HIGH PERFORMANCE CONCRETE USING NANO TITANIUM DIOXIDE AND METAKAOLIN AS ADDITIVE

MAJOR PROJECT REPORT

SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
FOR THE AWARD OF THE DEGREE
OF

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Submitted by:

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CANDIDATE'S DECLARATION

I, Vivek Yadav, Roll No. 2K18/STE/016 student of M.Tech. (Structural Engineering), hereby declare that the project Dissertation titled "HIGH PERFORMANCE CONCRETE USING NANO TITANIUM DIOXIDE AND METAKAOLIN AS ADDITIVE" 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.

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I hereby certify that the Project Dissertation titled "HIGH PERFORMANCE CONCRETE USING NANO TITANIUM DIOXIDE AND METAKAOLIN AS ADDITIVE" which is submitted by VIVEK YADAV, Roll No 2K18/STE/016, 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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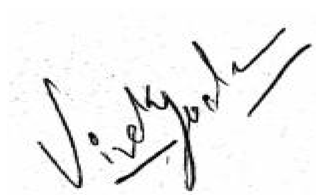

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ABSTRACT

In the modern developing world, the environmental protection is compromised due to increasing pollution with rapid development across various countries. The major problem arises is to maintain quality of development without having any negative impact over the environment. Use of new innovations and materials like nano particles containing high performance concrete can solve this issue without compromising the quality and environmental protection. Cement concrete has significant problems in achieving high compressive strength and high durability in structures.

In this content, metakaolin is a material with pozzolanic property which is used in wide variety of partial replacement of cement in concrete that has been treated as economical and also improves the strength and durability of concrete structure and making concrete with titanium dioxide and cement, which helps in removing smog from the atmosphere when the concrete is exposed to ultraviolet light. In order to clean smog air, the nitrogen oxides available need to be converted into different, less hazardous compounds such as ions of nitrate. The nitric acid is produced from the reaction of nitrate ions; this acid chemically reacts with the grout to form a less harmful neutral salt which is washed away using precipitation. This reaction occurs at slow rate in nature. The reaction is increased up with the presence of titanium dioxide, which serves as photo catalyst, which means it accelerate the reaction in the presence of light. The addition of metakaolin and titanium dioxide in cement concrete as a partial substitute material for cement is reviewed in this analysis that shows excellent results.

This will save the energy and natural resources and results in waste material reduction which leads to environmental protection. The techniques have already been incorporated into different concrete structures and undergoing performance testing. Concrete infused with titanium dioxide and metakaolin have better and increased compressive strength and flexural strength than ordinary concrete, providing both environmental and structural advantage.

In the analysis, the effect of Macro metakaolin particles and Nano Titanium Dioxide (TiO_2) is determined on ordinary Concrete of M-50 grade using different proportions as 0.5%, 1.0%, 1.5% of Titanium Dioxide and 5%, 10%, 15% of metakaolin in regarding with the cement weight. The Strength parameter, Workability at various proportions of Metakaolin along with Titanium Dioxide is tested at various time durations.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

Abbreviation

HPC : High Performance Concrete

MK : Metakaolin

TiO_2 : Titanium Dioxide

SP : Super Plasticizer

FM : Fineness Modulus

CA : Coarse Aggregate

FA : Fine Aggregate

PC : Poly Carboxylic

HRWRA : High Range Water Reducing Agent

OPC : Ordinary Portland Cement

nm : Nanometer

f_{ck}: Mean Compressive Strength of Concrete

w/c : Water Cement ratio

CaO : Calcium Oxide

SiO_2 : Silica Dioxide

Al_2O_3 : Aluminum Oxide

UPV : Ultrasonic Pulse Velocity

CHAPTER 1

INTRODUCTION

In construction, the most commonly used material is cement concrete. Concrete structures requiring regular repair and maintenance are a growing issue that requires considerable cost. Due to which processing of material was made possible worldwide to meet performance satisfaction including durability in long term. HPC is becoming very popular in recent time in development of concrete structures such as Flyovers, Nuclear power projects, multi-storied structures. Due to consideration of cost savings, energy savings and environmental issues both in terms of harm incurred by the production of raw materials and emission of carbon dioxide during the manufacture of cement for HPC has increased significantly with the growth of the cement industry.

