EFFECT OF SILICA AND TITANIUM DIOXIDE NANOCOMPOSITE ON PROPERTIES OF CONCRETE

MAJOR PROJECT REPORT

SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
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Submitted by:

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CANDIDATE'S DECLARATION

I, Abhideep Singh, Roll No. 2K18/STE/01 student of M.Tech. (Structural Engineering), hereby declare that the project Dissertation titled "Effect of Silica and Titanium dioxide nanocomposite on properties of concrete" which is submitted by me to the Department of Civil Engineering, Delhi Technological University, Delhi in partial fulfilment of the requirement for the award of the degree of Master of Technology, is original and not copied from any source without proper citation. This work has not previously formed the basis for the award of any Degree, Diploma Associate ship, Fellowship or other similar title or recognition.

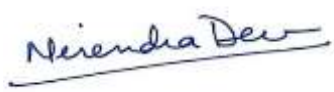
Abhideep

Place: Delhi **ABHIDEEP SINGH**

Date:31 /10/2020 **2K18/STE/01**

CERTIFICATE

I hereby certify that the Project Dissertation titled "Effect of Silica and Titanium dioxide nanocomposite on properties of concrete" which is submitted by Abhideep Singh, Roll No. 2K18/STE/01, Department of Civil Engineering, Delhi Technological University, Delhi in partial fulfilment of the requirement for the award of the degree of Master of Technology, is a record of the project work carried out by the student under my supervision. To the best of my knowledge this work has not been submitted in part or full for any Degree or Diploma to this University or elsewhere.



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ABSTRACT

Concrete has been the most prominently used material for construction of various infrastructure's, hence it's composition has been widely experimented with, a relatively new addition has been the use of nano material, there have been a lot of studies about effect of incorporating nano materials such as nano silica and nano titanium dioxide in concrete, but there are lack of studies showing effect of adding both of these together in the same concrete mix.

In this dissertation study has been performed by adding nano silica and nano titanium dioxide to concrete of grade M-50 designed using PC based super plasticizer with one mix containing 0.5%(by weight of cement) of each of these two, another mix containing 1%(by weight of cement) of each of these two and the third mix containing 1.5%(by weight of cement) of each of these two, also an attempt has been made to keep the slump in a range of 75mm-100mm by adjusting super plasticizer and the effect of these addition has been studied in terms of gain of 7 days concrete compressive strength, 28 days concrete compressive strength, UPVT, rebound hammer, effect of 28 days chloride curing on compressive strength, effect of 28 days sulphate curing on compressive strength, effect of combined sulphate and chloride curing for 28 days on compressive strength and effect of elevated temperature(400°C) on compressive strength of concrete.

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Al_2O_3 : Aluminum Oxide

Avg : average

BC : before Christ

CA : Coarse Aggregate

CaO : Calcium Oxide

cm : centi meter

C/M : control mix

FA : Fine Aggregate

FM : Fineness Modulus

f_{ck} : Mean Compressive Strength of Concrete

g : gram

HPC : High Performance Concrete

IS : Indian Standard

Kg : kilogram

Km/sec : kilometer per second

KN : Kilo Newton

M : metre

mm : millimeter

Mpa : Mega Pascal

nm : nano meters

N/mm^2 : Newton per millimetre square

$Na_2(S0)_4$: Sodium Sulphate

OPC : ordinary portland cement

PC : Poly Carboxylic

PPC : portland pozoolona cement

sec : second

SiO_2 : Silica Dioxide

SP : Super Plasticizer

S/T .5 : nano silica and nano titanium dioxide added concrete mix with each added as an amount equal to .5% of weight of cement added

S/T 1 : nano silica and nano titanium dioxide added concrete mix with each added as an amount equal to 1% of weight of cement added

S/T 1.5: nano silica and nano ttanium dioxide added concrete mix with each added as an amount equal to 1.5% of weight of cement added

TiO_2 : Titanium Dioxide

UPV : Ultrasonic Pulse Velocity

UPVT : Ultra Sonic Pulse Velocity Test

W/C : Water Cement ratio

CHAPTER 1

INTRODUCTION

1.1 Background

The most popular choice for construction material in construction industry in concrete, it by far overshadows all other construction materials that are used (Gagg, 2014, p. 114), in fact annual per capita consumption of concrete stands about 3000kg (Gagg, 2014, p. 114).Concrete uses vary from construction of columns and slabs of an ordinary dwelling to skyscrapers and to construction of colossal damns and even nuclear powerplant. Since all these structures serve different purposes and are likely to be subjected chloride attack on structure, attack of sulphate on structure, dynamic load, elevated temperature, etc. hence for suiting these varied purposes various changes were made in concrete composition and various forms of concrete emerged, there was development of high strength concrete, high performance concrete, self-compacting concrete and so on. An alteration made in concrete was introduction of nano technology in concrete.

Nano technology is a relatively new branch in engineering and sciences but it is appears to be a promising area of study. Nano Technology uses particles having size 1nm to 100nm. Nanotechnology is widely being used in diverse fields such as physics, electronics, chemistry and structural engineering. It has been observed that the properties of these nano sized particles are different from their macro scaled counter parts.

(Bayda et al., 2019, p. 112) stated that the father of nano technology in modern days is attributed to Richard Feynman but actually the debate on nano science started way back in 5 century BC when it was being pondered if matter is made up of small discreet particles or if it is continuous, it further states that Synthesis of nano materials can be done in two ways one is breaking dawn larger size material already existing in environment to nano scaled particles, this technique is called top down approach, other method of nano material synthesis involves use of combining atoms together using chemical process till they reach size of 1-100nm,this method is called bottom up approach.

(Bayda et al., 2019, p. 112) analyzed that the bottom up approach provides a better control on size of particles generated, further they also mention that if the end product is same but the approach used to synthesize it is different than the end product may have identical properties as is the case with nano silica.

Two of the nano particles used in construction industry are nano silica and titanium Dioxide. A lot of research has been performed to study impact of these two material in concrete some of these studies have been discussed in the literature review portion of this thesis.

1.2 Nano silica

Nano Silica is a white powdery substance having particles in range of 1nm-100nm this in turn increases the specific surface area of nano silica, nano silica has small size hence it reduces voids in concrete and which in turn results in better pore structure thereby increasing durability of concrete in terms of chloride penetration resistance, it has also shown to improve compressive and tensile strength of concrete, it also effects various other chemical, mechanical and rheological properties of concrete which is why it has been widely studied in terms of its impact on properties of concrete.

(Jo et al., 2007, p. 1354) studied the impact of nano silica on micro structure of cement mortar paste and found that addition of nano silica produced a dense matrix of C-S-H gel with very less pores and less $Ca(OH)_2$ whereas the mortar in absence of nano silica generated a matrix where C-S-H gel were separated having needle shaped hydrate resulting in a loosely packed matrix with comparatively poor pore structure.

(Rahman & Padavettan, 2012,) explains that Synthesis of Nano Silica is done from bottom up approach, this would result in an amorphous product, it adds that a top bottom approach of breaking down silica (mostly found in sand) to nano sized particles by top down approach is possible, this would result in a crystalline end product but is seldom used due to impurities present in sand. Further it mentions that commercially synthesis of nano silica is done by chemically reacting hydrogen and oxygen to silicon tetrachloride this method is known as chemical vapour condensation.

1.3 Nano titanium dioxide

Nano Titanium dioxide is a white powdered substance that has been widely used in various industries because of its photocatylitic properties, ability to resist corrosion and superior stability. It is available in two forms based on crystalline structure one being the anatase form and other being rutile form.

(Shi et al., 2013,) mentions that Titanium Dioxide also known as Titania is obtained from Titanium which is one of the top 10 most abundant metal obtained from the crust of the earth, they further state that Titanium dioxide does not burn and also lacks smell but can melt.

(Piccinno et al., 2012,)Estimates a median production of Nano Titanium Dioxide to be 3000 ton per year which is only second to Nano Silica whose median production according to the same study is 5500 ton per year, the same study further points that 70-80% of total nano titanium dioxide produced is used in cosmetic industry and the reaming is used in paint, plastic, cement industry etc.

(Ramos-Delgado et al., 2016,)informs there are two methods of production of nano titanium dioxide which includes the older process of digesting ilmenite with sulphuric acid and the newer process of heating the ilminite ore at about 950°C in presence of molecular oxygen , coke and chlorine gas, they further state that sulphate process produces both anatase and rutile structured nano titanium dioxide but is labour intensive and produces a lot of waste on the other hand the chloride process produces only rutile structured nano titanium dioxide but it is less labour intensive and also produces less wastage.

1.4 Research Motivation

Many studies have been performed to study the effect of nano silica and nano titanium dioxide on properties of concrete but these studies were limited to use of only one of these nano materials while researching for this thesis the author could not find any study that takes into account the effect of adding both these materials simultaneously on concrete, also most of the studies performed were using a constant water cement ratio and a constant super plasticizer content(if added) for various quantities of nano silica and nano titanium added to the concrete mix this mostly led to a decrease in compressive strength beyond 1-1.5% addition of the two nano materials studied in this thesis, on increasing the nano materials it was seen in these studies that a rapid decrease in slump of mixes on introduction of nano silica and nano titanium dioxide occured, this happens due to the excessive specific surface area of the nano particle which reduces the available water for lubrication and thereby causing honeycombing hence reducing strength of concrete, another explanation which is widely referred is the lack of dispersion of nano particles for this strength reduction, in this thesis an attempt has been made to maintain a constant slump range if 75-100 mm by varying the dosage of super plasticizer added to concrete mix while keeping the water cement ratio constant.

1.5 Objective of research

This thesis aims at finding the effect of simultaneous addition of nano silica and nano Titanium Dioxide on mechanical strength and durability of M50 grade concrete, therefore following tests have been performed on the specimens created:

- Obtaining compressive strength of concrete at 7 days and 28days.
- Obtaining UPV results on concrete.
- Obtaining rebound hammer test on concrete.
- Obtaining compressive strength of concrete after 28 days of curing (succeeding 28 days of normal water curing) in sodium chloride containing water.
- Obtaining compressive strength of concrete after 28 days of curing (succeeding 28 days of normal water curing) in sodium sulphate solution.
- Obtaining compressive strength of concrete after 28 days of curing (succeeding 28 days of normal water curing) in a solution containing both sodium chloride and sodium sulphate.
- Obtaining compressive strength of concrete after subjecting it to elevated temperature.
-

CHAPTER 2

LITERATURE REVIEW

(Yu et al., 2018) studied the impact replacement of cement by Nano titanium dioxide on compressive strength of concrete, in the study cement was replaced by Nano titanium dioxide by 2%, 4% and 6% of weight of cement and the results obtained showed an increase in compressive strength at 2% and 6% replacement and a decrement in strength in 4% replacement, it must be noted that the study showed increase in strength by 7.73% during 2% replacement and an increase in strength by 1.64% during 6 percent replacement, hence maximum increase in strength was at 2% replacement of cement.

(ARAVIND et al., 2016,) studied the impact of replacement of cement by Nano $Ti0_2$, the study made replacement of cement by nano titania in amounts of .5%, 1% and 1.5%,they found out that compressive strength increased in .5% and 1% replacement of cement by nano titania with maximum rise in compressive strength(for 28 days curing) obtained by 1% cement replacement, this strength was 15.15% above control mix strength whereas at 1.5% replacement of cement the strength reduced by 9.09% .

(Sorathiya et al., 2017,) studied the impact of replacement of cement by Nano Titania, the study made replacement of cement by nano titania in amounts of .5%, .75%, 1%, 1.25%, 1.5%,the findings of this study stated that slump decreased with increase in nano titania content whereas the compressive strength increased upto 1% with a maximum increase in strength amounting to 85% at 1% replacement and then the strength started to reduce but still even at 1.5% replacement the strength was 60.9% above control mix compressive strength.

(Sharma et al., 2019,) studied replacement of cement by nano titania in amounts of 1%, 1.5%, and 2% by weight of cement, this study found that compressive strength increased for all replacements but peaked at 1.5% replacement where the compressive strength was found to be 24.43% higher than strength of control mix.

(Iyappan et al., 2017,) studied the effect of replacement of cement by nano titanium dioxide, they replaced 0.5%, 1%, 1.5% and 2% of cement by nano TiO_2 and found that thought all the 4 replacement increased the compressive strength with respect to control mix but the increase in strength peaked at1.5% and then at 2% reduced with respect to strength at 1.5% cement replacement, in this study the strength at 1.5 % replacement of cement was increased by 34.23% from control mix strength.

(Guo et al., 2018,) studied the effect of curing in sea water vs. curing in normal water in following mix proportions of concrete

Nomenclature	W/C	CEMENT:FA:CA
A	.5	1:1.5:3
B	.45	1:1.5:3
C	.5	1:2:4
D	.45	1:2:4

Note. Adapted from “The Effect of Mixing and Curing Sea Water on Concrete Strength at Different Ages”, by Guo, Q., Chen, L., Zhao, H., Admilson, J., & Zhang, W., 2018, MATEC Web of Conferences.

