Indian Journal of Research Foundation, ISSN : 2454 – 6585, Volume 5, Issue 7 (July 2024).
Civil Engineering

MECHANICAL BEHAVIOUR OF NANO SILICA INCORPORATED HIGH STRENGTH CONCRETE

JEYA PRAKASH.I[a], VIDHYA.K[a], MANI SHANKAR.S[a], MOHAN.S[a]

[a]*Department of civil engineering, Mahendra engineering college, Namakkal, India, 637503*

ABSTRACT

The goal of this project is to evaluate how Nano Silica (NS) affects the qualities of high-strength concrete (HSC) in its fresh state, hardened state, and durability. Five different concrete mixtures were created and used for this purpose. NS was added to the cement weight at replacement levels of 0%, 0.5%, 1%, 1.5%, and 2%. M60 grade cement concrete mix design arrived. The high strength concrete made by using cement 53 grade, fine aggregate, coarse aggregate and nano silica and its properties are evaluated in laboratory. The fresh concrete properties testing procedure, harden concrete properties testing procedure and durability properties testing procedure are clear explained in this report. The fresh, harden and durability properties are evaluated. The workability result shows NS addition causes workability of concrete reduced. The 0.5 to 1.5% NS added concrete compressive strength, split tensile strength and flexural strength are improved. The 1.5% NS added concrete specimens lowest weight loss and strength loss are obtained from various hazardous environment. The optimum usage of NS percentage is 1.5%. 1.5% NS cement concrete achieved high strength cement concrete.

Key Words: Cement concrete, Durability, High strength, Mechanical strength, Nano silica, Slump; Strength loss, Weight loss.

1. INTRODUCTION

The practical limit of ready-mixed concrete was expected to be unlikely to surpass a compressive strength of more than 11,000 pounds per square inch (psi) in the early 1970s, according to experts [1]. The creation of high-strength concrete throughout the last 20 years has made it possible for builders to easily achieve and exceed this estimate [2]. Concrete in two structures in Seattle, Washington, has a compressive strength of 131N/mm^2. The compressive strength, or the maximal resistance of a concrete sample to applied pressure, is the main distinction between high-strength and normal-strength concrete. The American Concrete Institute defines high-strength concrete as having a compressive strength of more than

* For Correspondence: *jeyaprakash2677*@gmail.com

40N/mm^2, despite the fact that there is no exact boundary between high-strength and normal-strength concrete [3,4]. The line separating high-strength concrete from ultra-high performance concrete, which has better qualities and a higher compressive strength than high-strength concrete, is also not exactly defined. generating the best use possible of the fundamental materials that go into generating normal-strength concrete is the process of manufacturing high-strength concrete. Manufacturers of high-strength concrete are aware of the variables that influence compressive strength and know how to work with them to get the necessary strength. Producers change the amounts of cement, water, aggregates, and admixtures to maximize the combination of components, in addition to choosing a premium portland cement [5–8]. The link between the aggregate and the cement paste, the aggregate's strength, ideal size, and surface qualities are all taken into account by producers when choosing aggregates for high-strength concrete. Any of these characteristics could restrict high-strength concrete's maximum strength.

Ancient people used mud and lime for the construction work before the advent of concrete [9]. Mostly, they used earlier stage building material to construct their shelter to safeguard from the climatic conditions and animal attack. The mud and lime buildings easily affected by heavy rain fall and climatic changes [10–12]. So this reason researchers to finding a concrete it is used as a construction materials. Concrete is a mixture of fine & coarse aggregates bonded together by cement paste. It is stiffer and hardens when curing in water. Concrete mixture is the base for the civil construction work from small structure to big multi-storied building.

Global rise in the construction of residential, commercial, and other buildings is accompanied by a corresponding increase in concrete strength. The development of high-rise buildings, tall structures, variously shaped buildings, and industrial buildings with enormous loads provided on their floors is the cause behind the concrete's increasing strength. So the above reason take it main scope of the project. So this project create M60 high strength concrete developed by using nano silica [13–20].

2. MATERIALS AND METHODS

The project employed 53-grade Ordinary Portland Cement (OPC). A material test laboratory tests the cement's fineness, consistency, and first and final settings. 10 percent of the cement is fine, 25 percent is consistent, and the cement takes 155 minutes to set initially and 230 minutes to set completely. Oxygen and silicon combine to form silicon dioxide (SiO2), also known as silica. A covalent connection holds the two atoms together. Naturally occurring in quartz, it is one of the sand's constituents. Usually colorless or white, it is insoluble in ethanol and water. One solid, colorless material in crystal form is silicon dioxide. Due to its resistance to acids, silicon dioxide does not react with water. The compound has the chemical formula SiO2. As a member of the acidic glass-forming oxide group, silicon oxide interacts with alkalis and basic oxides at increasing temperatures. It is soluble in hydrofluoric acid and tends to produce a supersonic fusion, which makes glass an excellent dielectric. The density of SiO2 nanoparticles is 2634 kg/m3, and they are transparent. For SiO2, the molar mass is 60.0843 g/mol. It is observed that the melting point is 1986 K and the boiling point is 2503 K. Tridymite, quartz, or cristobalite make up its crystal structure.

