects. Additionally, properties like drying shrinkage, resistance to chloride penetration, freeze-thaw durability, and pore microstructure improved in the

presence of nano-TiO2 particles compared to the control specimen[17].

Dehbozori and Bazargan Lari (2019) Studied the effect of using paints containing copper oxide and zinc oxide (zinc rich) on the microbial corrosion behavior of sewage pipes[18].

The aim of this study was to investigate the effect of using paints containing zinc oxide and copper oxide on the corrosion behavior of concrete sewage pipes in Marvdasht city. These paints were applied to the internal surfaces of the pipes by two methods: spraying and brushing. Nine concrete pipes used in the sewage network, 60 cm long and 20 cm in diameter, were used for the study. Four of the pipes were coated with paint containing copper oxide and four others with paint containing zinc oxide, and one pipe was considered as a control pipe without paint. After applying the paint, the pipes were placed in the sewage flow path of Marvdasht city for 217 days. Then, aerobic and anaerobic bacteria were counted in the sewage at daily, weekly, and monthly intervals to determine the amount of aerobic and anaerobic bacteria in the sewage. The results showed that sulfide production by sulfate-reducing bacteria (SRB) in coated pipes was reduced by up to 100% compared to uncoated pipes, and these coatings were able to effectively reduce the number of bacteria in wastewater. Visual examinations also showed that the sludge formed on pipes containing zinc oxide paint was much thinner than on uncoated pipes, and in pipes where copper oxide paint was used, this sludge layer was even thinner than the layer formed on zinc oxide paint coatings. Atomic absorption experiments were performed on the inlet and outlet wastewater of the wastewater pond to examine the amount of copper and zinc ions introduced from the paint into the wastewater, and the results showed that the amounts of heavy metals entering the effluent was less than the permitted and standard levels, and as a result, they did not cause wastewater toxicity.

Mostafa et al. (2020) investigated influence of Nanoparticles from Waste Materials on Mechanical Properties, Durability and Microstructure of UHPC. They investigated the impact of various nanoparticles made from waste materials (Nano Metakaolin NMK, Nano Waste Glass NWG, and Nano Rice Husk Ash NRH) and nano-silica (for performance comparison with waste-derived nanoparticles). Their findings highlighted the highest compressive strength at 91 days was achieved with 3% Nano Rice Husk Ash content. Furthermore, the presence of nanoparticles reduced the water absorption of UHPC, with this effect being more pronounced for nano-silica content [19].

Faried et al. (2021) [20] evaluated mechanical and durability properties of ultra-high performance concrete incorporated with various nano waste materials under different curing conditions. They evaluated the mechanical properties, durability (sulfate attack), and microstructure of UHPC blended with nano waste materials (NMK, NRH, NWG, and NS) prepared chemically at different contents (1–3%) under various curing conditions (standard curing, internal curing, and air curing). Several UHPC mixes with nanomaterial dosages (1%, 2% and 3%) were investigated. Compressive strength, ultrasonic pulse velocity, sulphate attack and microstructure were analyzed. Results indicated the similarity between the performance of SC and IC in NS, NWG and NMK. Moreover, the addition of PEG exerted a negative effect on NRHA. Compressive strength increased by 17%, 24%, 14% and 13% under IC in NWG, NRH, NMK and NS, respectively. By contrast, sorptivity decreased by 84%, 60%, 48% and 60% in NS, NMK, NWG and NRHA under IC.

Norhasri et al. [21] studied Inclusion of nano metaclayed as additive in ultra high performance concrete (UHPC). They investigated the impact of nano met-clay at concentrations of (1–9%) on the physical properties, performance, strength, and microstructure morphology of UHPC up to the age of 365 days. The findings indicated that in the early ages, the compressive strength showed no significant alterations with increased nano content, but as the UHPC aged, it exhibited an enhanced compressive strength compared to the standard UHPC.