Table2.1: various mix proportions used (Guo et al., 2018,)

(Guo et al., 2018,) obtained following results of compressive strength at 28 days

Nomenclature	28 days compressive strength in fresh water(MPa)	28 days compressive strength in salt water(MPa)
A	47.17	49.17
B	54.33	49.98
C	49.02	49.70
D	59.09	58.56

Note. Adapted from “The Effect of Mixing and Curing Sea Water on Concrete Strength at Different Ages”, by Guo, Q., Chen, L., Zhao, H., Admilson, J., & Zhang, W., 2018, MATEC Web of Conferences.

Table 2.2: 28 days compressive strength in normal water and salt water (Guo et al., 2018,).

It can be observed that in the above study for W/C ratio of .5 there was an increase in compressive strength of concrete when they were cured for 28 days in NaCl solution whereas when the W/C ratio was .45 there was a decrease in strength for the same procedure.

(Abalaka & Babalaga, 2011,) studied effect of 28 days sodium chloride curing on strength of a concrete whose W/C was .40 and mix proportion was 1:1.05:3.34 and found that 28 days curing in 5% sodium chloride produced a strength less than 14.21% than those cubes of same mix cured for 28 days in normal tap water.

(Patel & Shah, 2015,) studied the effect of 28 days of 5% sodium sulphate curing and 28 days of 5% NaCl curing on M-30 concrete after they have cured for 28 days in normal tap water and found a reduction in compressive strength by 19.44% in sodium sulphate case and 16.75% in sodium chloride case.

(Ranjeeta et al., 2016,) studied the effect of 30 days of 10% sodium sulphate curing after 28 days of tap water curing on concrete with 28 days strength as 44.8Mpa and found that a reduction in strength by 15.17% after sodium sulphate curing as compared to 28 days tap water curing.

(Vijaya Sekhar Reddy et al., 2013,) studied the effect of 90 days curing of concrete in 10% solution of sodium sulphate and magnesium sulphate (5% of each) after 28 days normal water curing and found that the strength of their M-40 grade of concrete reduced by 10.6% from the strength obtained at after 28 days of normal curing and on 10% replacement of cement by silica fume the reduction is strength was 10.4%

(Halim et al., 2017,)studied the effect of 30 days of sodium chloride curing in a 3.5%NaCl solution on 28 days normal water cured concrete, this study found that concrete made up of OPC had an increase of 12.18% compressive strength on chloride curing as compared to just 28 days normal water curing.

(Sathawane et al., 2016,) studied the effect 28 days of normal water curing followed by 30 days of 3% sodium chloride curing on concrete strength, he used a concrete whose W/C ratio was .44 and mix proportion was 1:1.1:2.85 and found that 30 days of chloride cured concrete had compressive strength 3.89% less than cube cured for just 28 days in normal water.

(Gopala Krishna Sastry et al., in press,) studied the effect of sulphate and chloride attack on Geopolymer concrete in which nano TiO_2 was added amounting to 1,2,3,4and 5% of binder content, their control mix reached a strength of 34.51Mpa after 28 days of normal curing, also the samples were subjected to sodium chloride solution of concentrations 5% and sodium sulphate solution of concentrations 5% for 28 days after 28 days of normal water curing and obtained the following results(% variation form 34.51Mpa):

Percentage addition on nano TiO2 (%)	Variation in 28 days compressive strength(%) from that of control mix	Variation in compressive strength after chloride attack(%)from their respective mix's 28 days compressive strength	Variation in compressive strength after sulphate attack(%)from their respective mix's 28 days compressive strength
0	0	-1.52	-1.44
1	+18.4	-1.26	-1.21
2	+24.9	-1.14	-1.11
3	+34.3	-1.11	-1.02
4	+46.7	-.93	-.896
5	+52.3	-.827	-.80

Note. Adapted from "Influence of nano TiO2 on strength and durability properties of geopolymer concrete", by Gopala Krishna Sastry, K. V. S., Sahitya, P., & Ravitheja, A., in press, Materials Today: Proceedings.

Table 2.3: percentage variation in compressive strength due to sulphate and chloride curing (Gopala Krishna Sastry et al., in press,).

(Walzade & Tarannum, 2016,) studied the effect of cement replacement by nano silica in a M-80 concrete mix, in this study the specimen were first cured in normal water for 28 days and then shifted to water solution containing 5% sodium sulphate, they found out the following after 28 days for sulphate curing:

Percentage of nano silica in concrete	Percentage compressive strength reduction from compressive strength at 28 days by normal water curing
0	5.8
1	5.1
2	5
3	4.8
4	4.1
5	7.2

Note. Adapted from “Influence of Colliodal Nano- SiO2 on durability properties of high strength concrete”, by Walzade, S. B., & Tarannum, N., 2016, International Research Journal of Engineering and Technology (IRJET), 03(08), 1279.

Table2.4: Effect of sulphate curing on compressive strength (Walzade & Tarannum, 2016,)

(Chaudhary & Sinha, 2018,**)** studied the effect of addition of nano silica as a percentage of weight of cement in a M-35 concrete mix, they obtained a compressive strength of 44.24MPa after 28 days of normal curing and then some of them were transferred to 5% sodium sulphate solution and some were transferred to a 5% sodium chloride solution, these were cured in these solutions for 60 days, they obtained the following results:

Percentage addition on nano SiO2 (%)	Variation in 28 days compressive strength(%) from that of control mix	Variation in compressive strength after chloride attack(%)from their respective mix's 28 days compressive strength	Variation in compressive strength after sulphate attack(%)from their respective mix's 28 days compressive strength
0	0	-12.14	-18
0.5	+2.26	-8.31	-12.89
1	+9.07	-6.63	-8.84
1.5	+24.9	-4.85	-6.61
2	+15.48	-5.63	-9.86
2.5	+6.97	-5.89	-10.22

Note. Adapted from "Effect of nano silica on acid, alkali and chloride resistance of concrete", by Chaudhary, S. K., & Sinha, A. K., 2018, International Journal of Civil Engineering and Technology ,9(8),pp 858-859.

Table 2.5: 28 days compressive strength variation from CM compressive strength at 28 days and variation in compressive strength after sulphate and chloride attack from their respective mix's 28 days compressive strength (Chaudhary & Sinha, 2018,**)**.

(Maes & De Belie, 2014,)Studied the effect of combined chloride and sulphate attack on cement mortar for 7 weeks and 14 weeks and concluded that that the chloride present actually reduce the impact of sulphate attack for this short duration whereas on the other hand they noted that there was an attenuation in chloride penetration in the mortar for the same duration.

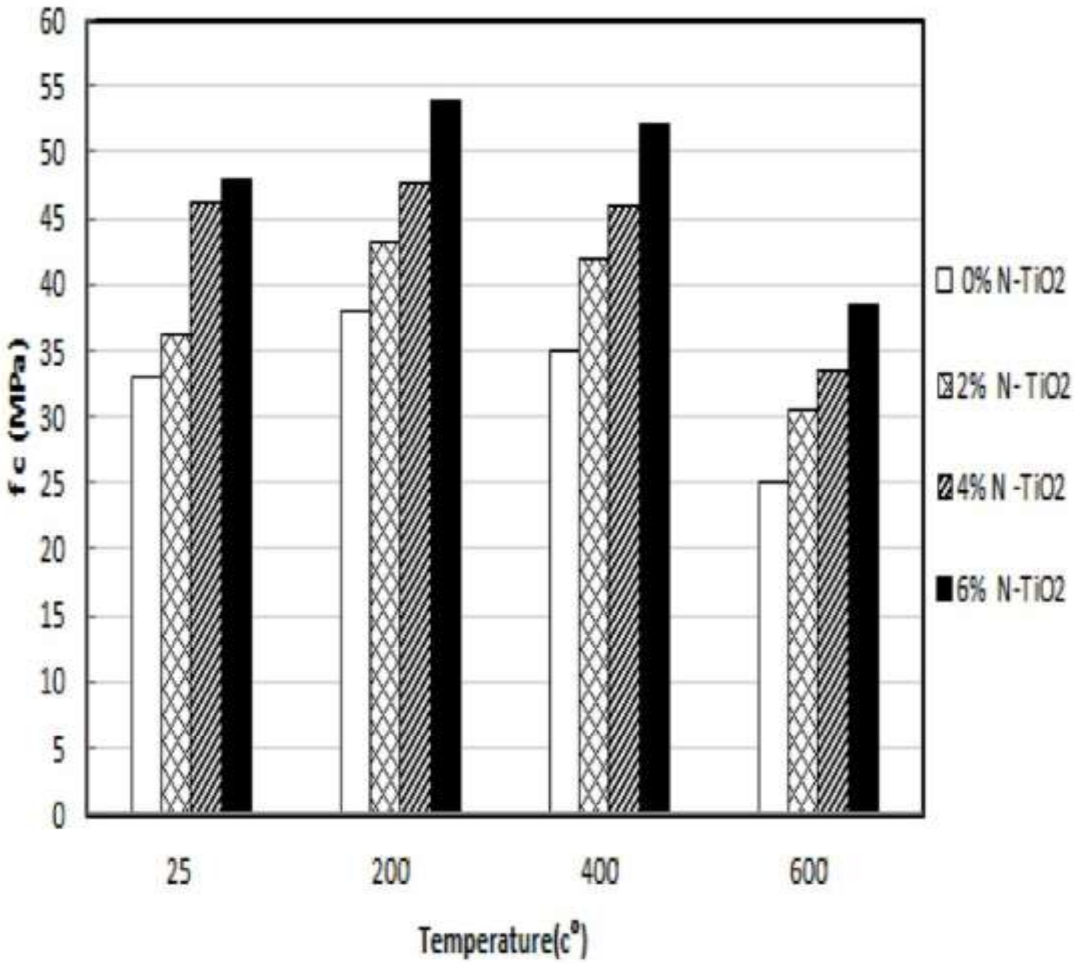
(Bingöl & Gül, 2009,)studied the effect of elevated temperature on concrete compressive strength after 28 days of curing of concrete having 28 days strength as 20 and 35MPa, these cubes were subjected to various temperatures in range of 50 to 700°C , the set temperature was reached with a per minute increase in temperature as 12-20°C and the final temperature was maintained for 3 hours and the concrete specimen were allowed to cool down in air , it was observed that at 400°C the reduction in strength for 20MPa mix was 31% and for 35MPa was 20% as compared to cubes not subjected to any temperature increase.

(Nikbin et al., 2020,) studied the effect of elevated temperature on a heavy concrete subjected to partial replacement of cement with nano Titania, they found increase in compressive strength at 200°C and 400°C, whereas at 600°C the strength reduced, in this study at 400°C the following results were obtained:

Percentage of nano titania	Percentage variation in compressive strength at 400°C from strength at compressive strength at room temperature
0	+6.06
2	+18.06
4	-1.07
6	+7.22

Note. Adapted from "Effect of high temperature on mechanical and gamma ray shielding properties of concrete containing nano-TiO2", by Nikbin, I. M., Mehdipour, S., Dezhampanah, S., Mohammadi, R., Mohebbi, R., Moghadam, H. H., & Sadrmomtazi, A., 2020, Radiation Physics and Chemistry, 174, 108967.
Table2.6: Percentage variation in compressive strength of concrete after subjecting them to 400°C from their respective mix's 28 days compressive strength (Nikbin et al., 2020,)

(Nikbin et al., 2020,) recorded following compressive strengths at various temperature:

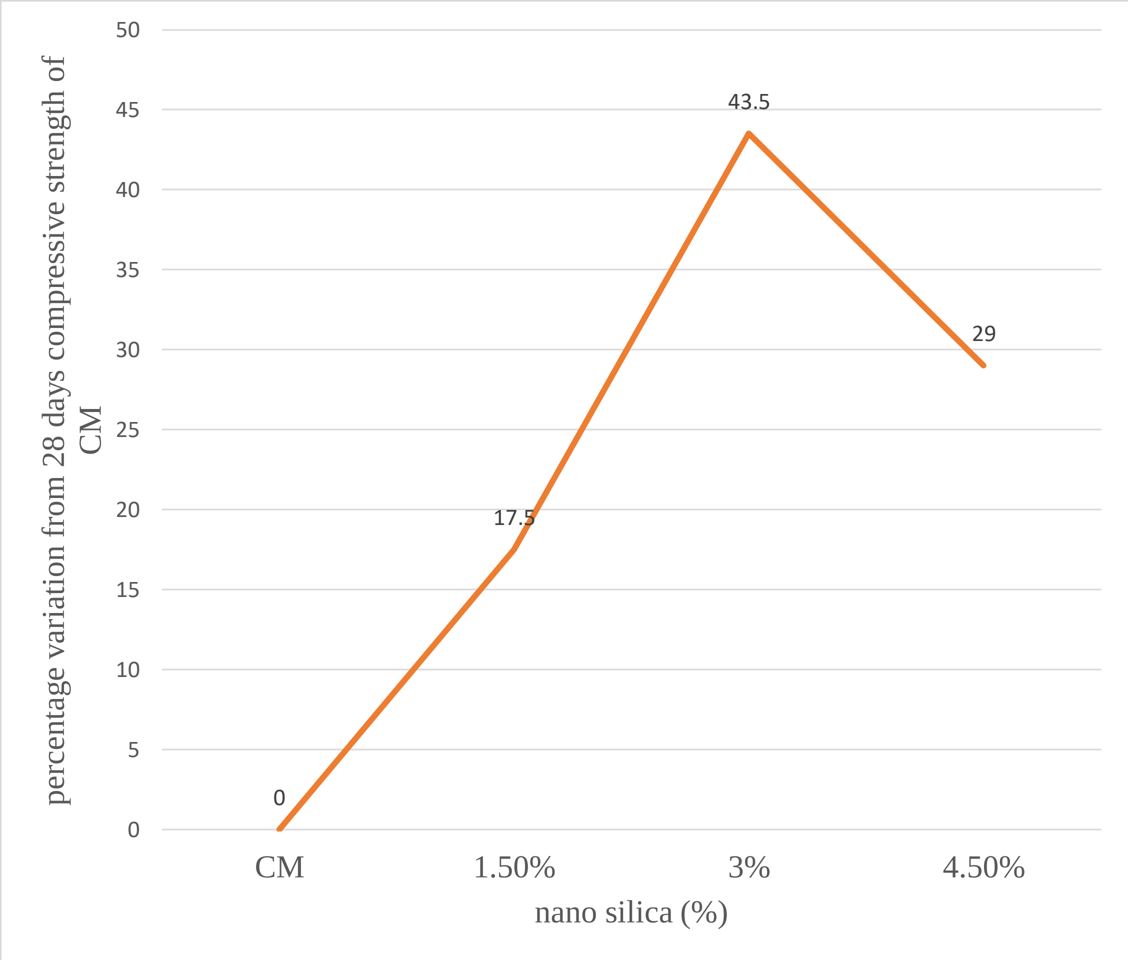


Note. Reprinted from “Effect of high temperature on mechanical and gamma ray shielding properties of concrete containing nano-TiO2”, by Nikbin, I. M., Mehdipour, S., Dezhampanah, S., Mohammadi, R., Mohebbi, R., Moghadam, H. H., & Sadrmomtazi, A., 2020, Radiation Physics and Chemistry, 174, 108967.

Figure2.1: Effect of various temperature regimes on concrete’s compressive strength (Nikbin et al., 2020,)

(Elkady et al., 2019,) studied the effect of cement partial replacement by nano silica and then subjecting the concrete at elevated temperatures, in this study they found that the

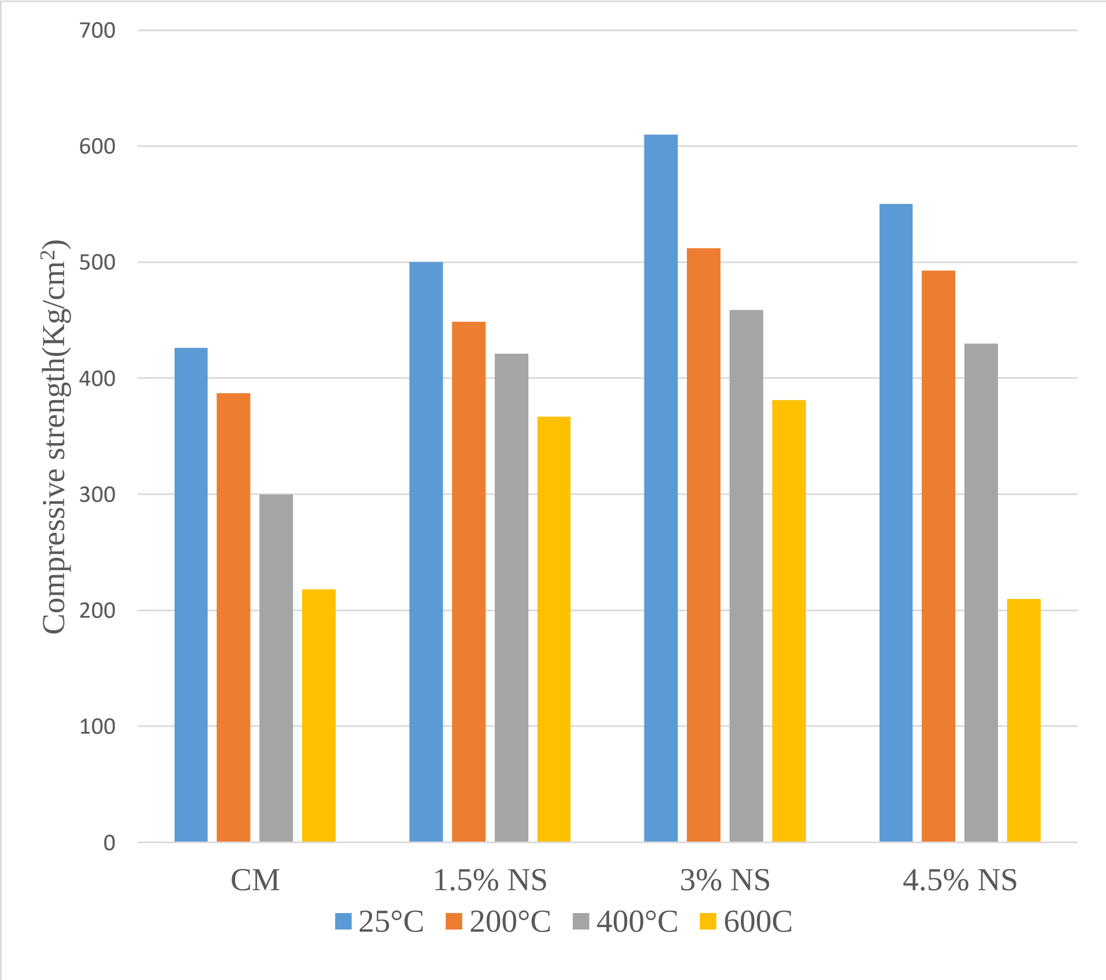
28 day compressive strength of control mix as 426 Kg/cm^2 and further their study found out:



Note. Adapted from "Assessment of mechanical strength of nano silica concrete (NSC) subjected to elevated temperatures", by Elkady, H. M., Yasien, A. M., Elfeky, M. S., & Serag, M. E.,2019, Journal of Structural Fire Engineering, 10(1), 90–109.

Figure2.2: 28 days compressive strength variation from control mix (Elkady et al., 2019,)

(Elkady et al., 2019,) found that at elevated temperature their specimen yielded following results:



Note. Adapted from “Assessment of mechanical strength of nano silica concrete (NSC) subjected to elevated temperatures”, by Elkady, H. M., Yasien, A. M., Elfeky, M. S., & Serag, M. E.,2019, Journal of Structural Fire Engineering, 10(1), 90–109.

Figure2.3: Compressive strength variation at different temperature’s (Elkady et al., 2019,)

CHAPTER 3

MATERIALS USED AND THEIR PROPERTIES

3.1 Cement

Cement is the material added to concrete which binds together all the other constituents of concrete.

Most popular form of cement available in Indian market are ordinary portland cement and pozzolona portland cement, commercially they are available in 33, 43 and 53 grade. IS 269:2015 is the code referred to in India for OPC whereas is the code referred to in India for PPC is IS1489:2015. PPC is obtained by adding pozzolonic material amounting to 10-30% of weight of cement clinker in OPC.

In our study OPC 43 grade is used. The company producing the cement used is Wonder Cement and the cement conforms to IS 269:2015

Figure 3.1 Wonder Cement of 43 grade opc

Composition of cement:

Constituent	Lime	Silica	Alumina	Iron	Manganese	Sulphur	Alkalies
Percentage	63	20	6	3	2	1.5	1.5

Table 3.1 Composition of 43 grade OPC used

3.1.1 Normal consistency of cement

The water content at which 33-35mm penetration of vicat apparatus 1 cm circular needle circular occurs in a paste of cement and sand in ratio of 1:3 is known as normal consistency of cement.

For the cement used in this thesis standard consistency came out to be 30%

3.1.2 Initial setting time of cement

The time duration after adding water to cement when the cement start losing its plasticity is called Initial Setting time

It is determined by adding water equal to .85 times the normal consistency of cement to 1:3 cement is to sand paste and measuring the time when a square needle of 1mm side in vicat apparatus can penetrate only 33 to 35 cm in cement sand paste.

Cement	Initial setting time recorded	Initial setting time limit as per IS 4031(PART-5):1988
Wonder OPC 43 grade	45 minutes	Greater than 30 min

Table 3.2: Initial setting time of cement

3.1.3 Final setting time of cement

It marks the duration after adding water to cement sand mixture when the entire plasticity has been lost in the paste.

It is determined by adding water equal to .85 time the normal consistency of cement in 1:3 cement: sand mixture and a needle of 1mm with and annular collar of 5 mm is used in vicat apparatus. The time when the ring makes an impression but the annular collar doesn't is called as Final setting time of concrete.

Cement	Final setting time recorded	Final setting time limit as per is 4031(PART-5):1988

Wonder OPC 43	330 minutes	Less than 600 min

Table 3.3: Final setting time of cement

3.1.4 Specific gravity of cement

Cement	Specific gravity	Specific gravity range
Wonder OPC 43	3.1	3.1-3.15

Table 3.4: Specific gravity of cement

3.2 Aggregates

According to (Understanding the Role of Aggregates in Concrete, 2018) Aggregates are inert material used as fillers or extenders used in concrete and are responsible for resisting compressive stresses , inducing elastic properties and better thermal response from concrete, it further states that 70-85 % of concrete mass are aggregates and that 60-80% of concrete volume is aggregate, the article further mentions that aggregates are used to form bulk of concrete as they are quite cheap from cement.

Aggregates can be differentiated on the basis of their origin:

- Natural aggregates
- Artificial aggregates

Natural aggregates are obtained from Stones whereas artificial aggregates can be obtained from blast furnace slag, over burnt bricks etc.

For our study we have used natural aggregates.

Aggregates can be differentiated on the basis of their shape:

- Flaky aggregates
- Rounded aggregates
- Crushed aggregates
- Angular aggregates

Flaky aggregates have low strength and low workability and will be obtained from laminated rocks, rounded aggregates have high workability but low strength and are obtained from river beds. Crushed aggregates have high strength due to interlocking but are less workable and are obtained by crushing existing rocks. Angular aggregates also have high strength but low workability and are obtained from gravel Pits.

For our study we have used crushed aggregates.

Based on size there are two types of aggregates used in concrete:

- Coarse aggregate
- Fine aggregate

3.2.1 Coarse aggregate

Aggregate which are retained on 4.75mm sieve are called coarse aggregate.

For our study we have used coarse aggregates such that they are crushed aggregates. In each batch of concrete prepared half of the total coarse aggregate used have nominal size of 10mm and the other half of coarse aggregate have 20 mm nominal size.

Figure 3.2: 20 mm aggregates used

Figure 3.3: 10mm aggregate used

Nominal Size(mm)	Percentage of total coarse aggregate
20	50
10	50

Table 3.5: Coarse Aggregate composition in each batch of concrete

3.2.1.1 Specific Gravity and water absorption of Coarse aggregate

After mixing equally by weight both types of coarse aggregate the specific gravity of C.A. was obtained in accordance to IS-2386-Part-3, 1963

W_1 = Weight of aggregate and water along with container in grams

W_2 = Weight of water and container in grams

W_3= Weight of aggregates in grams in saturated and surface dry phase

W_4 = Weight of aggregates after oven drying in grams

Specific gravity = W_4 / [W_3 - (W_1 - W_2)]

Water absorption = (W_3 - W_4)100 / W_4

W1 =3386g

W2 =2754g

W3 =1000g

W4 =992g

Specific gravity = 992 / [1000 - (3386 - 2754)] = 2.70

Water absorption (%) = (1000 - 992)100 / 992 = .8%

3.2.2 Fine aggregate

Aggregates which pass through 4.75mm sieve are known as fine aggregate.

In India Sand obtained from a region called Ennore is treated as standard sand. River sand which is grey in colour is widely used sand though in Delhi region a variety of sand called Badarpur Sand is profoundly available. For this thesis Badarpur sand has been used.

Figure 3.4: Sand used

3.2.2.1 Grading of fine aggregate

Particle size distribution analysis was done as per IS 2386-Part-1-1963

Weight 0f sample taken = 1000 grams

Sieve size(mm)	Weight retained(grams)	Percentage weight retained	Cumulative percentage weight retained	Percentage finer
4.75	11	1.1	1.1	98.9
2.36	8.9	.89	1.99	98.01
1.18	39.1	3.91	5.9	94.1
.6	500	50	55.9	44.1
.3	391	39.1	95	5
.15	42.7	4.27	99.27	.73

Table 3.6: Sieve analysis of sand

As per Table 9 of IS 383-2016 the fine aggregates belong to Zone II grading.