Fine aggregates are defined as those that pass through a 4.75 mm sieve but are retained at a 0.075 mm sieve. The River to Zone-II that complies with IS: 383-2016 was used as the fine aggregate in the current study. It was confirmed to be clean, inert, and free of silt, clay, and natural dust. The river sand specific gravity obtained from laboratory value is 2.60 , fineness modulus 2.79, bulk density is 1.74g/cc and water absorption, free moisture content values is 1.4%, 0.71%. Coarse aggregates are often defined as those that pass through a 20mm sieve. As the coarse aggregate in this study, locally accessible crushed rocks that had been put through a 20 mm filter were used. The coarse aggregate was properly cleaned to remove dust and other impurities before being dried under dry shell conditions and tested in accordance with IS 383-2016. A number of tests were performed, and the outcomes are listed. The river sand specific gravity obtained from laboratory value is 2.79 , fineness modulus 5.74, bulk density is 1.67g/cc and water absorption value is 0.25%.

Water plays a significant role in the chemical events that lead to the formation of the hydration product, calcium-silicate-hydrate (C-S-H) gel, in concrete. According to Neville (2000), the amount of water injected should be the bare minimum for chemical reaction of unhydrated cement, since excess water would merely result in unwanted gaps (capillary holes) in the hardened cement paste of concrete. Both mixing and curing of concrete cubes were done with drinking water. The superplasticizer is the most crucial chemical admixture; it is necessary to utilize superplasticizer when constructing mixes to obtain HPC. The w/b ratio, as can be shown, has a significant impact in achieving the strength specifications. It must be mixed in with concrete to generate thick concrete with low permeability. This substance is referred to as "High-Range Water-Reducing Admixtures" by ASTM (HRWRA). These are also known as water reducers since they may lower water content by up to 30%. For this study, a superplasticizer called GLENIUM SP430G was utilized to provide workable concrete with a low w/b ratio. BIS: 9103-1999, BS: 5075 part 3 and ASTM C 494, Type B are all met by GLENIUM SP430G. NSF condensates are used in GLENIUM SP430G. Advantages of using GLENIUM SP430G super plasticizer are: improved workability, increased strength, improved quality of concrete, higher cohesion & chloride free. Superplasticizer used is shown in Figure 1.

Table 1 Details of M60 mix proportion for high strength concrete

Mix	Cement (kg/m^3)	NS (%)	NS (kg/m^3)	Sand (kg/m^3)	CA (kg/m^3)	SP (Lit/m^3)
M1	543	0	0	590	1218	5.43
M2	543	0.5	10.86	590	1218	5.43
M3	543	1	21.72	590	1218	5.43
M4	543	1.5	32.58	590	1218	5.43
M5	543	2	43.44	590	1218	5.43

The slump test is used to determine whether or not new concrete is workable. The workability was determined by performing a slump test in compliance with IS: 1199 code requirements. Because of the simplicity of the apparatus and the test protocols, the commonly used workability test is slump cone test. The slump test describes how a compacted concrete cone behaves when subjected to gravity forces. Below Figure 13 shows the results of the workability test. The slump observations of control concrete CC mix and HSC mixes reveal that with the same w/c ratio, the change between slump values of subsequent mixes is relatively negligible.

Using cubes, the compressive strength of concrete was evaluated at 7 days, 14 days, and 28 days. The test was performed on a 150mm x 150mm x 150mm cube in accordance with IS: 516-1959. The test was carried out using a typical Compression Testing Machine (CTM) with a capacity of 2000kN. The demolded cubes for each percentage, three cubes were cast. Figure 4 depicts the failure of cube specimens. Totally 5mixes each mix 9cubes means 5 × 9 = 45 cube specimens cast, cured at the ages of 7 days, 14 days, and 28 days and tested. This is an indirect test for determining cylindrical specimens' tensile strength. The tests were performed using a compression testing machine with a capacity of 2000 kN on cylinder specimens with a diameter of 150 mm and a length of 300 mm, according to IS 5816-1970, at the ages of 7 days and 28 days of curing. The cylindrical specimens were held below the wooden strips to avoid direct strain on the specimen. Totally 5mixes each mix 6cylinders means 5 × 6 = 30 cylindrical specimens cast, cured at the ages of 7 days and 28 days and tested.The flexural strength of a concrete cube was calculated using the following formula: 516–1959. For each mix percentage, a Prism of size 100 x 100 x 500 mm was cast. The specimen was placed in the Flexural testing machine after 7 days and 28 days of curing in such a way that the weight applied was to the opposing sides of the prism as cast, not the top and bottom. For testing, the third point loading frame approach is used. Totally 5mixes each mix 6prism means 5× 6 = 30 prism specimens cast, cured at the ages of 7 days, 28 days and tested.