1.1 CONCRETE

The flexibility of producing cement concrete from materials which are locally available has made concrete the second largest consumed material on earth and also makes it easy to form it into any size and shape and economy in its manufacturing.

- Concrete is manufactured more than any other materials which are manmade. Yearly manufacturing shows one thousand kilogram for each people on this earth.
- Concrete is used in all major construction projects due to its versatility.
- The purpose of aggregates used in concrete is to provide around 60 % to 75 % of the total volume of a mixture of concrete which also affects the economics of structure since aggregates used in concrete are not very costly.
- The productions of materials used in construction project are responsible for the emission of 80% CO_2 during structure design life cycle.
- The production of concrete is highly affordable and less expansive in comparison to the other building materials.

1.2 METAKAOLIN

Kaolin is a type of clay mineral which involves four various polymorphs namely, kaolinite, halloysite, nacrite and dickite. Metakaolinite is formed due to dehydroxylation during heating of kaolin mineral.

Kaolinite clay, commonly accessible inside earth`s crust, is heated in the range of 600°c to 800°c resulting in dehydroxylation of the kaolinite crystalline structure to produce MK. MK shows same properties as that of group of material with similar latent hydraulic properties . Alkali activators are also used such as alkali metal hydroxides and water glass for activation of metakaolinite hydraulicity.

Hydraulic properties of metakaolin is activated with $Ca(OH)_2$ in building materials based on cement binder which produced during the cement hydration process. Keeping this in mind, metakaolin can partially substitute cement binder without compromising the final product strength.

1.3 TITANIUM DIOXIDE

TiO_2 is the most commonly researched photo catalyst with potential for use in many industry sectors. The construction industry represents the field where the photoactive TiO_2 has already been successfully used. Concretes, paints and plasters are materials for construction where there is extensive testing of the photoactive TiO_2.

The quantity of TiO_2 in these materials is therefore limited in terms of their final properties. Concrete in which the TiO_2 replaces the certain amount of cement results in decrease of compressive strength when the photo catalyst is incorporated in inadequate amount.

1.4 PROJECT OBJECTIVE

The primary objective of this study is to use the materials like MK and TiO_2 in addition with cement in desired quantity to have positive differences in the concrete properties and also their effect on the construction industry`s economic growth and exploring the use of added materials respectively. In addition, the effects of materials used are calculated by determining the workability, durability, compressive strength and tensile strength etc. for cement concrete. Complete evaluation and characterization of the possible application of concrete can be done with these tests

The primary objective of the research is given below:

1) Mechanical properties of concrete are determined under the influence of partial substitution of MK and TiO_2 in cement.

2) Analyzing the impact of variation in percentage of MK and TiO_2 on concrete properties would also be considered as significant section of experimental research.

3) Making more sustainable concrete structure and determine economical solution for HPC construction.

4) Using TiO_2 as additive in cement to produce concrete with better self cleaning properties.

CHAPTER 2

LITERATURE REVIEW

2.1 REVIEW MATERIAL

2.1.1 TiO_2 based photocatalyst composite and derived product on a Metakaolin, RENAATO ANCORA, Brindsi (IT); M. BORSA, Bergamo (IT): L. CASSAR, S. D. Milanese (IT) (2010) states that a photocatalytic composite composed of TiO_2 Supported on MK is defined herein. The composite of the present invention makes it possible to obtain binders and derived products with high photocatalytic efficiency compared to established industry embodiments, even when using photocatalyst concentrations that are smaller than those present in prior technical art products.