3.2.2.2 Fineness modulus

$$\text{Fineness modulus} = \frac{1.1+1.99+5.9+55.9+95+99.27}{100} = 2.59$$

3.2.2.3 Specific gravity and water absorption of Fine aggregate

IS-2386-Part-3, 1963 was used for finding specific gravity and water absorption of fine aggregate.

R1 = weight of sample in saturated but surface dry condition measure in grams

R2 = weight of sample and water filled in glass jar along with pycnometer in grams

R3 = weight of water in pycnometer along with weight of glass jar in grams

R4 = weight of oven dried sample in grams

Specific gravity = $R_4 / [R_1 - (R_2 – R_3)]$

Water absorption (%) = $(R_1 - R_4)100 / R_4$

R1 = 500 gram

R2 =1827 gram

R3 =1517 gram

R4 =495 gram

Specific gravity = 495 / [500 - (1827 – 1517)] = 2.60

Water absorption (%) = (500 - 495)100 / 495 = 1%

3.3 Superplasticizer

Super plasticizer are chemical additives used to increase workability at same water content and hence can also be used to reduce water content without altering the workability, as the Abram's states that on decreasing water cement ratio strength of concrete increases hence, superplasticizer is used to achieve higher strengths of concrete.

Some of the super plasticizer traditionally used are sulphonated naphatamine based, sulphonated melamine based. For this study polycarboxylate based super plasticizer procured from Kunaplast Company was used.

Figure3.5: Kunaplast super plasticizer

Properties of super plasticizer as supplied by the manufacturer:

Appearance	Brown coloured
Mass	1.07±.03 kg per litre
Ph	Greater than 6
Advised dosage	.25 to 2 percent of cement weight

Table 3.7: Used Super plasticizer properties

3.4 Nano Titanium Dioxide

Type	Anatase
Specific Surface Area	35-60 m^2/g
Specific gravity	3.7-3.8
Size	21 nm
Melting point	1830°C

Table 3.8: Used Nano TiO_2 properties

Figure 3.6: Nano TIO_2 used

3.5 Nano Silica

Figure 3.7: Nano silica used

Specific Surface area	180-220 m^2/g
Size	10-12nm
Specific gravity	1.1
Melting point	1550°C

Table 3.9: Properties of nano Silica used

CHAPTER 4

EXPERIMENTAL PROGRAMME

4.1 Design mix

For this thesis M50 grade concrete as per IS 10262:2009 was developed.

Characteristic compressive strength required after 28 days = 50MPa

- Target Mean strength after 28 days = f_{ck} + 1.65 x S

  = 50 + 1.65 x 5 [S=5, for M-50 concrete]

  = 58.25 MPa
- Design done using a W/C of 0.35
- Maximum nominal size aggregate used = 20mm
- Maximum water content for 20 mm aggregates(SSD) = 186 Kg(for 25-50mm slump)
- Slump desired = 75-100mm

  Therefore, water content = 186[1 + (6 / 100)] = 197.16Kg

  Trial mix designed using 197.16 kg of water content had less slump than desired , instead the desired slump was reached at a water content of water was about 12% above 186 Kg(other contents adjusted accordingly to maintain a constant W/C of .35) which amounted to 209 kg
- A water reduction of 14% due to super plasticizer was considered.

  Hence finally used water content is 209 x .86 = 179.74kg
- As W/C =.35

  Cement (C) = 179.74 / .35 = 513.5kg
- As zone of sand is 2, hence ratio of $V_{C.A.}$ (Volume of C.A) to $V_{T.A.}$ (Volume of total aggregates). is .62 for W/C of .5 subjected to an increase of .1 for each .05 decrease in W/C

  Hence, for W/C = .35

  $V_{C.A.} / V_{T.A.}$ = .62 + 3 x .01

  $V_{C.A.} / V_{T.A.}$ = .65

The mix is designed pumpable, hence a further reduction in of .1 is made in $V_{C.A.}/ V_{T.A}$ value so

value of $V_{C.A.} / V_{T.A}$ adopted = .9 x .65 = .59

So $V_{C.A.} / V_{T.A.} =$ .59

Hence $V_{F.A.} / V_{T.A.} =$ 1 - .59 = .41, here $V_{F.A.}$ is volume of fine aggregate

- Mix calculation

As adopted value of super plasticizer is only .3% of weight of cement hence its mass and volume have not been considered while designing the mix

Concrete's volume = 1 m^3

Volume of Cement (V_C) = 513.5 / (3.1x1000) = .166 m^3

Volume of water (V_W) = 179.74 / (1000) = .179 m^3

Volume of total aggregate $V_{T.A.}$ = 1- V_C - V_W

$V_{T.A.}$ = 1 - .166 - .179 = .655 m^3

Mass of Coarse aggregate = $V_{T.A}$ x ($V_{C.A.} / V_{T.A.}$) x $S_{C.A.}$ x 1000

= .655 x .59 x 2.70 x 1000

= 1043.4 kg

Mass of Fine aggregate = $V_{T.A}$ x ($V_{F.A.} / V_{T.A.}$) x $S_{F.A.}$ x 1000

= .655 x .41 x 2.60 x 1000

= 698.23 kg

Mass of super plasticizer = .3% of weight of cement

= (.3 / 100) x 513.5

= 1.54 Kg

Quantities of constituent required per cubic metre of concrete

Water = 179.74 Kg

Cement = 513.5 Kg

Coarse aggregate = 1043.4 Kg

Fine aggregate = 698.23 Kg

Super plasticizer = 1.54 Kg

Mix proportion

Cement : FA : CA :: 513.5 : 698.23 : 1043.4

Cement: FA : CA :: 1 : 1.36 : 2.03

4.2 Batching of concrete

Figure 4.1: Batching of concrete

An attempt was made to maintain a slump value as close as possible to design mix even after addition of nano particles in concrete, for this super plasticizer dosage was adjusted as per requirement, it was observed that increasing super plasticizer by 25% of weight of total nano particles added the slump was maintained in range of 75mm-100mm.The super plasticizer used is PC based which itself works as an dispersing agent for nano particles.

Figure 4.2: Nano particles being mixed with water and super plasticizer

100mmx100mmx100mm cubes were casted for this thesis. At one time 9 cubes of concrete were casted and for the same the following amount of materials were used:

For control mix (CM)

Water	: 1.86 Kg
Cement	: 5.33 Kg
Fine aggregate	: 7.25 Kg
Coarse aggregate (20 mm)	: 5.41 Kg
Coarse aggregate (10 mm)	: 5.41 Kg
Super plasticizer	: 16 gram

For mix containing addition of 0.5% each of nano titanium dioxide and nano silica(S/T .5)

Water	: 1.86 Kg
Cement	: 5.33 Kg
Fine aggregate	: 7.25 Kg
Coarse aggregate (20 mm)	: 5.41 kg
Coarse aggregate (10 mm)	: 5.41 Kg
Super plasticizer	: 29.3 gram
Nano silica	: 26.6 gram
Nano titanium dioxide	: 26.6 gram

For mix containing addition of 1% each of nano titanium dioxide and nano silica(S/T 1.0)

Water	: 1.86 Kg
Cement	: 5.33 Kg
Fine aggregate	: 7.25 Kg
Coarse aggregate (20 mm)	: 5.41 kg
Coarse aggregate (10 mm)	: 5.41 Kg

Super plasticizer : 42.65 gram

Nano silica : 53.3 gram

Nano titanium dioxide : 53.3 gram

For mix containing addition of 1.5% each of nano titanium dioxide and nano silica(S/T 1.5)

Water : 1.86 Kg

Cement : 5.33 Kg

Fine aggregate : 7.25 Kg

Coarse aggregate (20 mm) : 5.41 kg

Coarse aggregate (10 mm) : 5.41 Kg

Super plasticizer : 56 gram

Nano silica : 80 gram

Nano titanium dioxide : 80 gram

4.3 Mixing

Concrete was mixed in a pan mixer. Firstly concrete was dry mixed in mixer and then mixed for 2 minutes by continuous addition of water.

The super plasticizer and Nano materials were added to water and mixed well using tamping rod available in laboratory prior of being added to dry constituents of concrete.

Figure 4.3: Mixing of concrete

Figure 4.4: Concrete after mixing

4.4 Casting

Concrete was then transferred to cube mould of 100mmx100mmx100mm dimension and were compacted on vibrating table.

Figure 4.5: Casted concrete specimen

Figure 4.6: Demoulded concrete specimen

4.5 Curing

Casted cubes were left to dry in open air at room temperature inside laboratory for 24 hours, thereafter they were demoulded and transferred to curing tank to be cured for either 7 days or 28 days as per requirement.

Figure 4.7: Image of curing tank

Figure 4.8: Some specimen being cured in combined sodium sulphate and sodium chloride

4.6 Tests to be performed on concrete

4.6.1 Compressive Strength at 7 days and 28 days

After 7 and 28 days of curing the concrete were tested for their compressive strength on compression testing machine. The loading rate was maintained as 2.33KN per sec.

Figure 4.9: Specimen being tested in compression testing machine

Figure: 4.10 Specimen after failure

4.6.2 Rebound hammer test

Rebound hammer is a non-destructive test performed on concrete, it helps tell the hardness of surface of concrete, it gives idea about quality of concrete upto 30mm from surface.

It was performed on concrete after 28 days of curing.

Figure 4.11: Rebound hammer Test being performed

4.6.3 Ultrasonic Pulse Velocity test

UPVT is a non-destructive test performed on concrete, it helps us inform about density of concrete and if the concrete has voids.

It was performed on concrete after 28 days of curing.

Figure 4.12: UPV test being performed

4.6.4 Effect of chloride on compressive strength of Concrete

Chloride is present in sea water and its concentrations can reach as high as 4%, it has detrimental effect of concrete strength. Though it is present in various forms but most predominant in sodium chloride.

Cubes were casted then cured for 28 days in normal water and then for 28 days in water containing sodium chloride at a concentration of 4% by weight of water and thereafter their compressive strength was checked.

4.6.5 Effect of sulphate on compressive strength of concrete

Sulphate is present both in sea water and also in soil and affects concrete properties, sulphate is present in soil and water in forms such as magnesium sulphate, sodium sulphate. Sodium sulphate is found profoundly in both these medium, this sulphate when comes in contact with concrete has detrimental effect on strength of concrete.

For this thesis cubes casted were first cured for 28 days in normal water and then transferred to a solution containing sodium sulphate of concentration 5% by weight of water for another 28 days and then were analyzed for their compressive strength.

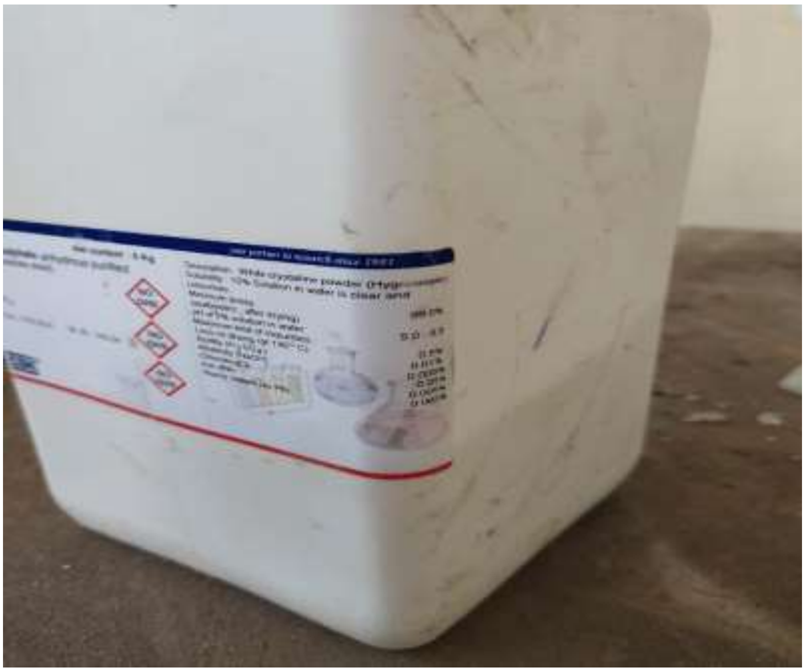


Figure 4.13: Image of Sodium sulphate packaging

Figure 4.14: Image of sodium sulphate powder

4.6.6 Combined effect of chloride and sulphate on compressive strength of concrete

Since in nature both chloride and sulphates can exist simultaneously hence an analysis of combined effect of both of these was also made.

A solution having sodium chloride 4% by weight of water and sodium sulphate of concentration 5% by weight of water was prepared and cubes were cured for 28 days after 28 days of normal curing, and then analyzed for compressive strength

4.6.7 Effect of elevated temperature on cubes compressive strength

After 28 days of normal curing the cubes were left to dry naturally for 24 hours, then oven dried for 2 hours at 90°C in order to evaporate water and avoid explosive spalling, thereafter they were placed in muffle furnace and temperature was raised to 400°C in one and a half hour and then this temperature was maintained for 3 hours, thereafter they were let to naturally dry for 24 hours and then their compressive strength was checked.