The water absorption of the high-strength geopolymer concrete specimens was assessed. The concrete cube specimen measured 150 mm in height, width, and depth. For each mix proportion, concrete cubes were cast. After 28 days of curing, the specimens' wet weights were measured, and they were subsequently stored in an oven at 105° C for 24 hours. The specimens were removed from the oven after 24 hours, allowed to cool to room temperature, and then their dry weights were recorded. Once more, the specimen spent 24 hours submerged in water. Wet weight measurements were performed after 24 hours. The amount of water absorbed is indicated by the difference between the specimen's dry weight and wet weight. The purpose of the water permeability test was to identify, study, and the porosity of CCC and HSC. Before the test, the concrete density of the test specimens was established. During the test, the concrete cover was in contact with the pressure chamber to prevent any water seepage from the concrete cover. For standard specimens and fiber added concrete specimens to be evaluated, a water pressure of 2 to 3 pascal was proposed. The calibration test should take no less than one hour to complete. If there is a permeability of water, the coefficient of permeability may be calculated using the steady flow approach. If there is no permeability of water, the coefficient of permeability can be calculated using the depth of penetration approach. The depth of penetration technique was used to determine the co-efficient of permeability (K) by splitting cubes and measuring the depth of penetration in the specimen. Water permeability tests were performed in accordance with IS 3085- 1965.

The CCC and HSC specimens underwent the sulfate resistance test in compliance with ASTM C 1012 to assess the concrete samples' resistance to sulphate attack. A material measuring 100 mm by 100 mm by 100 mm was cast, and it was left to cure for 28 days. For a period of 28 days at room temperature, cast specimens were immersed in a 5% solution of magnesium sulphate. After 28 days of removing the concrete samples from the sulfate solution, the weight and strength losses resulting from the sulphate treatment were calculated. By comparing the weight and strength loss of HSC and CCC, the sulphate resistance of the geopolymer concrete was ascertained. as demonstrated in Figure 9. A total of fourteen specimens were cast and subjected to a sulfate resistance test. To evaluate the salt resistance of the CCC and HSC specimens measuring 100 x 100 x 100 mm was cast and cured for 28 days. As shown in Figure 10, cast specimens were submerged in 3.5% NaCl solution for 28 days at room temperature. Concrete samples were removed from the salt solution after 28 days, and the weights of control GPC and HSC were measured. Concrete's weight and strength loss percentage variation and salt resistance were computed using the test results. Totally 14 specimens cast and tested for salt resistance.

The acid resistance of 100 mm x 100 mm x 100 mm CCC and HSC specimens was assessed in accordance with ASTM C 642. The cast specimens were allowed to cure for 28 days in the open air and then immersed in a 3% HCl solution at ambient temperature for a further 28 days. After 28 days, the concrete samples were taken out of the HCl solution to measure weight loss and strength loss. The variations in the weight and strength loss of the concrete samples were used to compute acid resistance. A total of 14 samples were cast and submitted for acid resistance testing. The alkaline resistance of 100 mm x 100 mm x 100 mm CCC and HSC specimens was assessed in accordance with ASTM C 642. The cast specimens were allowed to cure for 28 days in the open air and then immersed in a 3% NaOH solution at ambient temperature for a further 28 days. After 28 days, the concrete samples were taken out of the NaOH solution to measure any weight and strength loss. The concrete samples' variations in weight and strength loss were used to compute alkaline resistance. Alkaline resistance was tested on a total of 14 cast samples.

The temperature ambiance environment was increased due to the environmental aspects. Concrete specimens which was taken for the experiment is compared accordingly to their compression strength after a period of time under higher temperature. To investigate the thermal resistance test of CCC and HSC, a total of 12 specimens were cast. After curing for 28 days, the specimens adopted for thermal resistance test. An object's or material's ability to withstand heat flow is measured by its thermal resistance, which is a heat property. The reciprocal of thermal conductance is thermal resistance. The temperature differential that occurs across a structure when a unit of heat energy passes through it in a unit of time is known as absolute thermal resistance. It is thermal conductance reciprocal.

Fig 1 GLENIUM SP430G

Fig 2 Slump cone test

Fig 3 Cube specimen Demolding

Fig 4 Cube failure mode

Fig 5 Typical splitting tensile failure mode patterns

Fig 6 Testing of Prism

Fig 7 Water Absorption test

Fig 8 Permeability apparatus and testing

Fig 9 Sulphate resistance test

Fig 10 Salt resistance test

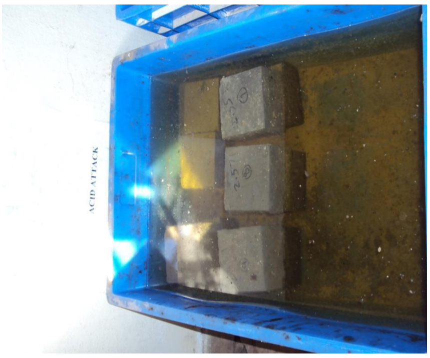

Fig 11 Acid resistance test

Fig 12 Alkaline resistance test

3. RESULTS AND DISCUSSION

All the mixes fresh concrete workability check by slump cone test. The slump cone test result shows the addition of NS 0.5%, 1% , 1.5% and 2% to the workability value reduced. The mechanical properties of 0.5 to 1.5% nano silica added mixes improved and 2% addition nano silica concrete compressive strength slightly reduced compare to 1.5% NS added concrete.