2.1.2 Metakaolinite/TiO_2 composite: Photoactive admixtures of building material based on Ordinary Portland cement binder, V. MATIJKA, P. MATIJKA, P. KOVAR, J. VLCEK, J. PRIKRYL, P. CERVINKA, Z. LANCY, J. KUTSCHOVA(2009) noted that Novel latent hydraulic and photoactive MK/TiO_2 admixture has been was produced, characterized and evaluated as a partial replacement of OPC in mortars. MK is the main component of the novel composite material, containing the nano particles of anatase anchor on the surface. Without this admixture, the compressive strength values determined for the mortars containing MK/TiO_2 composites attained increased values compared with the mortar. Mortar photo degradation operation with a specified quantity of MK/TiO_2 admixture versus nitric oxide was evaluated using the updated ISO standard. Results have shown that the NO conversion increases as the amount of TiO_2 is increased. In the construction industry, the synergistic impact photo degradation process and inherent hydraulicity in the material is to be used to reduce selected air pollutants concentration for example traffic pollution in affected areas.

2.1.3 Utilization of Photoactive Kaolin/TiO_2 Composite in Cement Based Building Products, V. Metajka, P. Kovar, P. Babkov, J. Prikyl, K. Mamlova-Kutakova, and P. Capkova (2010) refers to the fact that TiO_2 is the most researched photocatalyst with possible applications in various industrial sectors. The construction industry represents the field, where there is extensive testing of the photoactive TiO_2. The amount of photoactive TiO_2 used as construction products in paints, concretes and plasters is tested extensively. The quantity of TiO_2 in these materials is therefore limited in terms of their final properties. The kaolinite particles surface will be used as a matrix for growth of nano particles of TiO_2 resulting in formation of photoactive composite of kaolin/TiO_2. The method of kaolin dehydroxylation after the calcination of this composite, and it originates metakaolin/TiO_2 composite with inherent hydraulicity properties.

2.1.4 White Cement in Architectural Concrete, Possessing Photocatalytic Properties, L. CASSARL, C. PEPE, G. TAGNON, G. L. GUERINI, R. AMADELI (2003) explains that TiO_2 containing cement materials primarily in the form of anatase improve the efficiency of oxidation of organic substances they come into contact with while radiating with sufficient light. Structural elements that contain white cements in which TiO_2 is applied will preserve their aesthetic appearance unaltered in a timely manner.

2.1.5 A Review paper for use of MK in Cement concrete and mortar, Dr. K. Sri NIVAS, M L N KRISHAN SAI, V SAIRAM KUMAR (2014) mentions that the use of MK in cement concrete and mortar is of high importance. Using MK in concrete as 25 percent in cement replacement shows better strength results and improved durability. Water absorption and permeability has been greatly improved which leads to increased concrete density by the use of MK. Usage of MK in the preparation of concrete acid resistance for example sulfate resistance, chloride permeability provide improved results. Enhancing the use of MK with silica fume, steel fibers and fly ash produced improved results than standard concrete. Use of MK has shown greater flow capability of mortar and cement concrete.

2.1.6 Properties of MK Concrete - A Review, F. K. MOHDADDAM, R. SRIRAVINDARAJAH, V. SIRIVATNANON (2014) makes the following outcomes from the study of the performance and properties of metakaolin concrete as partial substitute for the use of metakaolin in cement.

- The compaction of concrete is not affected by increasing the quantity of MK but it results in decrease in concrete consistency.
- Comparatively finer as well as high pozzolanic metakaolin used as a partial substitution of cement provides modified porous structure, decreases porosity and readjustment of pore size in the hardened concrete.
- MK contributes using filler effect and serves as a accelerating admixture for improving initial stage hydration of cement. At former stage, MK contributes in improvement of the hardened concrete properties by pozzolanic reactivity.
- Partial cement substitution with MK greatly improves compressive strength and also improves the degree of enhancement of cement strength as the quantity of MK increases and ratio of water to base increases. It was found, however, the effect is decreased as the time increases.
- Concrete flexural and Tensile strength show less improvement as the quantity of MK increases in comparison to Young modulus and compressive strength of concrete.
- With the increase in quantity of MK, the effect of creep and drying shrinkage decreases in significant values.

2.1.7 Effect of TiO_2 on the Compressive Strength of Concrete, ABISHEK KUSWAHA, R, SAXENA, SHILPA PAL (2015) determine that the improvement in compressive strength of concrete with replacement of cement by 1% TiO_2 but it also shows decrease in strength of concrete with increase of TiO_2 content. TiO_2 use in the research work is anatase base with 20 to 25µm particles size. Further investigation on different concrete properties can be expanded by varying the particles size of TiO_2 and different concrete grades.