Figure 4.15: Specimen being heated at 90°C in oven

Figure 4.16: Specimen being heated at 400°C in muffle furnace

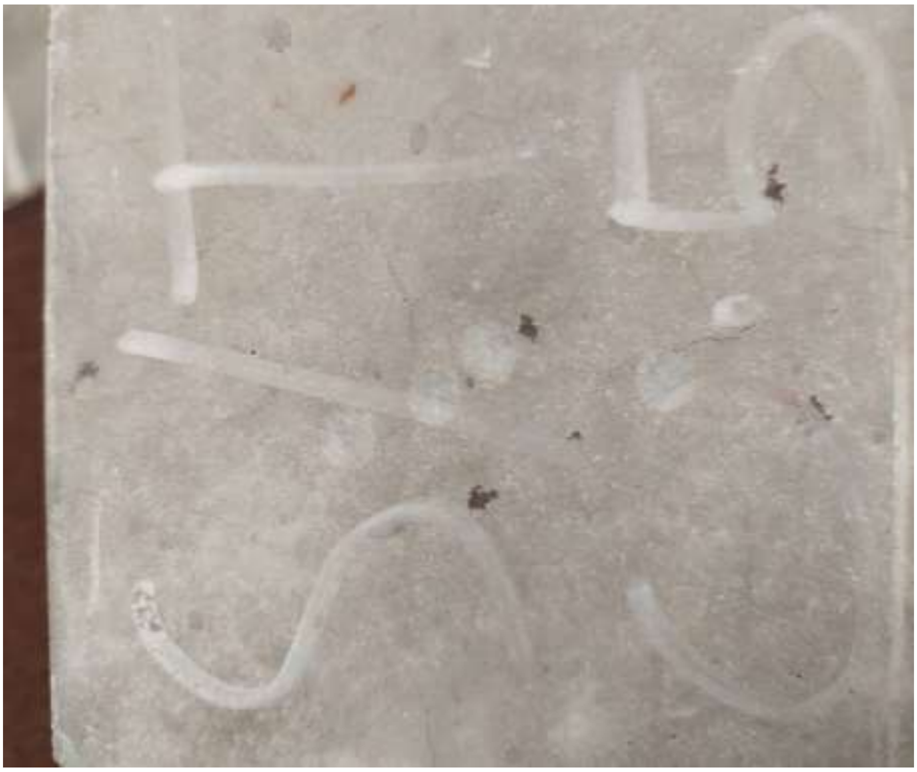


Figure 4.17: Hairline cracks after specimen subjected to 400°C

CHAPTER 5

RESULTS

5.1 Compressive strength at 7 days

	C/M	S/T .5	S/T 1	S/T 1.5
Specimen 1 (MPa)	41.45	49.8	49.54	53
Specimen 2 (MPa)	40.32	46.1	47.14	48.96
Specimen 3 (MPa)	37.66	41.44	45.4	47.23
Average strength (MPa)	**39.81**	**45.78**	**47.36**	**49.73**

Table 5.1: 7 days compressive strength of different mix cubes

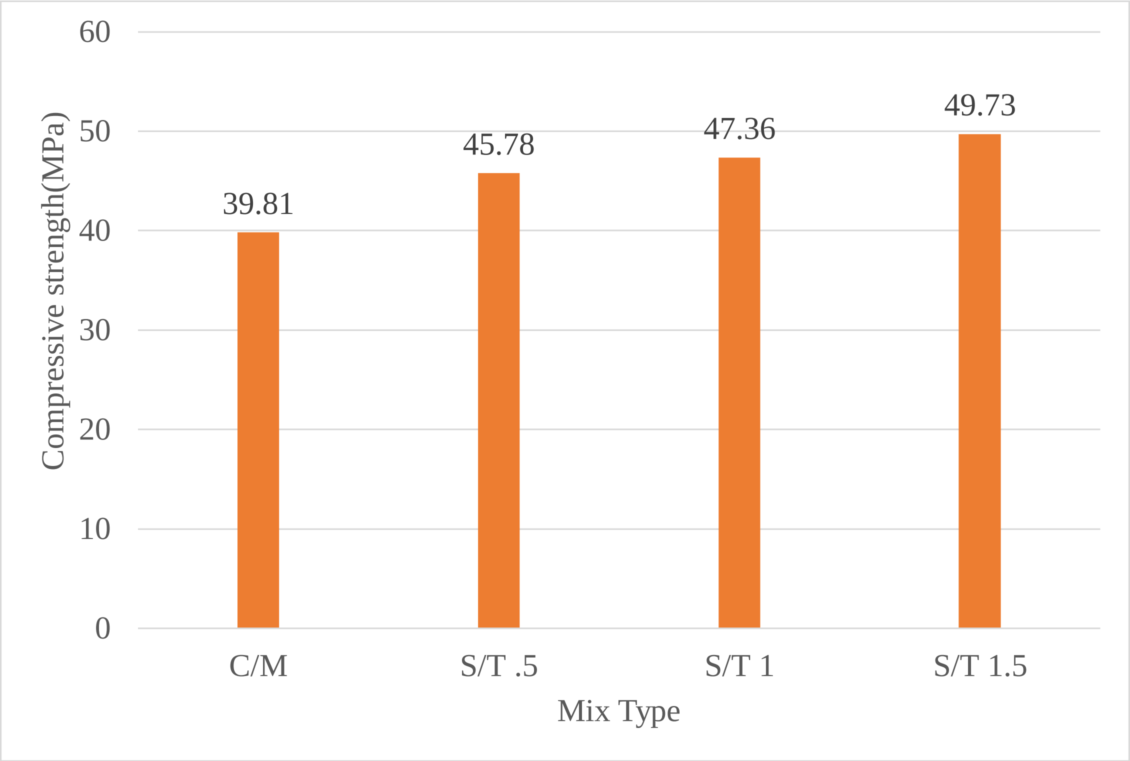


Figure 5.1: Average compressive strength of cubes of different mix after 7 days of curing

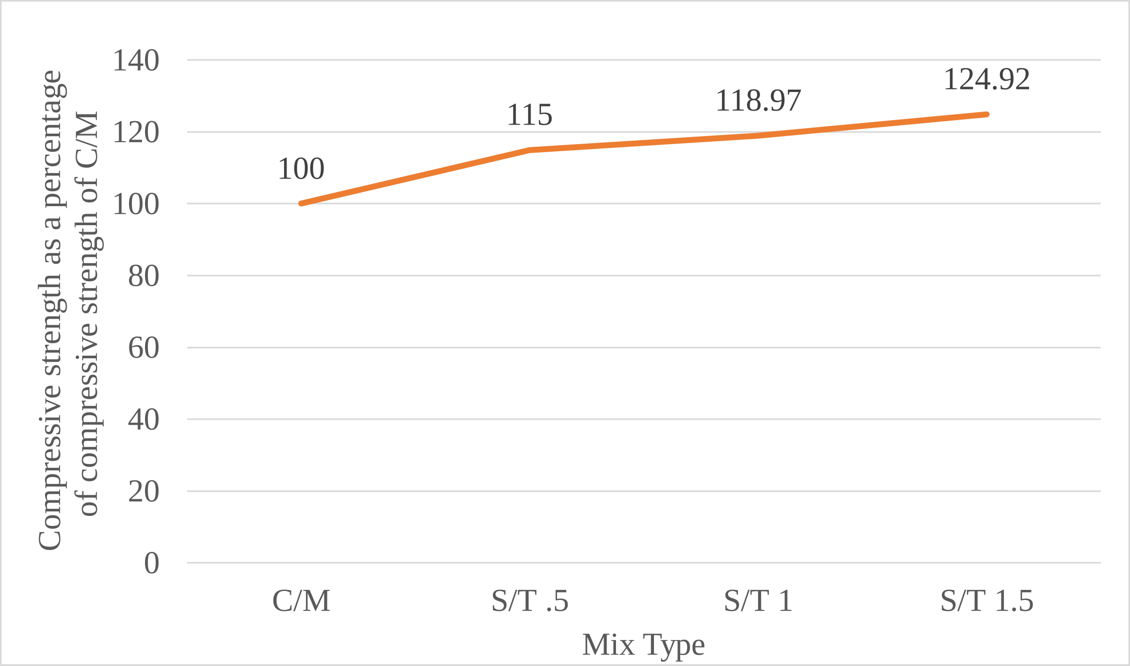


Figure 5.2: Average compressive strength of different mix after 7 days of curing as a percentage of compressive strength of C/M

5.2 Compressive strength at 28 days

	C/M	S/T .5	S/T 1	S/T 1.5
Specimen 1 (MPa)	64.3	69.7	75	79.36
Specimen 2 (MPa)	61.83	68.17	72.32	77.44
Specimen 3 (MPa)	57.62	64.12	61.3	64
Average strength (MPa)	**61.25**	**67.33**	**69.54**	**73.6**

Table 5.2: 28 days compressive strength of different mix cubes

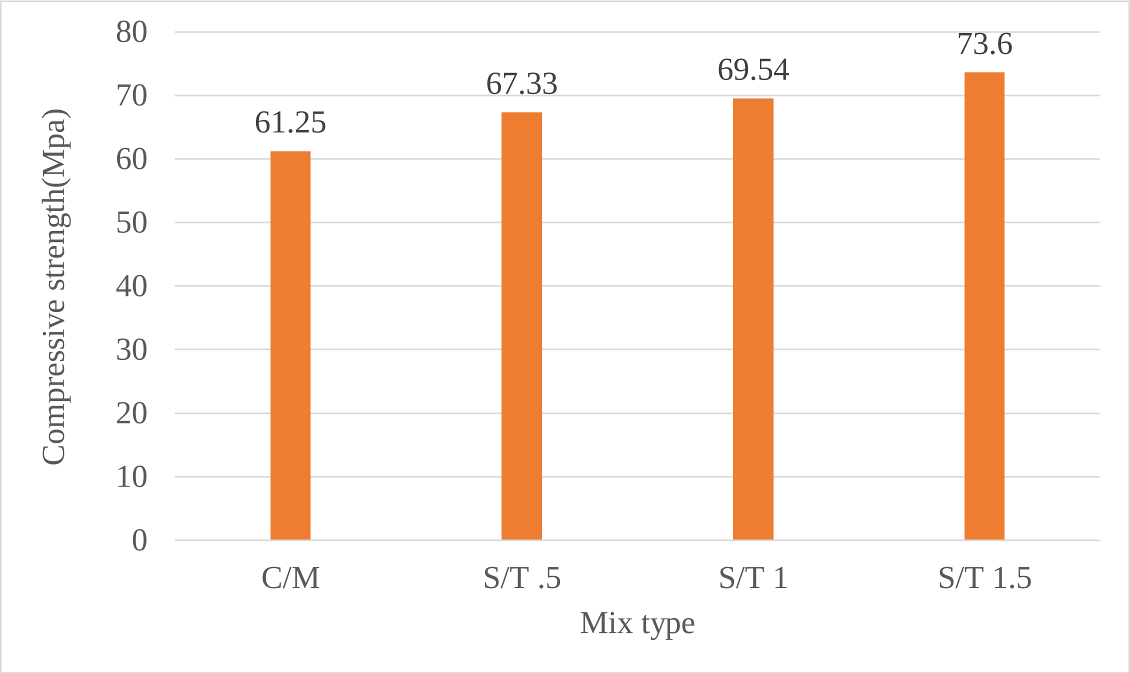


Figure 5.3: Average compressive strength of cubes of different mix after 28 days of curing

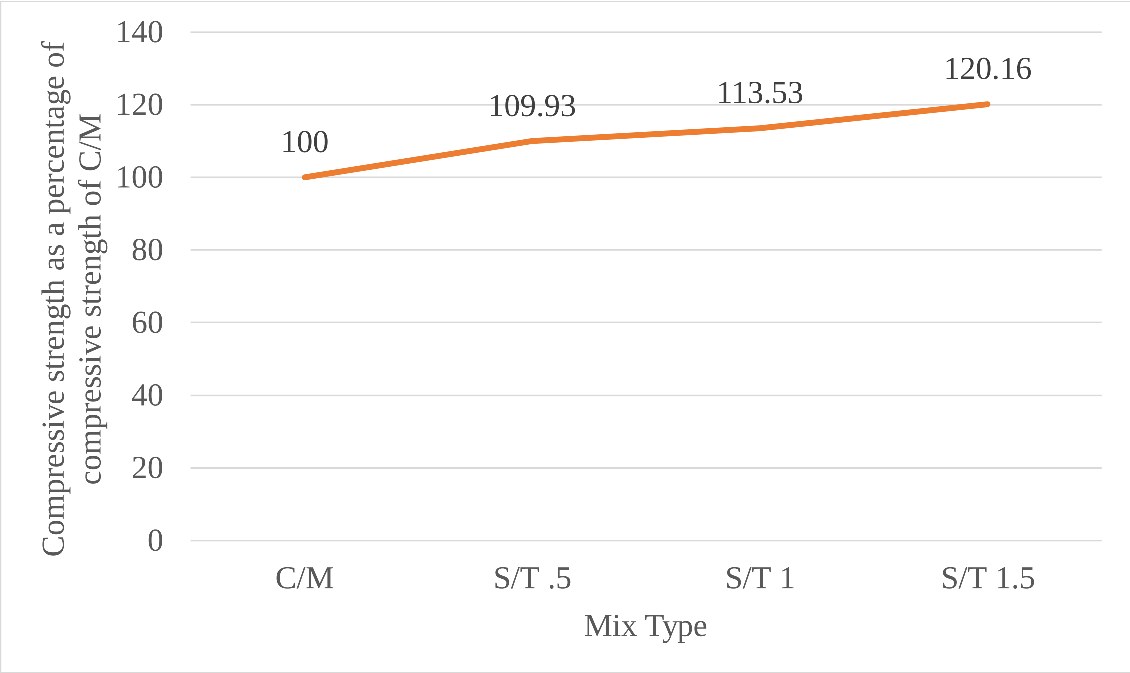


Figure 5.4: Average compressive strength of different mix after 28 days of curing as a percentage of compressive strength of C/M