Faried et al. [22] investigated the impact of 7 different types of nano NRHA with varying contents (1–5%), fabricated at diverse temperatures (300°C - 900°C) with a consistent burning time of 3 hours, and multiple burning durations (3–9 hours) at different temperatures (ranging from 300°C to 900°C). Their results highlighted that the inclusion of NRHA had boosted both the compressive strength and impermeability of the UHPC.

Huang et al. (2022) [23] studied the influence of carbon nanotube (CNT) and graphite nanoplatelet (GNP) used at 0 to 0.3%, by mass of binder, on composition, structure, and nano-mechanical characteristics of C-S-H of ultra-high performance concrete (UHPC). Hydration kinetics, pore structure, and mechanical properties of UHPC were also investigated. The non-proprietary UHPC was proportioned with 17% lightweight sand for internal curing. Test results indicated that the addition of 0.3% CNT or GNP led to approximately 20 MPa increase in compressive strengths of non-fibrous UHPC mortar and fibrous UHPC (2% steel fibers), compared to those prepared without any nanomaterial.

Camiletti et al. 2013 [24] assessed the influence of nano $CaCO_3$ (ranging from 2.5% to 15%) on the early properties of UHPC. Their outcomes inferred that nano $CaCO_3$ has a notable potential to expedite the setting and hardening process of UHPC.

In this study, the effects of nano-calcium carbonate (CaCO3) addition on the early-age properties of ultra-high-performance concrete cured at simulated cold and normal field conditions were investigated. The nano-CaCO3 was added at rates of 0, 2·5, 5, 10 and 15% as a partial volume replacement for cement. Similar mixtures incorporating chloride- and non-chloride-based accelerating admixtures were also tested for comparison. Results indicate the high potential of nano-CaCO3 to accelerate the setting and hardening process of ultra-high-performance concrete through providing nucleation sites, increasing contact points and increasing the effective water-to-cement ratio. Although nano-CaCO3 exhibited a comparable or slightly lower accelerating effect to that of the chloride- and non-chloride-based accelerating admixtures, it brings a number of benefits to concrete production. These include the development of low-maintenance structures through eliminating the risk of steel corrosion induced by chloride-based accelerating admixtures, as well as a more environmentally friendly concrete through reducing the cement factor of ultra-high-performance concrete.

Ghafari et al. [25] investigated the experimental study herein to evaluate the influence of nanosilica (nS) addition on properties of ultra high performance concrete (UHPC). Thermo gravimetric analysis results indicated that nS consumes much more $Ca(OH)_2$ as compared to silica fume, specifically at the early ages. Mercury intrusion porosimetry measurements proved that the addition of nS particles leads to reduction of capillary pores. Scanning electron microscope observation revealed that the inclusion of nS can also efficiently improve the interfacial transition zone between the aggregates and the binding paste. The addition of nS also resulted in an enhancement in compressive strength as well as in transport properties of UHPC. The optimum amount of cement replacement by nS in cement paste to achieve the best performance was 3 wt.%. However, the improper dispersion of nS was found as a deterrent factor to introduce higher percentage of nS into the cement paste.

New aspect and innovation in research:

Investigating the effect of the role of using CuO nanoparticles additive and silica fume and superplasticizer in concrete is an innovative aspect of this research.

2. Methods

The cement used in this research, according to the concrete design used in the construction of the concrete pipe, was Portland cement type 5 Tehran in according to (ASTM)-C150 [27] was used. Silica fume in according to ASTM-C1240 [28] was used. Chemical composition of cement is presented in Tab.1. The microsilica used in this thesis was purchased from Iran Concrete Clinic Company. Polycarboxylate based superplasticizer is according to with the standard specifications of ASTM-C494 [29].

The normal superplasticizer used is Sure Plast WR 300, which complies with the standards TYPE F–C494 – TYPE A&F and ISIRI2930 Table 304 and EN 934-2 Table 3.1, 3.2, with a mixing ratio of 0.5% by weight of cement. This superplasticizer is a water-reducing additive produced based on naphthalene.

The copper nanooxide with an average size of 50 to 80 mm and spherical shape used in this research was purchased from Pishgaman Company.