CHAPTER 3

MATERIALS USED AND ITS PROPERTIES

3.1 Selection of Material:

HPC mixture proportions vary from those in standard concrete proportions, such that the HPC has more content of cement powder and low content of coarse aggregates. In addition to this, HPC integrates greater quantity of high range water reducers. (Super plasticizers)

3.1.1 Ordinary Portland Cement (OPC - 43 GRADE)

Cement is a major ingredient used to make concrete which acts as a binder. OPC is available in different grades, such as 33, 43 and 53, depending on the strength of the characteristics after 28 days of curing. The OPC (43grade) is used as per IS: 8112-2013. Many tests have been carried out on OPC cement such as specific gravity, setting time test, Consistency test etc. 43 grade ordinary Portland cement was produced by integrally mixing of argillaceous, calcareous, silica, alumina or oxide of iron containing material. The properties of ordinary Portland cement are shown in Table 3.1 and Figure 3.1 shows the OPC 43 grade cement.

Figure 3.1- WONDER OPC 43 Grade

COMPOSITION of OXIDES	CaO	SiO_2	Al_2O_3	Fe_2O_3	MgO	SO_2	K_2O	Na_2O
PERCENTAGE (%)	63	20	6	3	2	1.5	1	0.5

Table 3.1-Composition of OPC

3.1.2 AGGREGATES:

The bulk of a concrete mixture is due to inclusion of aggregates which provide concrete dimensional stability. Among the different aggregate properties are the shape and gradation which are essential for HPC. While several research have been carried out on the effect of coarse aggregate content on HPC`s flow behavior, adequate attention is not given to quantify the impact of the aggregate shape.

Rounded aggregates will have better flow ability and less blocking capacity for a given ratio of water to cement in comparison to semi rounded and angular aggregates in case of HPC. In addition, the availability of elongated and flaky particles can cause problems of blockage in confined or congested areas and may also improve the stress for minimum yield. Incorporating aggregate form into the design of the mixture would allow the selection of necessary paste material needed to solve these problems. This aspect however needs to be tested**.**

Figure 3.1.2 Fine and Coarse Aggregate

3.1.2.1 SAND

Sand is a type of cohesion less aggregates with smooth, rounded, sub rounded, angular, sub angular or flat pieces of more or less unaltered mineral rock which consist of 90 % of particles more than 0.06 mm and less than 2 mm in size. Apart from it, they are silica particles which are coarse grain in nature resulting from the rock disintegration.

They are of 3 varieties:

Coarse sand:

This sand includes 90 % of particles more than 0.6 mm and less than 2 mm in size.

Medium sand:

This sand includes 90 % of particles more than 0.2 mm and less than 0.6 mm in size.

Fine sand:

This sand includes 90 % of particles more than 0.06 mm and less than 0.2 mm in size.

The Performance and durability of concrete mixture requires proper sand selection for use. The sand must have following properties:

- Clean, clear, hard and angular in shape
- Free from flaky materials such as mica, clay etc.
- The sand should be graded means it is constitute of be fine, medium and coarse sand which need to be free from sea salt contamination.
- Water content consistency should be less than 7%.
- Special attention should be given to water content during mixing of concrete.

3.1.2.2 COARSE AGGREGATES

Coarse aggregate is a type of aggregate which is retained on IS sieve of size 4.75 mm and constitutes just as much fine material as the specification permits. The coarse aggregate is defined in various types according to the source as:

- **Uncrushed Gravel or Stone:** It is formed due to natural disintegration of stone.
- **Crushed Gravel or Stone**: It is formed due to crushing of hard stone or gravel.
- **Partially Crushed Gravel or Stone**: It is formed by mixing of the uncrushed and crushed aggregates.

3.1.3 SUPERPLASTICIZER

Super plasticizer (SP) is a type of water reducing agent, also called as **High Range Water Reducers** (HRWA) and is used as additives to render concrete of high strength. Plasticizer is a chemical compounds which enables concrete to be manufactures to allow around 20 % less water usage. Super plasticizers allow 25 % or higher reduction in water content. This additive is used at the stage of a low percent of cement weight. Super plasticizers decreases the curing period of concrete.