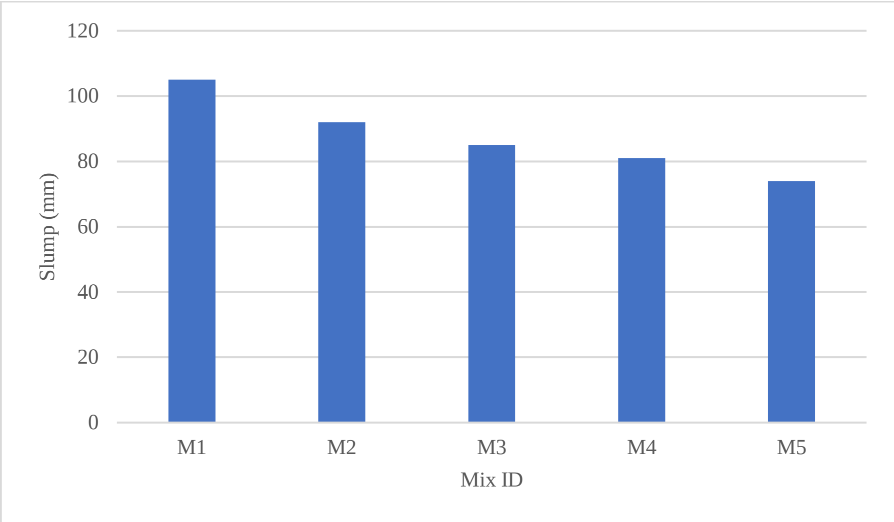

Fig 13 Slump value for high strength concrete

Table 2 Mechanical properties for high strength concrete

Sl.No	**Mix**	**% of NS**	**Compressive strength**		**split tensile strength**		**Flexural strength**	
			7Days (MPa)	28Days (MPa)	7Days (MPa)	28Days (MPa)	7Days (MPa)	28Days (MPa)
1	M1	0	51.63	68.40	4.99	6.61	4.37	5.78
2	M2	0.5	53.22	70.54	5.14	6.81	4.50	5.96
3	M3	1	55.74	73.28	5.38	7.08	4.71	6.20
4	M4	1.5	58.16	76.86	5.62	7.42	4.92	6.50
5	M5	2	55.44	73.53	5.35	7.10	4.69	6.22

The compressive, split tensile and flexural strength are increased up to 1.5% addition of NS. 1.5% NS added specimen achieved 28days compressive strength is 76.86N/mm^2. After 1.5% or 2% NS added concrete mechanical properties reduced. The compressive strength of 1.5% added nano silica concrete 12% high compare to the control specimen. 2% added nano silica concrete slightly reduce the compressive strength. Similar result obtained from split tensile and flexural strength. The graphical representation of compressive, split tensile and flexural strength is shown in Figure 14, 15 and 16.