With the help of laboratory method, the effect of using silica fume, copper nanooxide additive instead of a percentage of cement in increasing or decreasing the compressive strength and the permeability property of concrete will be investigated. 15 mixing schemes were proposed to compare the effect of the use of silica fume and copper nanooxide additive on the compressive strength and permeability properties of concrete based on previous studies that were reviewed and are presented in Tab.2. To evaluate the compressive strength and permeability, the compressive strength and permeability of the samples were measured according to ASTM standards. Tab. 2 shows the mix proportion designs of this study.

Tab. 1: Chemical composition of cement

sample	Sio2	Al2O3	Fe2O3	Cao	Mgo	So3	K2o	C4AF
Type ۵	22,24	4,13	4,36	63,71	3,49	2,4	0,32	13,3
sample	Free cao	CI	L.O.I	I.R	C3S	C2S	C3A	
Type ۵	0.82	-	0.93	0.50	49	26.8	3.6	

Tab. *2*: Mix designs

rows	Sample name	Characteristic of samples
۱	A1	Concrete sample with 360 kg of type 5 cement per cubic meter without additives
۲	AS	Concrete sample with 360 kg of Type 5 cement per cubic meter with Sure Plast WR 300 superplasticizer admixture at 0.5% by weight of cement
۳	AS1	Concrete sample with 360 kg of type 5 cement per cubic meter with Sure Plast WR 300 superplasticizer additives and 1% by weight of nano copper oxide cement
۴	AS2	Concrete sample with 360 kg of type 5 cement per cubic meter with Sure Plast WR 300 superplasticizer additives and 3% by weight of nano copper oxide cement
۵	AS3	Concrete sample with 360 kg of type 5 cement per cubic meter with Sure Plast WR 300 superplasticizer additives and 5% by weight of nano copper oxide cement
۶	B1	Concrete sample with 300 kg of type 5 cement per cubic meter without additives
۷	BS	Concrete sample with 300 kg of Type 5 cement per cubic meter with Sure Plast WR 300 superplasticizer admixture at 0.5% by weight of cement
۸	BS1	Concrete sample with 300 kg of type 5 cement per cubic meter with Sure Plast WR 300 superplasticizer additives and 1% by weight of nano copper oxide cement
۹	BS2	Concrete sample with 300 kg of type 5 cement per cubic meter with Sure Plast WR 300 superplasticizer additives and 3% by weight of nano copper oxide cement
۱۰	BS3	Concrete sample with 300 kg of type 5 cement per cubic meter with Sure Plast WR 300 superplasticizer additives and 5% by weight of nano copper oxide cement
۱۱	C1	Concrete sample with 300 kg of type 5 cement per cubic meter with Sure Plast WR 300 superplasticizer additives with 0.5% by weight of cement and 4% by weight of microsilica cement

۱۲	C2	Concrete sample with 300 kg of type 5 cement per cubic meter with Sure Plast WR 300 superplasticizer admixtures with 7% by weight of microsilica cement
۱۳	D1	Concrete sample with 350 kg of type 5 cement per cubic meter with 0.5% Sure Plast WR 300 superplasticizer and 4% by weight of microsilica cement
۱۴	D2	Concrete sample with 350 kg of Type 5 cement per cubic meter with 0.5% Sure Plast WR 300 superplasticizer and 7% by weight of microsilica cement
۱۵	E1	Concrete sample with 400 kg of type 2 cement per cubic meter with 5.5% by weight of propylene fiber cement

Tab 3. Results of the effect of nano copper oxide on the Compressive Strength of concrete samples

copper nanooxide						
Amount of cement kg/cm^3	Age of concrete (day)	**Compressive Strength kg/cm^2**				
		A1	**AS**	**AS1**	**AS2**	**AS3**
		0	0+0.5	1	3	5
360	7	172	206	243	269	204
	28	280	340	317	393	271
	42	304	381	375	422	307
		B1	**BS**	**BS1**	**BS2**	**BS3**
300	7	113	141	186	223	130
	28	201	232	251	281	228
	42	253	279	310	344	248

Figures (3) and (4) show the effect of nano copper oxide on the strength of concrete samples with a grade of 360 and 300 kg/cm^3. In the case of nano copper oxide up to 3%, we see an improvement in strength, but after that, the strength results of the samples decrease. As a result, the best mixing design is 3% nano copper oxide with a cement grade of 360 kg/cm^3.