5.3 Rebound hammer values at 28 days

	C/M	S/T .5	S/T 1	S/T 1.5
Specimen 1	51.3	51.8	54.8	56
Specimen 2	50.5	51.6	53.9	56
Specimen 3	47.3	51.4	52.5	52.5
Average Rebound No.	**49.70**	**51.60**	**53.73**	**54.83**

Table 5.3: Rebound hammer values at 28 days of different mix cubes

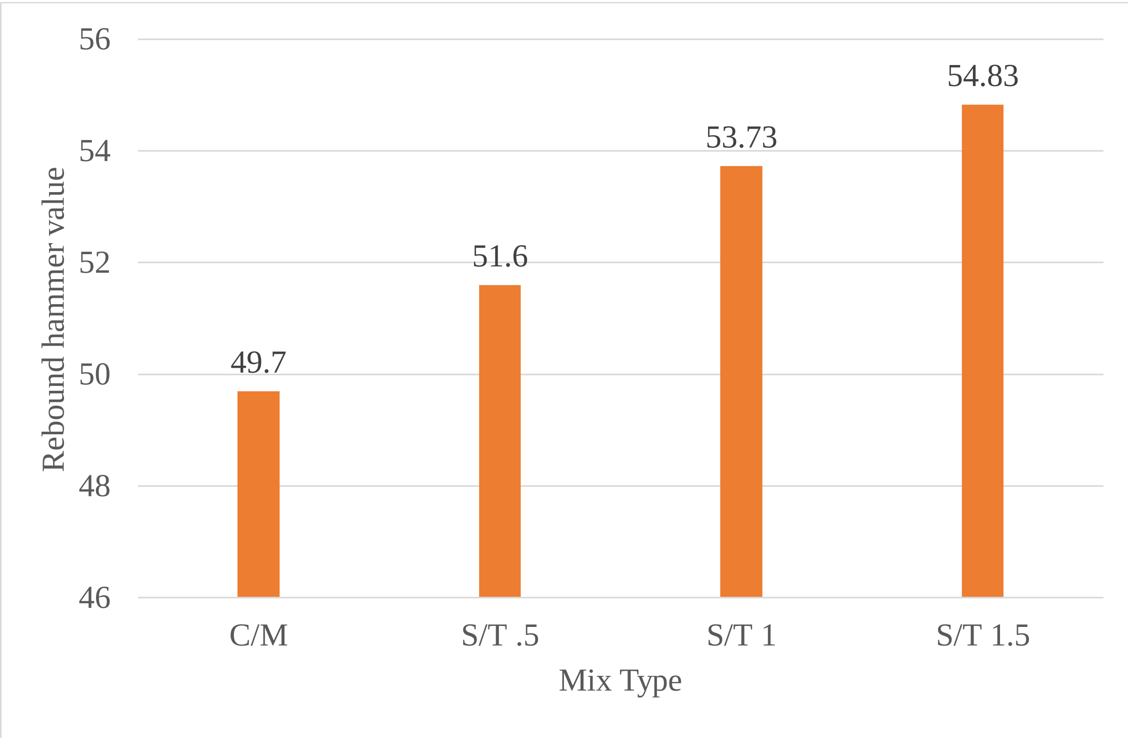


Figure 5.5: Average Rebound hammer values at 28 days of different mix

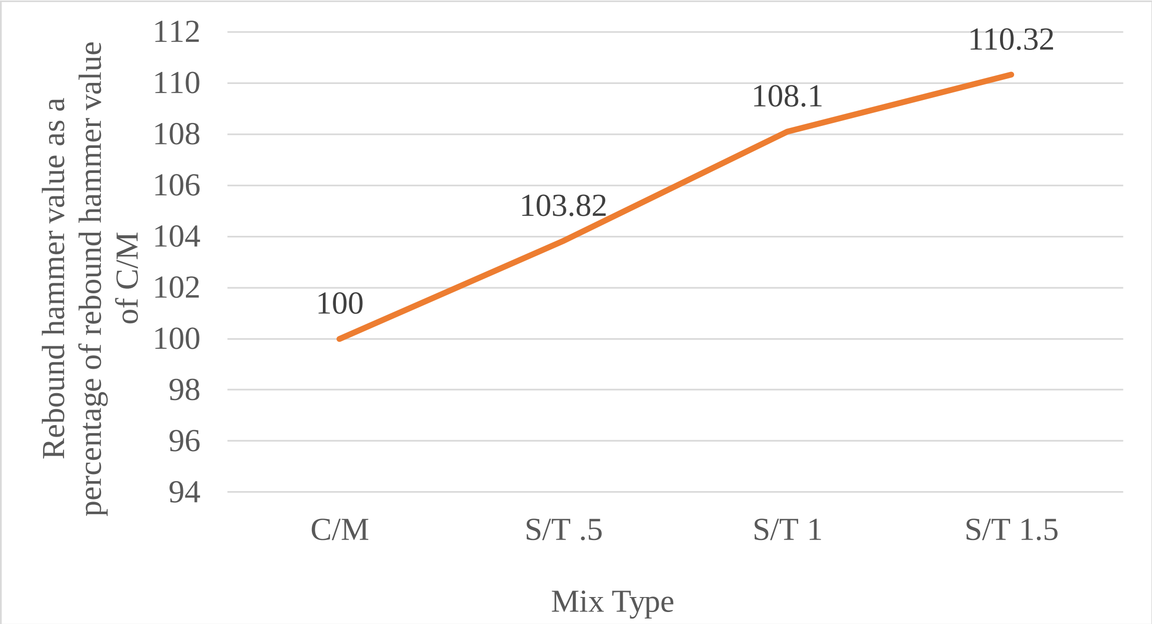


Figure 5.6: Average rebound hammer values of different mix at 28 days as a percentage of rebound hammer value of C/M

5.4 UPVT values at 28 days

	C/M	S/T .5	S/T 1	S/T 1.5
Specimen 1 (Km/sec)	3.93	4.30	4.46	4.56
Specimen 2 (Km/sec)	3.86	4.21	4.41	4.46
Specimen 3 (Km/sec)	3.85	4.18	4.33	4.42
Average strength (Km/sec)	**3.88**	**4.23**	**4.40**	**4.48**

Table 5.4: UPVT values at 28 days of different mix cubes

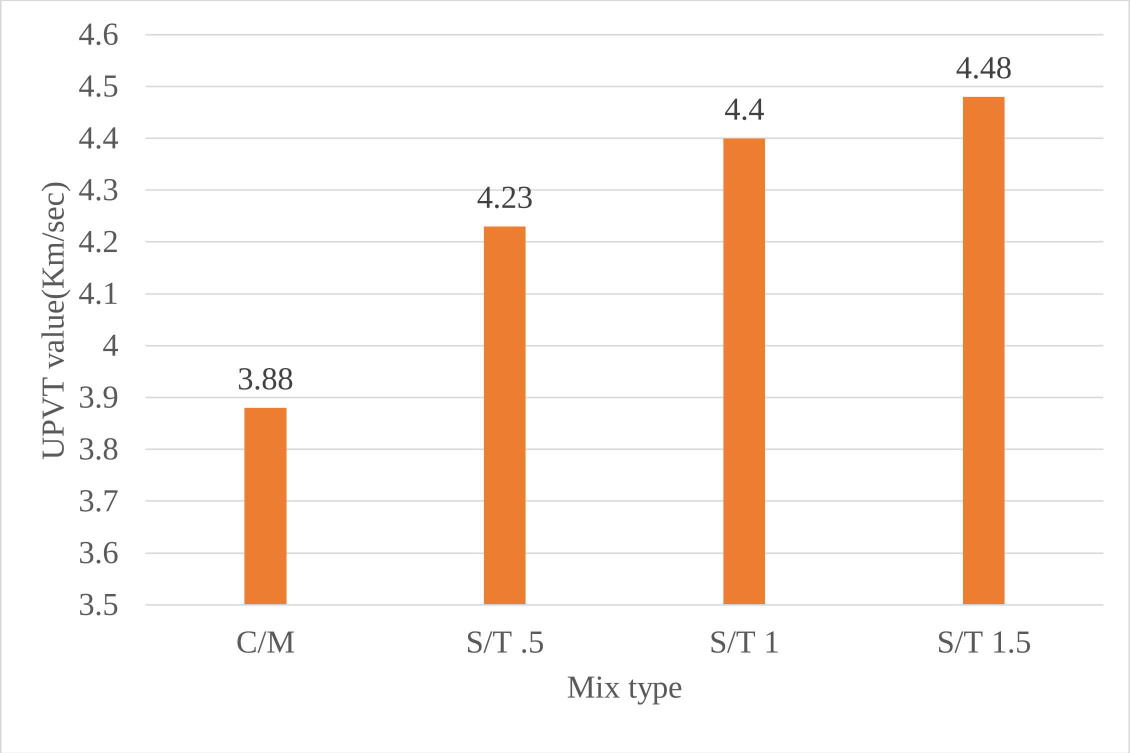


Figure 5.7: Average UPVT values (Km/sec) at 28 days of different mix

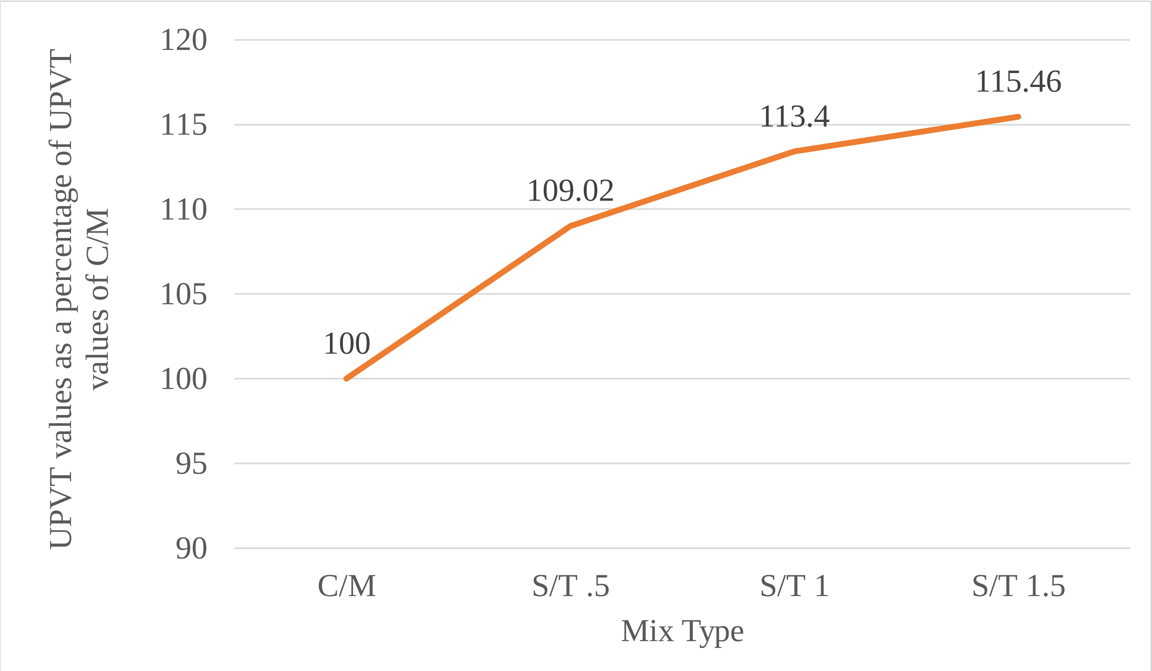


Figure 5.8: Average UPVT values of different mix at 28 days as a percentage of UPVT values of C/M

5.5 28 days chloride curing compressive strength

	C/M	S/T .5	S/T 1	S/T 1.5
Specimen 1 (MPa)	63.05	68.30	71.81	76.27
Specimen 2 (MPa)	58.13	65.19	69.50	70.35
Specimen 3 (MPa)	53.18	62.35	61.28	67.97
Average strength (MPa)	**58.12**	**65.28**	**67.53**	**71.53**