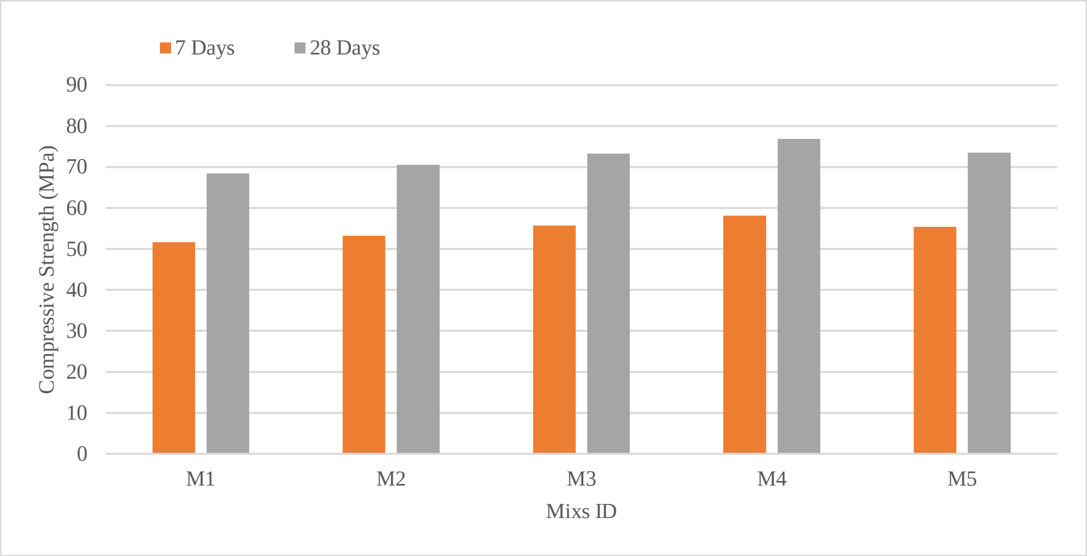

Fig 14 Compressive strength for high strength concrete

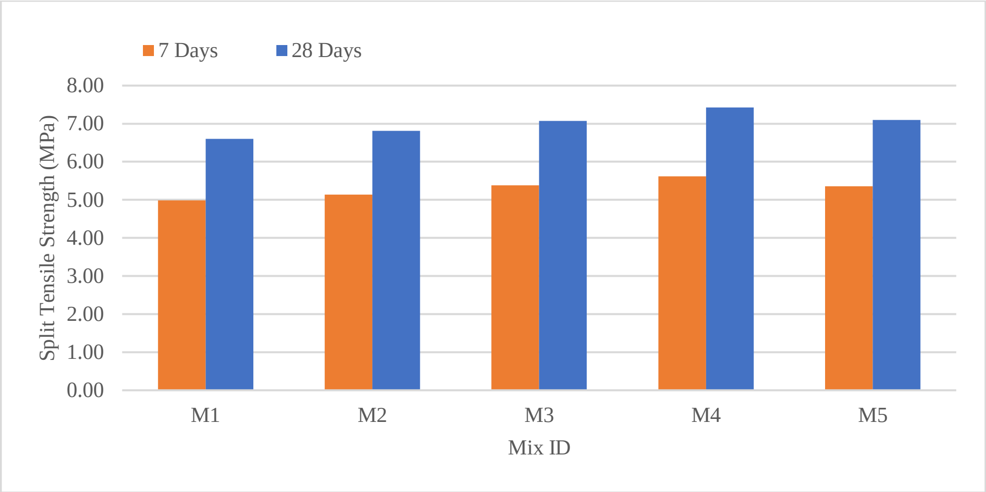

Fig 15 Split tensile strength for high strength concrete

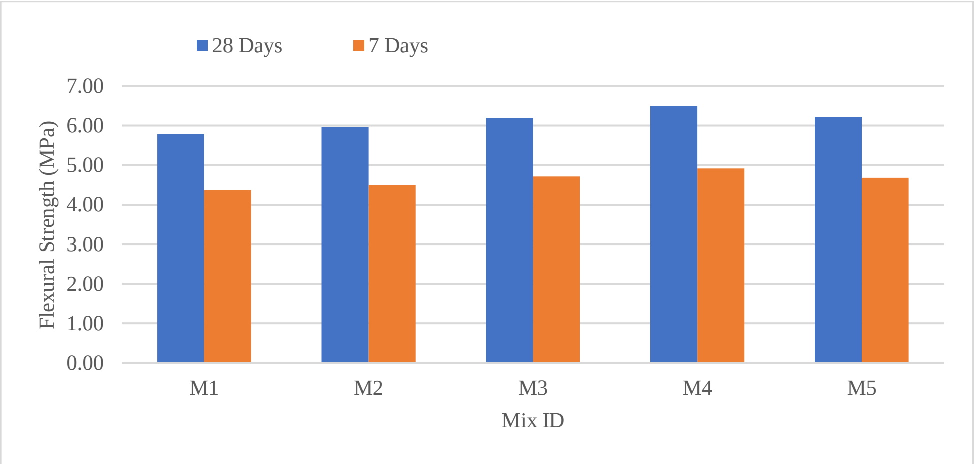

Fig 16 Flexural strength for high strength concrete

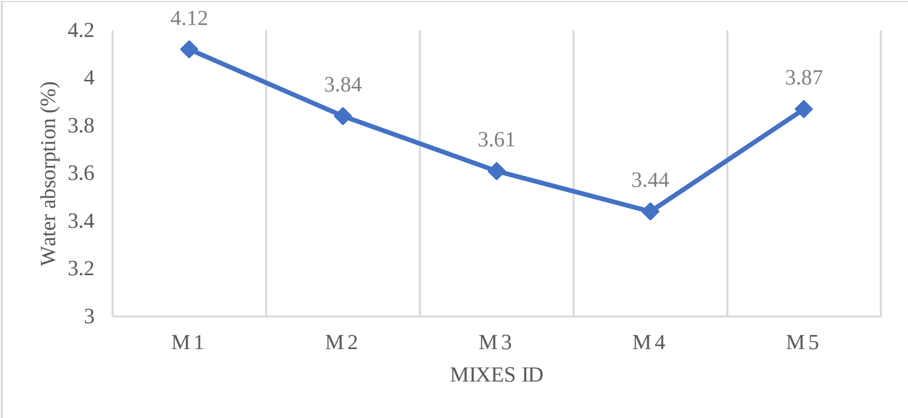

Fig 17 Water absorption for high strength concrete

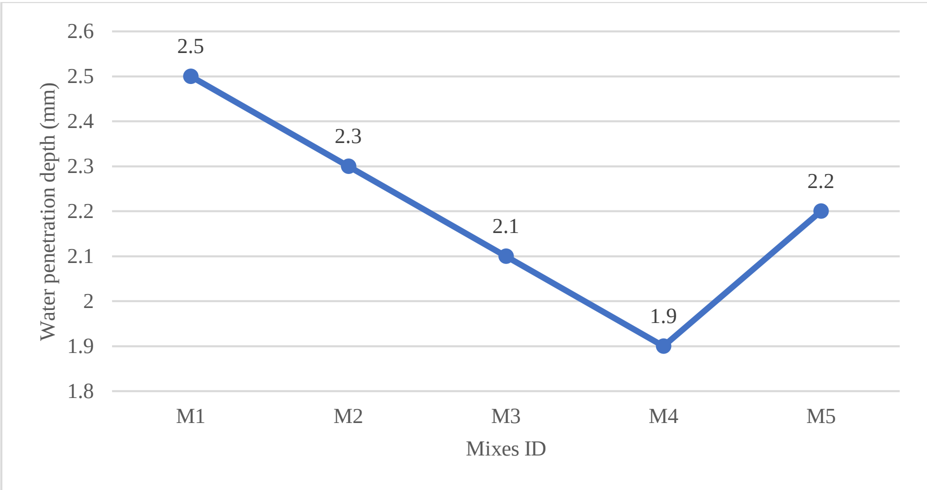

Fig 18 Water penetration depth for high strength concrete

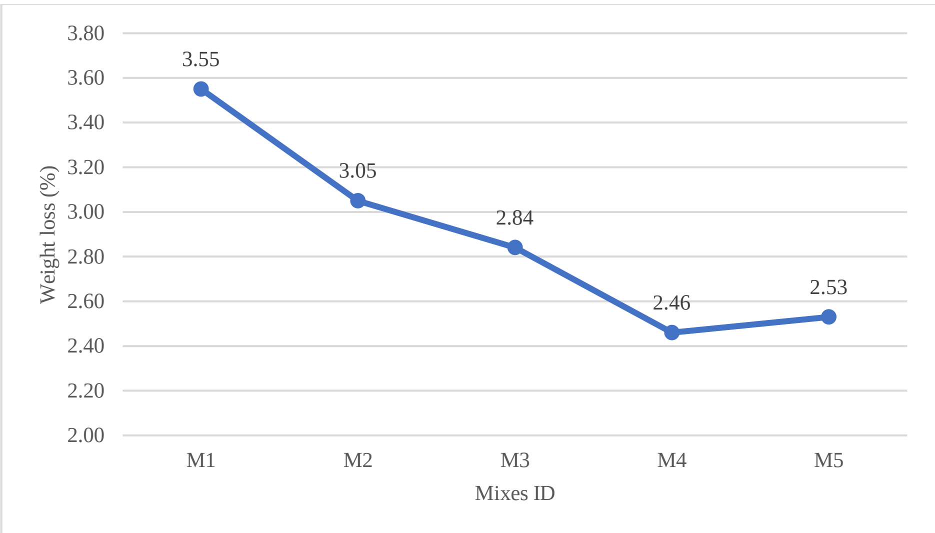