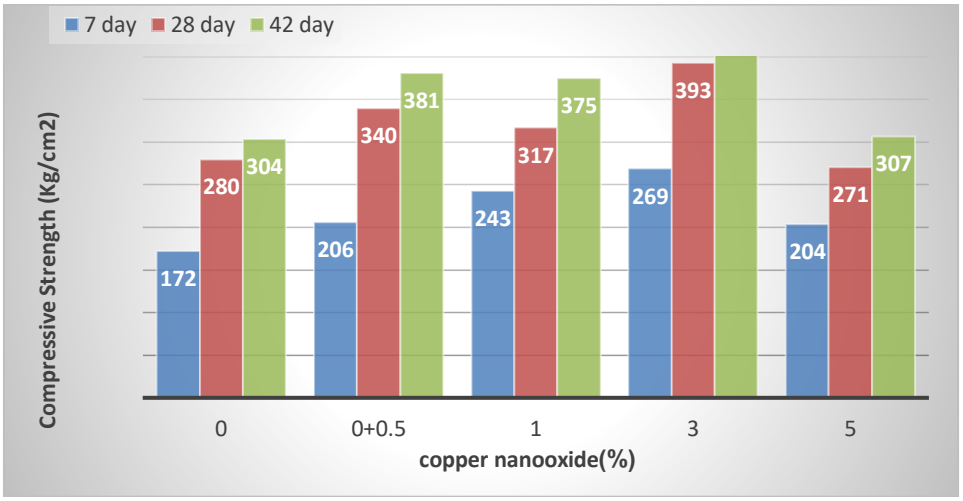


Figure 3 - Effect of nano copper oxide on the strength of concrete samples with grade (360 kg/cm^3)

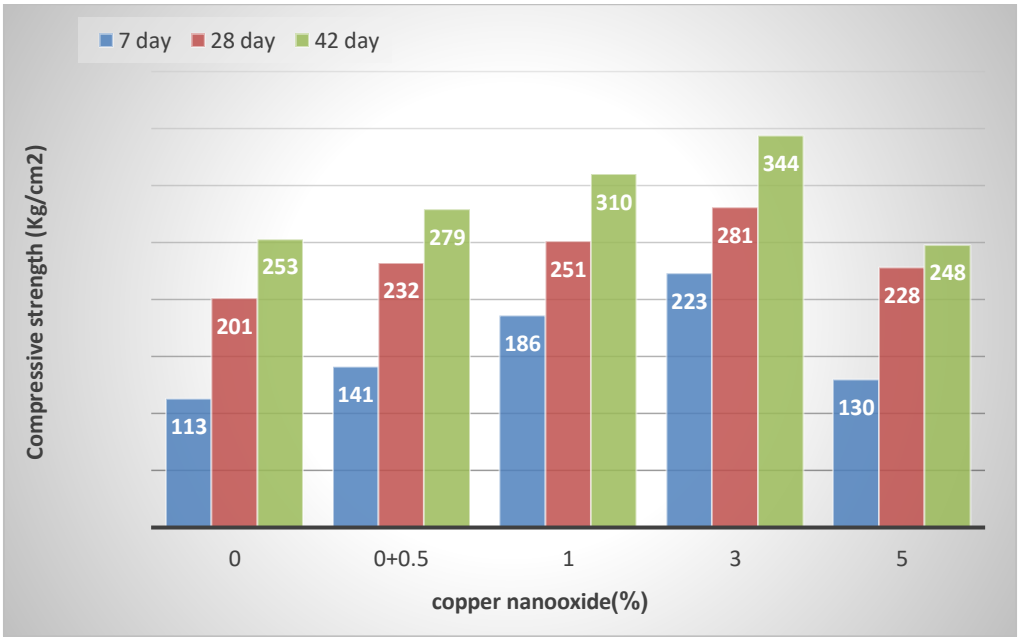


Figure 4 - Effect of nano copper oxide on the strength of concrete samples with grade (300 kg/cm^3)