Table 5.5: 28 days chloride curing compressive strength of different mix cubes

MIX TYPE	28 days normal water curing	Compressive strength after 28	Percentage

	compressive strength(Mpa)	days of chloride curing(Mpa)	variation
C/M	61.25	58.12	-5.1
S/T .5	67.33	65.28	-3.04
S/T 1	69.54	67.53	-2.89
S/T 1.5	73.6	71.53	-2.81

Table 5.6: Compressive strength comparison between normal curing with chloride curing

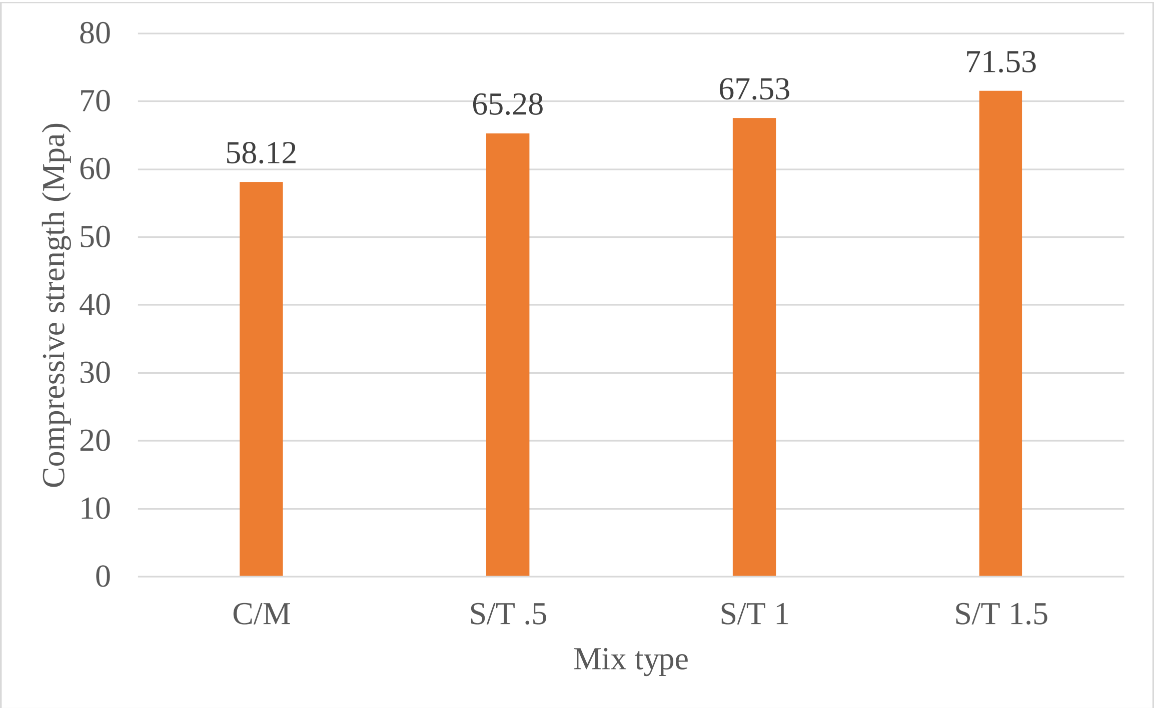


Figure 5.9: Average 28 days chloride curing compressive strength of different mix

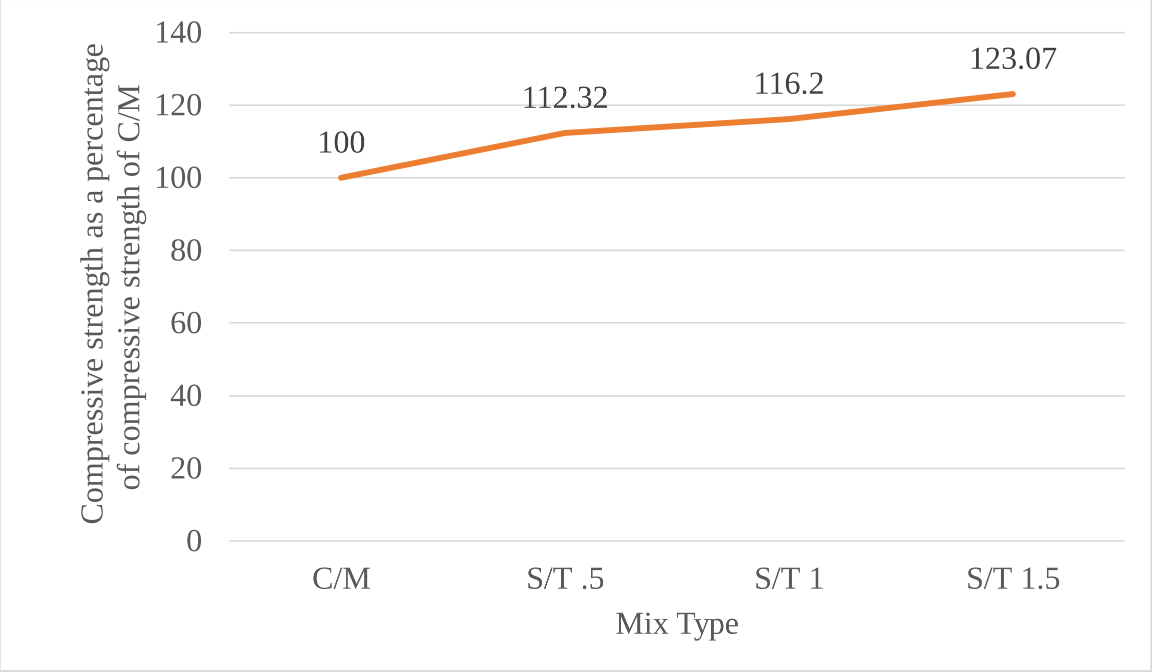


Figure 5.10: Average 28 days chloride curing compressive strength of different mix as a percentage of 28 days chloride curing compressive strength of C/M

5.6 28 days sulphate curing compressive strength

	C/M	S/T .5	S/T 1	S/T 1.5
Specimen 1 (MPa)	55.16	65.30	69.83	74.30
Specimen 2 (MPa)	54.99	59.15	66.58	66.89
Specimen 3 (MPa)	52.24	58.49	53.79	61.37
Average strength (MPa)	**54.13**	**60.98**	**63.40**	**67.52**

Table 5.7: 28 days sulphate curing compressive strength of different mix cubes

MIX TYPE	28 days normal water curing compressive strength(Mpa)	Compressive strength after 28 days of sulphate curing(Mpa)	Percentage variation
C/M	61.25	54.13	-11.62
S/T .5	67.33	60.98	-9.43
S/T 1	69.54	63.40	-8.83
S/T 1.5	73.6	67.52	-8.26

Table 5.8: Compressive strength comparison between normal curing with sulphate curing

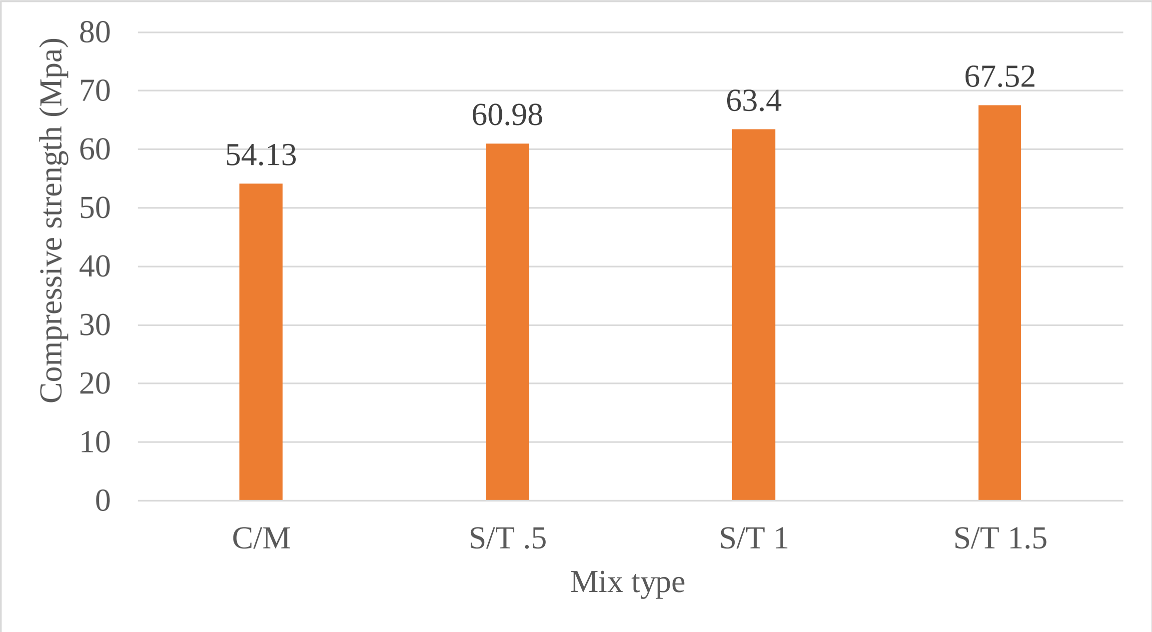


Figure 5.11: Average 28 days sulphate curing compressive strength of different mix

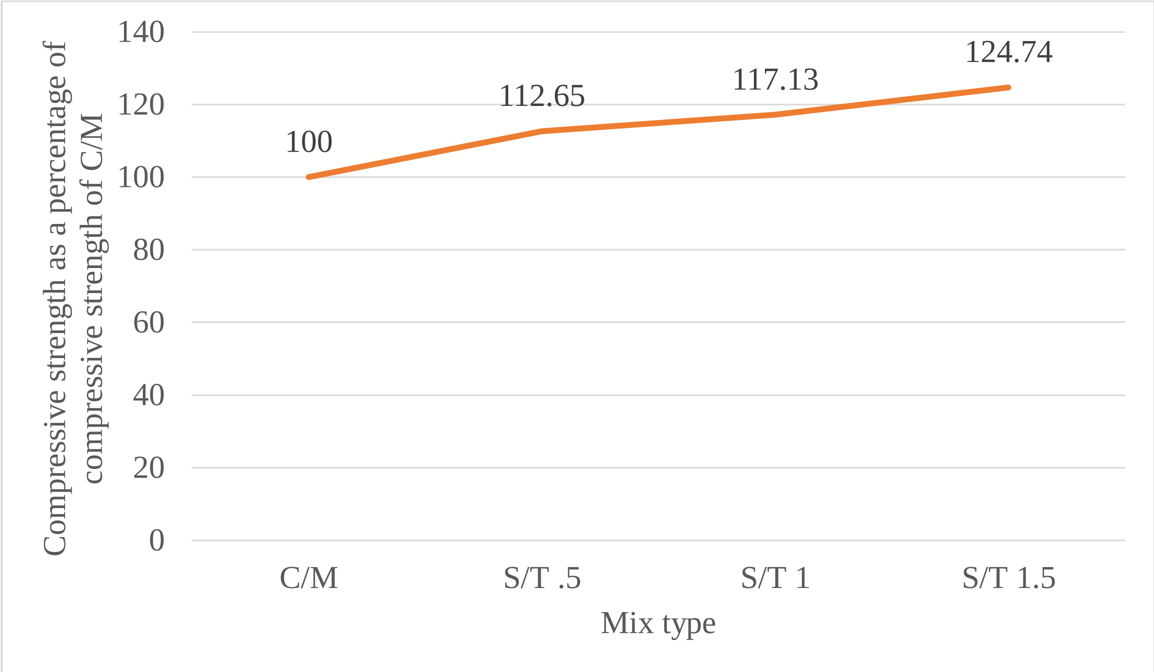


Figure 5.12: Average 28 days sulphate curing compressive strength of different mix as a percentage of 28 days sulphate curing compressive strength of C/M

5.7 28 days combined sulphate and chloride curing compressive strength

	C/M	S/T .5	S/T 1	S/T 1.5
Specimen 1 (MPa)	62.35	67.85	73.45	76.86
Specimen 2 (MPa)	58.37	63.80	68.99	69.44
Specimen 3 (MPa)	52.92	63.26	59.70	67.99
Average strength (MPa)	**57.88**	**64.97**	**67.38**	**71.43**

Table 5.9: 28 days combined sulphate and chloride curing compressive strength of different mix cubes

MIX TYPE	28 days normal water curing compressive strength(MPa)	Compressive strength after 28 days of combined sulphate and chloride curing(MPa)	Percentage variation
C/M	61.25	57.88	-5.50
S/T .5	67.33	64.97	-3.50
S/T 1	69.54	67.38	-3.10
S/T 1.5	73.6	71.43	-2.95

Table 5.10: compressive strength comparison between normal curing with combined sulphate and chloride curing.