Fig 19 Weight loss for high strength concrete due to sulphate attack

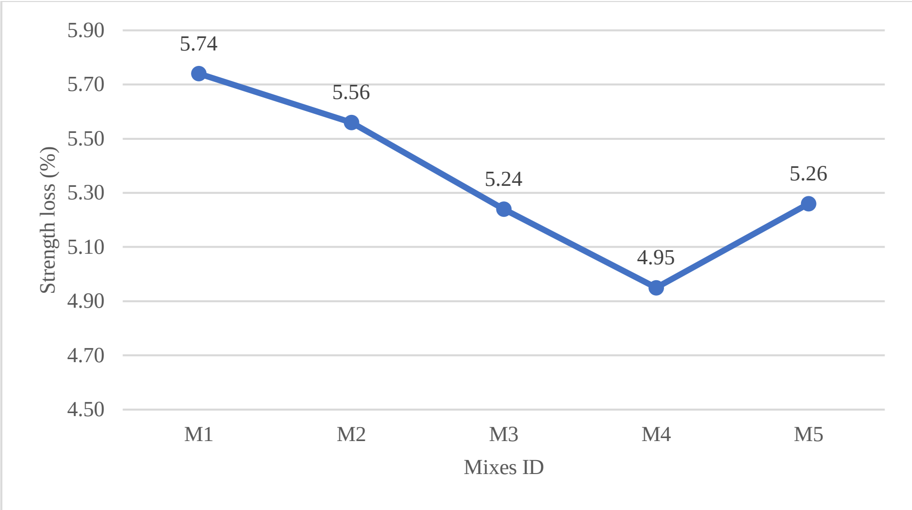

Fig 20 Strength loss for high strength concrete due to sulphate attack

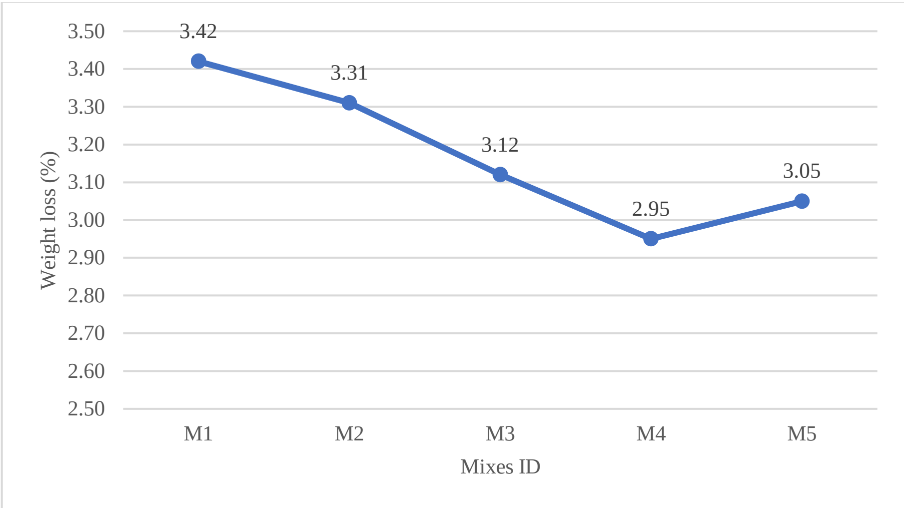

Fig 21 Weight loss for high strength concrete due to salt attack

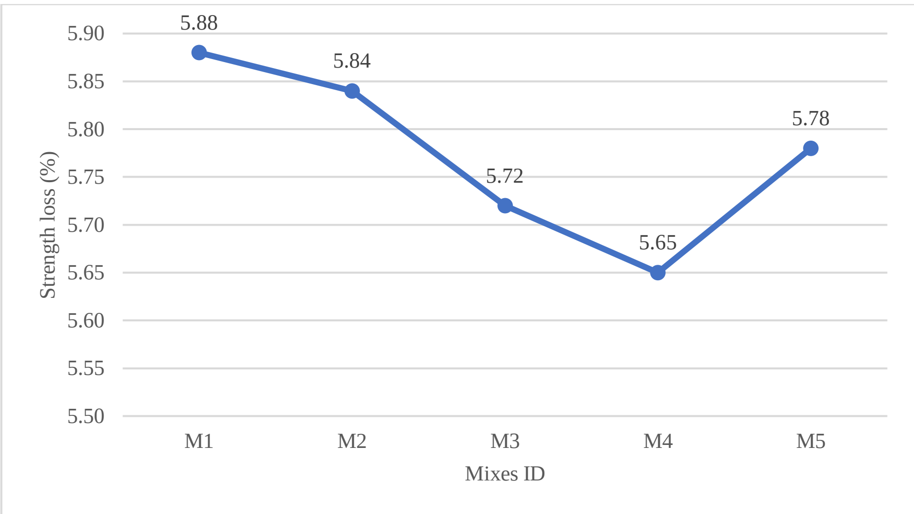

Fig 22 Strength loss for high strength concrete due to salt attack

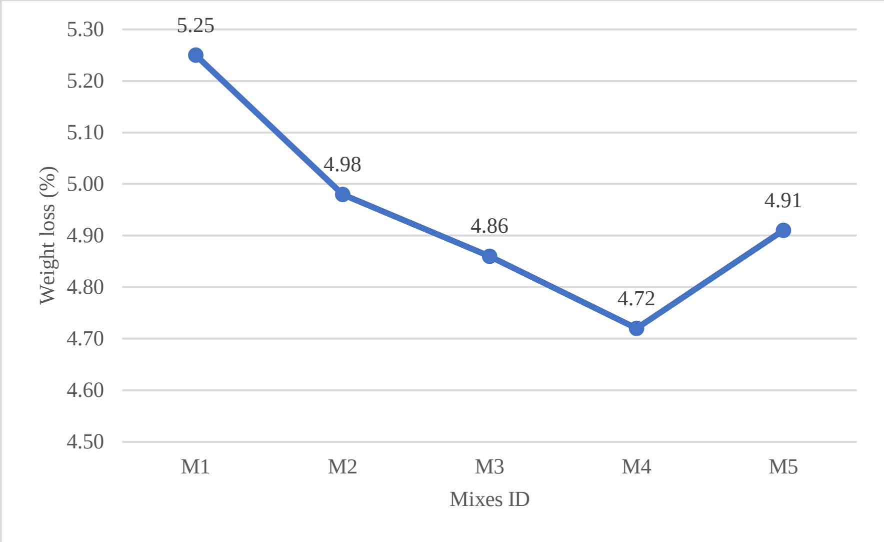

Fig 23 Weight loss for high strength concrete due to acid attack

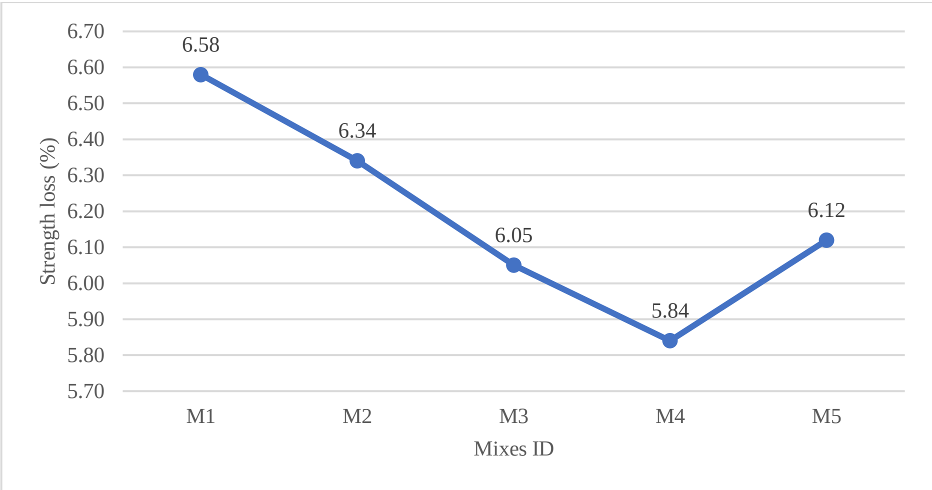