Tab 4. Results of the effect of nano copper oxide on the permeability of concrete samples

copper nanooxide						
Amount of cement kg/cm^3	Age of concrete (day)	**Permeability (mm)**				
		A1	**AS**	**AS1**	**AS2**	**AS3**
		0	0+0.5	1	3	5
360	7	70	45	58	55	64
	28	69	32	35	33	57
	42	58	29	30	27	36
		B1	**BS**	**BS1**	**BS2**	**BS3**
300	7	92	71	76	62	71
	28	82	62	52	47	62
	42	44	39	30	43	248

Figures (5) and (6) show the results of the effect of nano copper oxide on the permeability of concrete samples with a cement content of 360 and 300 kg/cm^3. However, since structures built over a long period of time must have the necessary resistance to the penetration of external factors, the resistance of the samples at the age of 42 days is used as the criterion for comparison. Therefore, the best performance against permeability has been shown in samples containing 3% nano copper oxide with a cement content of 360 kg/cm^3.

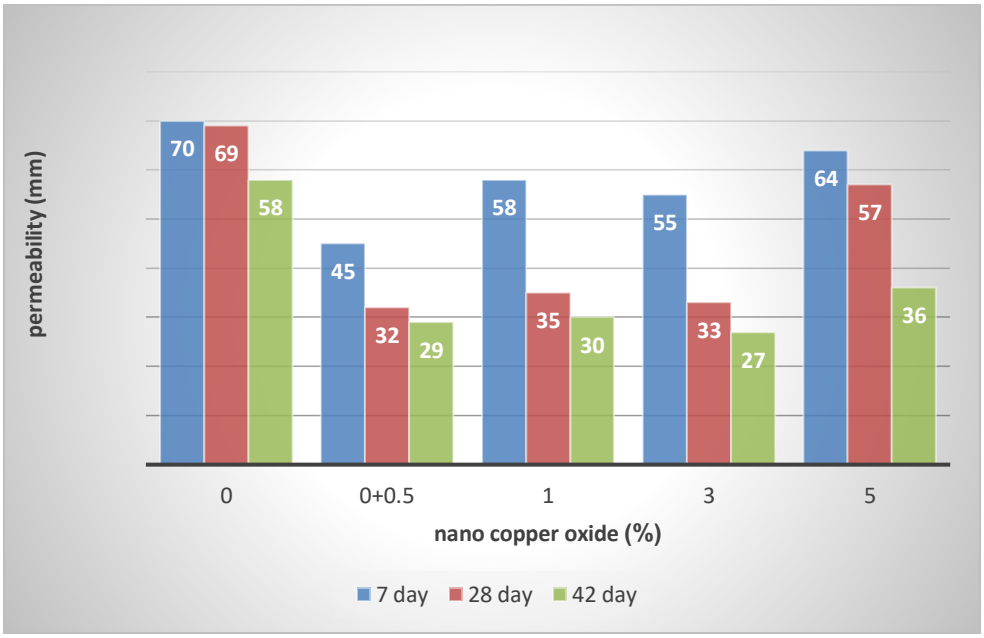


Figure 7- Effect of nano copper oxide on the permeability of concrete samples

with grade (360 Kg/cm^3)