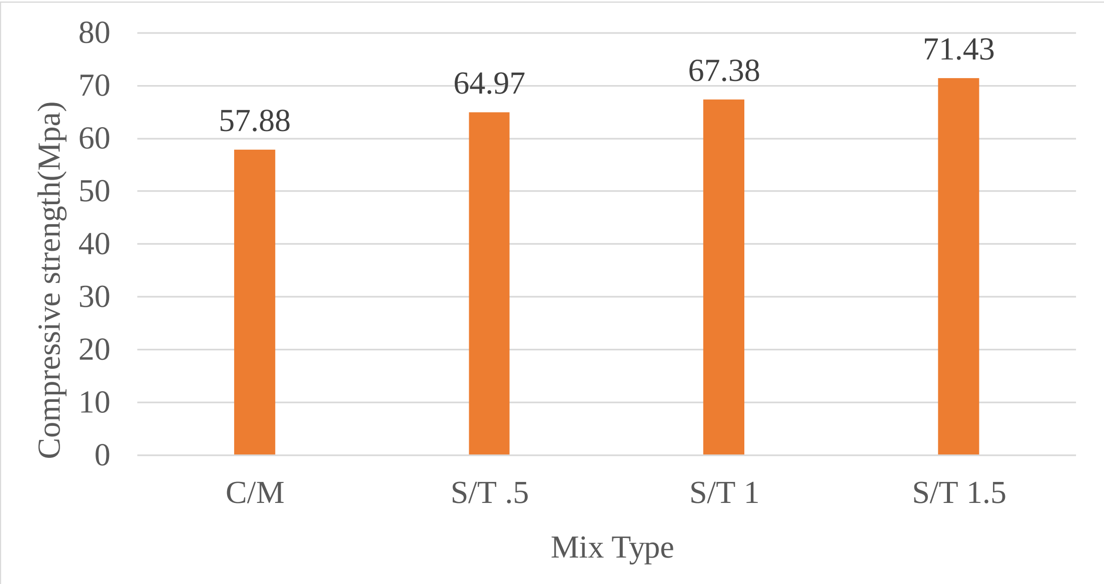


Figure 5.13: average 28 days combined sulphate and chloride curing compressive strength of different mix

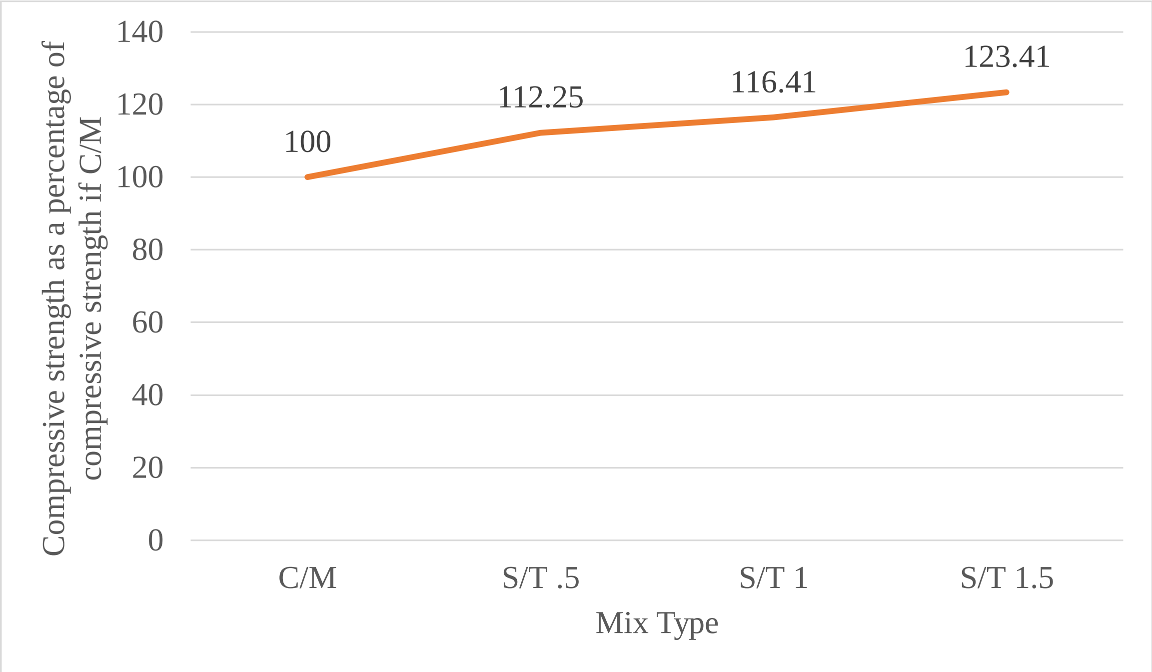


Figure 5.14: Average 28 days combined sulphate and chloride curing compressive strength of different mix as a percentage of 28 days combined sulphate and chloride curing compressive strength of C/M

5.8 Effect of elevated temperature on compressive strength

	C/M	S/T .5	S/T 1	S/T 1.5
Specimen 1 (MPa)	51.36	62.58	61.80	67.35
Specimen 2 (MPa)	48.01	56.80	56.64	56.89
Specimen 3 (MPa)	40.28	52.37	55.35	54.62
Average strength (MPa)	**46.55**	**57.25**	**57.93**	**59.62**

Table 5.11 Compressive strength of different mix cubes after subjected to elevated temperature

MIX TYPE	28 days normal water curing compressive strength(MPa)	Compressive strength after specimen subjected to elevated temperature(MPa)	Percentage variation
C/M	61.25	46.55	-24
S/T .5	67.33	57.25	-14.97
S/T 1	69.54	57.93	-16.7
S/T 1.5	73.6	59.62	-18.99

Table 5.12: Compressive strength comparison between normal curing with post elevated temperature.

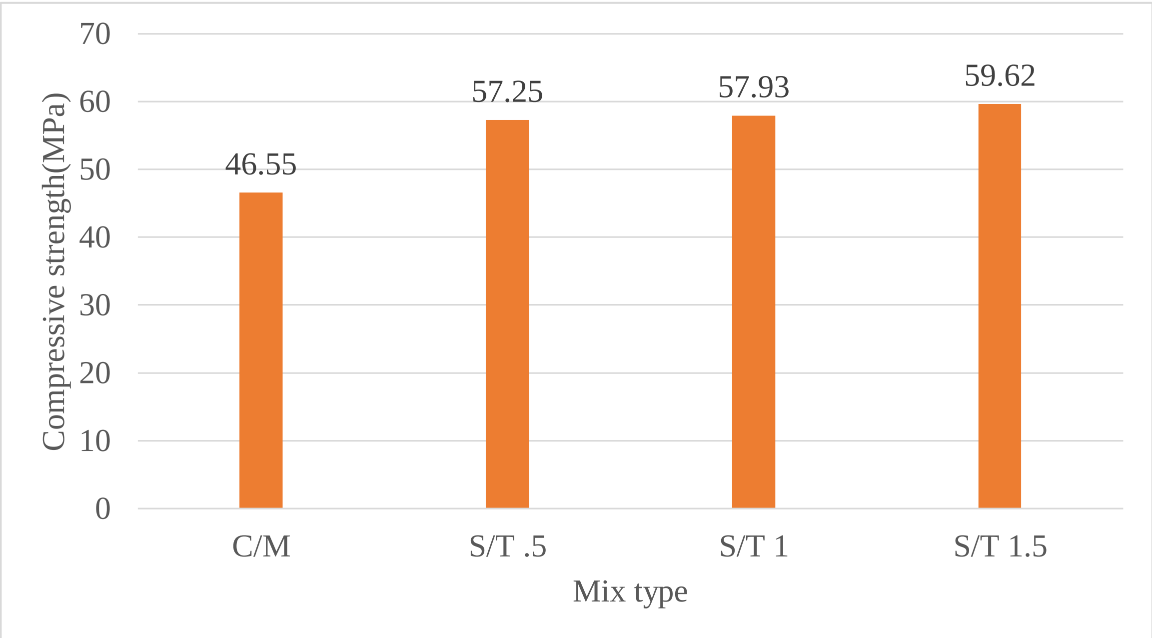


Figure 5.15: Effect of elevated temperature on average compressive strength of different mix cubes

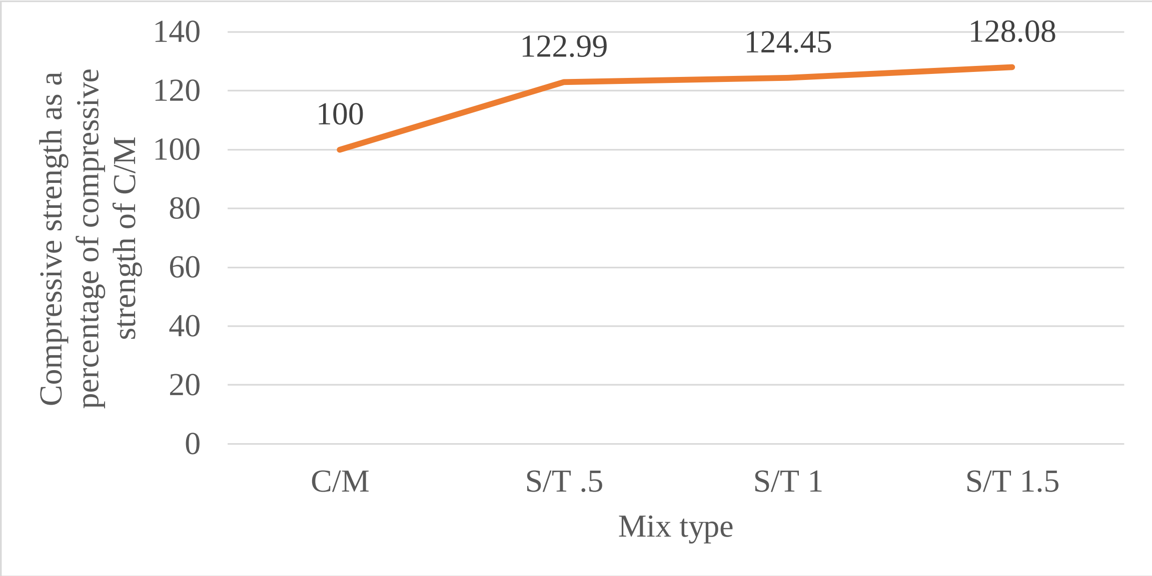


Figure 5.16: Effect of elevated temperature on average compressive strength of different mix cubes as a percentage of Effect of elevated temperature on average compressive strength of C/M

CHAPTER 6

CONCLUSION AND SCOPE OF FUTURE WORK

6.1 Conclusion

After analyzing all the experiments done the following points can be concluded:

- Compressive strength at 7 days enhanced by addition of nano silica and nano titanium dioxide in all three proportion with maximum gain of 24.92 % in S/T 1.5 mix.
- Compressive strength at 28 days enhanced by addition of nano silica and nano titanium dioxide in all three proportion with maximum gain of 20.16 % in S/T 1.5 mix.
- Rebound hammer value kept on increasing with addition of nano materials in mix. Maximum rebound hammer value was obtained in S/T 1.5 mix which was 10.32% higher than that of control mix.
- UPVT value kept on increasing with addition of nano materials in mix. Maximum UPVT value was obtained in S/T 1.5 mix which was 15.46% higher than that of control mix.
- Chloride curing for 28 days after 28 days of normal curing also witnessed that more the nano material in concrete less is the deterioration in compressive strength with minimum deterioration of 2.81% of 28 days compressive strength occurring in S/T 1.5 mix on the contrary deterioration was highest in control mix amounting to 5.1% of its 28 days compressive strength.
- Sulphate curing for 28 days after 28 days of normal curing also witnessed that more the nano material in concrete less is the deterioration in compressive strength with minimum deterioration 8.26% of 28 days compressive strength occurring in S/T 1.5 mix on the contrary this deterioration was highest in control mix amounting to 11.62% of its 28 days compressive strength.

- Combined chloride and sulphate curing for 28 days after 28 days of normal curing also witnessed that more the nano material in concrete less is the deterioration in compressive strength with minimum deterioration 2.95% of 28 days compressive strength occurring in S/T 1.5 mix on the contrary this deterioration was highest in control mix amounting to 5.5% of its 28 days compressive strength.
- At elevated temperature of 400°C, all mix types witnessed a reduction in strength, with maximum reduction of 24% of 28 days compressive strength witnessed in control mix, it was also observed that with addition of nano material the percentage reduction in strength decreased as compared to control mix, in mixes where nano material were introduced the minimum percentage reduction which amounted to 14.97% of 28 days compressive strength of respective mix was observed in S/T .5 mix and maximum reduction of strength which amounted to 18.99% of 28 days compressive strength of the mix was observed in S/T 1.5 mix.

6.2 Scope of future work

- Since all properties of concrete except response to elevated temperature were seen to improve till maximum concentration of nano materials used in this study hence, further studies of higher addition of these two nano materials added together can be be studied.
- This study only analyze the effect of 28 days of various aggressive environment effect on concrete with these two nano materials hence studies incorporating longer time duration can be performed.
- The study on uses on elevated temperature of 400°C, so new studies studying the effect of various other temperatures can be performed.
- Compressive strength at longer duration of curing can be also studied.

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