Fig 24 Strength loss for high strength concrete due to acid attack

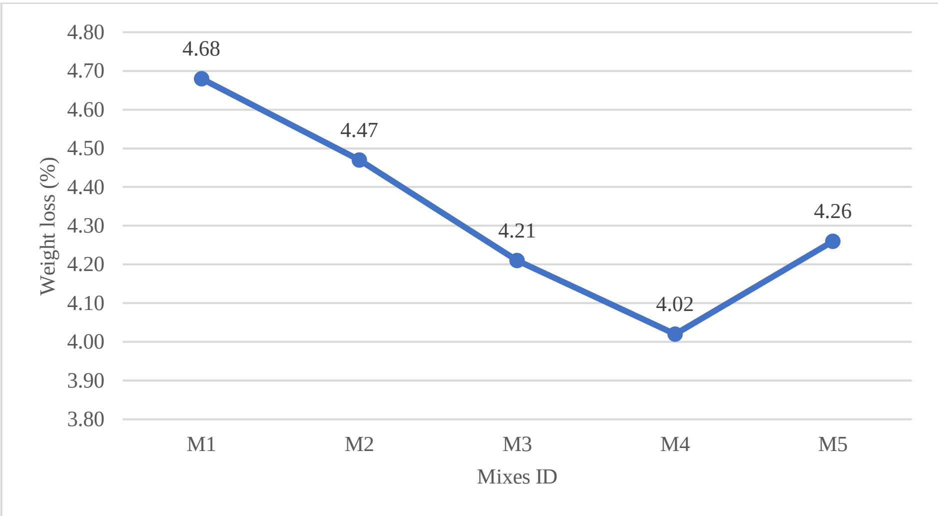

Fig 25 Weight loss for high strength concrete due to alkaline attack

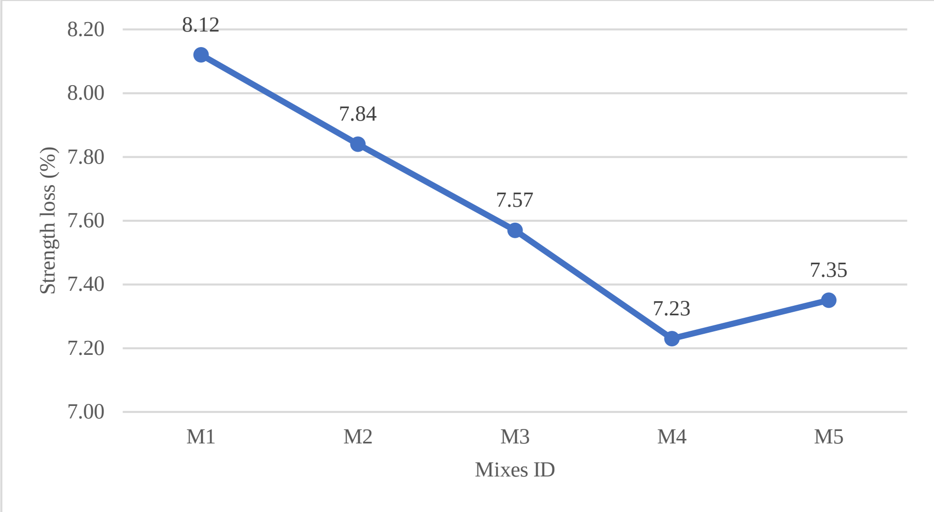

Fig 26 Strength loss for high strength concrete due to alkaline attack

The best durability properties are get from 1.5% NS added concrete specimens it will be lowest strength and weight loss due to various hazarders environment. 1.5% NS added specimens achieve high strength concrete. The strength loss and weight loss represented in Figure 17 to 26.

4. CONCLUSION

The addition of NS cause workability of concrete reduced. The concrete's flexural, split tensile, and compressive strengths are all enhanced by the 0.5 to 1.5% NS addition. The 1.5% NS added concrete specimens lowest weight loss and strength loss are obtained from various hazardous environment. The optimum usage of NS percentage is 1.5%.

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Received 25 April 2024
Revised 15 May 2024
Accepted 21 June 2024
Published Online 7 July 2024