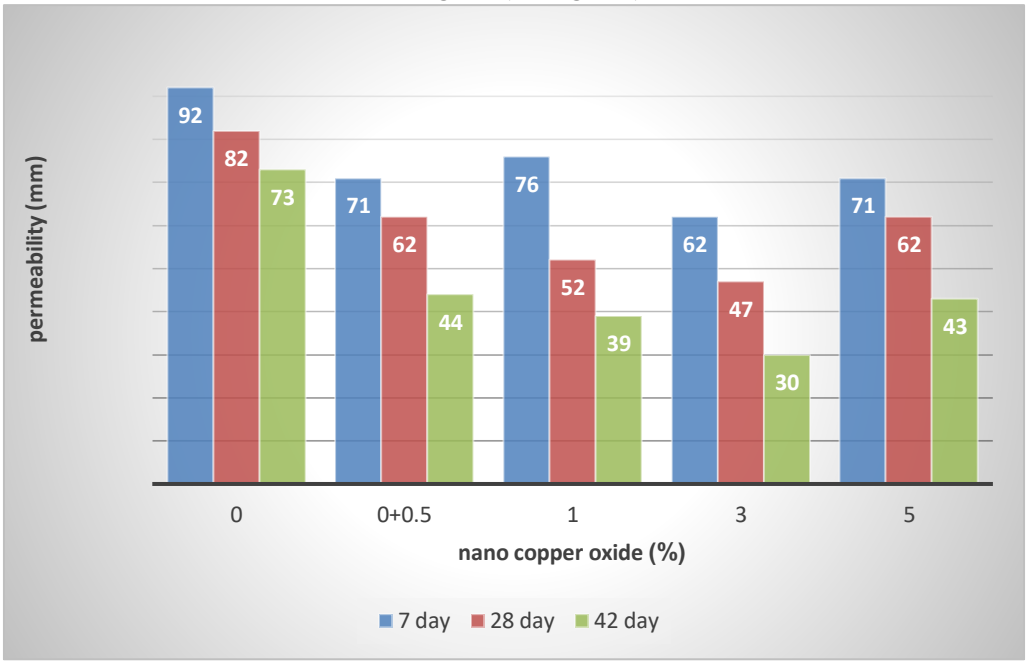


Figure 8 - Effect of nano copper oxide on the permeability of concrete samples with grade (300 Kg/cm^3)

According to Table (5) and Figures (9) and (10), the strength of concrete samples containing microsilica at the age of 42 days with a grade of 300 kg/cm2 with 7% microsilica has the best performance.

Tab 5. Results of the effect of Microsilica on the Compressive Strength of concrete samples

Microsilica			
Amount of cement kg/cm^3	Age of concrete (day)	**Compressive Strength kg/cm^2**	
		C1	**C2**
		4	7
300	7	378	408
	28	420	489
	42	523	610
		D1	**D2**
350	7	387	395
	28	500	505
	42	527	574

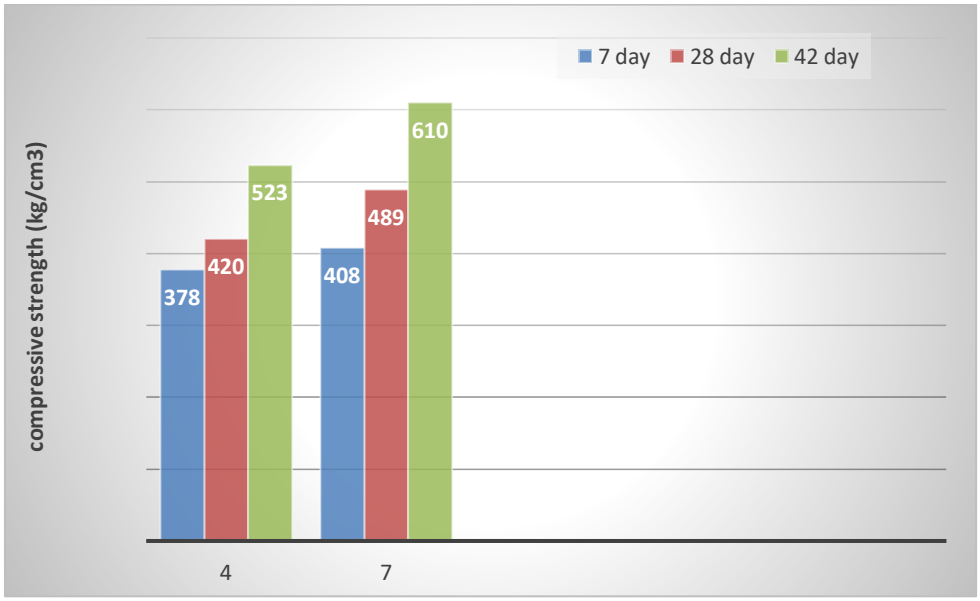


Figure 9- Effect of microsilica on the weight of compressive strength of concrete samples of concrete samples with grade (300 Kg /cm^3)

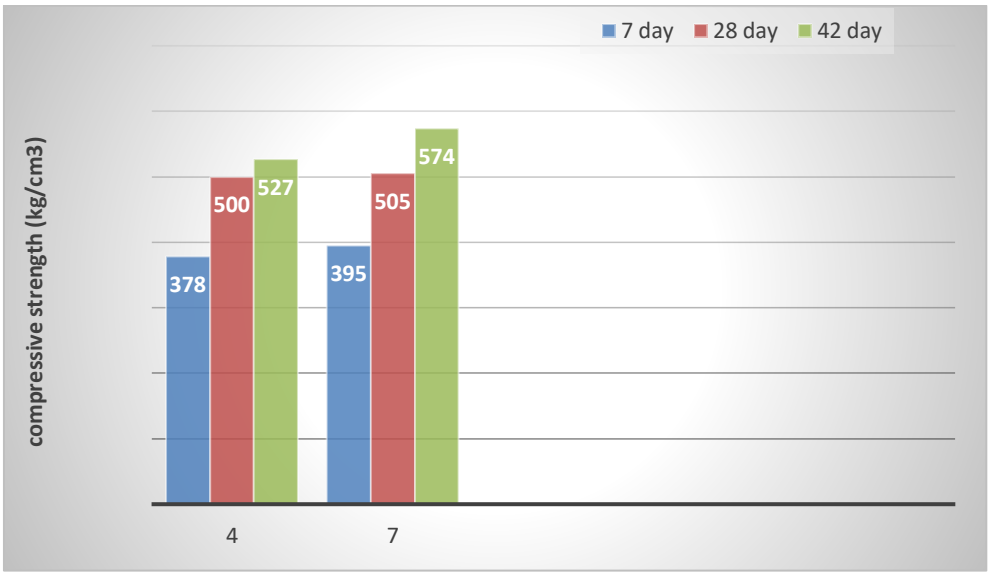


Figure 10- Effect of microsilica on the weight of compressive strength of concrete samples of concrete samples with grade (350 Kg/cm^3).

Table (6) shows the results of the effect of microsilica on the permeability of concrete samples with grades of 300 and 350 kg/ Kg/cm^3. The results show that increasing the amount of cement and increasing the age of concrete significantly improves the permeability of concrete. The results show that at all ages of concrete, the best permeability value was obtained with 7% microsilica and a cement grade of Kg/cm^3.

Table 6 - Results of the effect of microsilica on the permeability of concrete samples

Microsilica			
Amount of cement kg/cm^3	Age of concrete (day)	**Permeability (mm)**	
		C1	**C2**
		4	7
300	7	25	32
	28	20	30
	42	19	16
		D1	**D2**
350	7	25	25
	28	17	19
	42	15	13



Figure 11 - Effect of microsilica on the permeability of concrete samples Concrete samples with grade (300 Kg/cm^3)

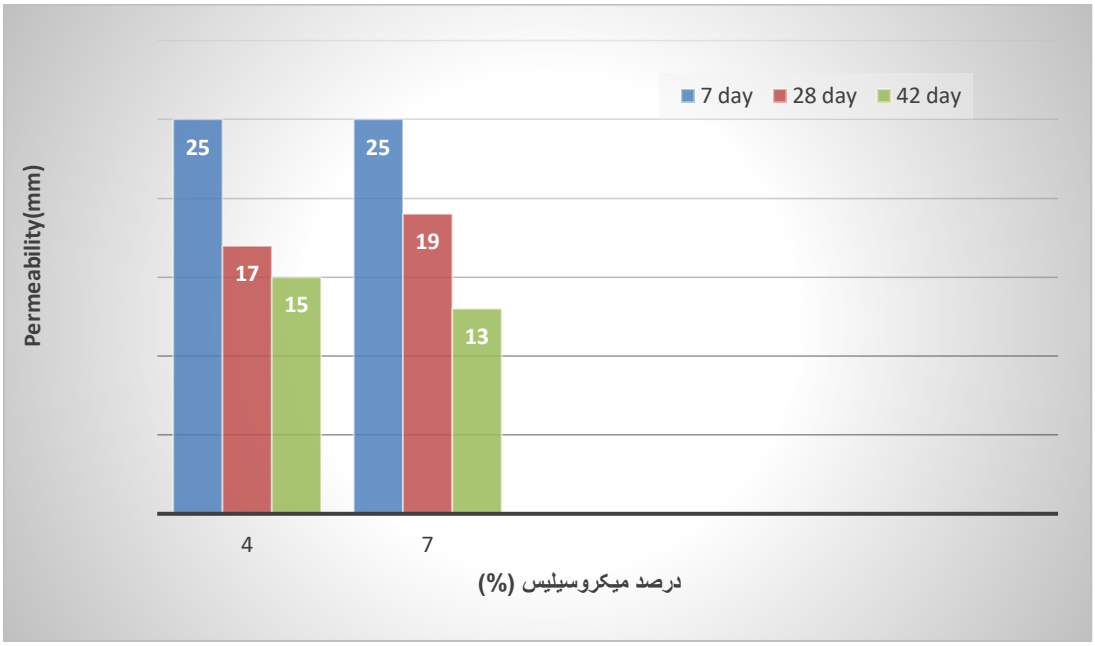


Figure 12 - Effect of microsilica on the permeability of concrete samples Concrete samples with grade (350 Kg/cm^3)

3. CONCLUSIONS

The use of concrete as a strong and cheap material in the construction of concrete structures in sewage facilities such as canals and water and sewage pipes has been widely used. Simultaneously with the development of concrete, strengthening the strength of concrete structures with the help of steel bars and protecting it against chemical corrosive agents has been considered. High temperature and humidity conditions in water structures provide a suitable environment for the biochemical activities of various bacteria. Therefore, increasing the durability of concrete channels against high temperature and humidity conditions and the biochemical activities of various bacteria in water with the help of appropriate coating has been one of the most important issues in water transmission facilities and lines in recent years.

The purpose of this study is to investigate the effect of nano copper oxide and micro silica on improving the permeability properties of concrete used in the construction of concrete sewage pipes. For this purpose, nano copper oxide and micro silica were used. Different samples were subjected to permeability and compressive strength tests by adding different percentages of nano copper oxide to concretes made with two types of cement grades of 361 and 300 kg/cm^3) for micro silica. Based on the results obtained, the following can be deduced:

1- In the case of nano copper oxide up to 3%, we see an improvement in resistance, but after that, the resistance results of the samples decrease. As a result, the best mixing design is 3% nano copper oxide with a grade of 361 kg/cm^3.

2- The resistance of samples containing 7% micro silica at the age of 42 days with a grade of 300 kg/cm^3 has better resistance than other grades tested.

3- The strength of concrete samples containing microsilica performed better than nano copper oxide, and the best strength was obtained at the age of 42 days for concrete samples containing 7% microsilica with a cement content of 300 kg/cm^3.

4- The results show that increasing cement and increasing the age of concrete significantly improve the permeability of concrete. The best performance against permeability was shown in samples

containing3% nano copper oxide with a cement content of 361 kg/cm^3.

5- According to the results, increasing the cement content of concrete caused an acceptable level of permeability, so 7% microsilica with a cement content of 350 kg/cm^3 had the best performance.

6- According to the results of nano copper oxide and microsilica, microsilica was able to perform better than nano copper oxide in improving the permeability characteristics at a cement content of 350 kg/cm^3, at an amount of 7% of the weight of cement at the age of 42 days.

7- Nano copper oxide and microsilica can reduce cement consumption in concrete while maintaining the required strength and permeability characteristics.

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