Concrete is made using plasticizer for maintaining workability, durability and concrete strength. Concrete plasticizers are typical water reducing admixtures which decreases the water content needed by around 5 to 12 percent for a concrete mixture.

PC Based Super plasticizers is a modern variety of super plasticizer admixture which is based on modified **Polycarboxylic Ether** (PC Liquid) that enables delayed absorption of cement particles and effectively disperses the cement particles. With the help of this material, a high quality concrete mixture with accelerated strength production and increased workability can be obtain without delay in setting properties.

Figure 3.1.3 PC Super plasticizer

3.1.4 METAKAOLIN

Metakaolin is a type of clay material, which is potentially the most effective pozzolanic substance for concrete application. MK is a product that is produced for usage apart from a byproduct and it is form when china clay, the kaolin mineral, is heated in the range of

600 to 800ºC temperature. Its amount is regulated during processing, which result in a material that is far less variable than pozzolans used in industries which are by product..

During 1960s in Brazil, MK is used for construction of large dams. Initially, metakaolin is used to prevent damage from reaction of alkali and silica, and later on, MK is included successfully in the concrete applications.

The concrete manufactured is usually more compact and less likely to bleed when used to replace cement at various proportions of 5 to 10 % by weight of cement. Due to which, process of pumping and finishing need less effort. At this stage of replacement, the compressive strength of hardened concrete is improved, providing a cement mixture of low porosity and permeability with slightly higher replacement up to 20 %. This results in increased resistance of the hardened concrete specimen to sulfates attack, chloride ions, other harmful elements such as organic and mineral acids. Resistance against freezing and thawing is increased and the result of risk damage due to effect of abrasion and impact is decreased for a properly cured and finished MK concrete.

PROPERTIES	**UNIT**	**TYPICAL VALUE**
Specific Surface Area	m^2/g	12
Particle Size	μ m	2.5
Color		Pinkish White
Physical Form		Powder
Specific Gravity		2.45

Table 3.1.4 Physical Properties of Metakaolin

Figure 3.1.4 Metakaolin

3.1.5 NANO TITANIUM DIOXIDE

Titanium dioxide (TiO_2) is also an opaque, white, naturally occurring mineral which exist in various crystalline types with anatase and rutile being the most common forms, and also called as Titania. The naturally occurring types of oxides can be mined and used as a commercial titanium source.

TiO_2 is odorless and absorbent in nature. Its most significant feature in powder form is as a commonly used pigment for whitening and opacity. Titanium dioxide is commonly used in nano science techniques and nanotechnology applications due to its unique property. TiO_2 was one of the first nanotechnology materials to be used in concrete applications.

However, the controversial issue is the possible toxicity of TiO_2 nano particles. Various cosmetic firms use nano particles made from titanium dioxide. It is used in products such as inks, face cream, powder, paints, coatings, papers, toothpaste, and food coloring.

PROPERTIES	**UNIT**	**TYPICAL VALUE**
Specific Surface Area	m^2/g	50 ± 15
Particle Size	nm	21
pH (4% dispersion)		3.5-4.5
TiO_2 content	wt %	99.50
Density	g/l	130 (approx)

Table 3.1.5 Physio Chemical Property of TiO_2

Figure 3.1.5 Nano TiO_2

3.2 Testing On Materials:

3.2.1 Gradation of Sand (as per IS: 383-1970)

Weight of dried soil sample taken is 1500g.

Sieve size	Weight retained(g)	% wt. Retained	Cumulative% wt. retained	% finer	Remarks
4.75mm	3	0.2	0.2	99.8	Sand falls in Zone Category II
2.36mm	11	0.733	0.933	99.067	
1.18mm	80.5	5.36	6.293	93.707	
600µ	747.5	49.8	56.09	43.91	
300µ	598	39.86	95.95	4.05	
150µ	50.5	3.36	99.31	0.69	

Table 3.2.1 Sieve Analysis of sand

As percentage passing 600µ sieve is between 35 and 59, the sand belongs to gradation.

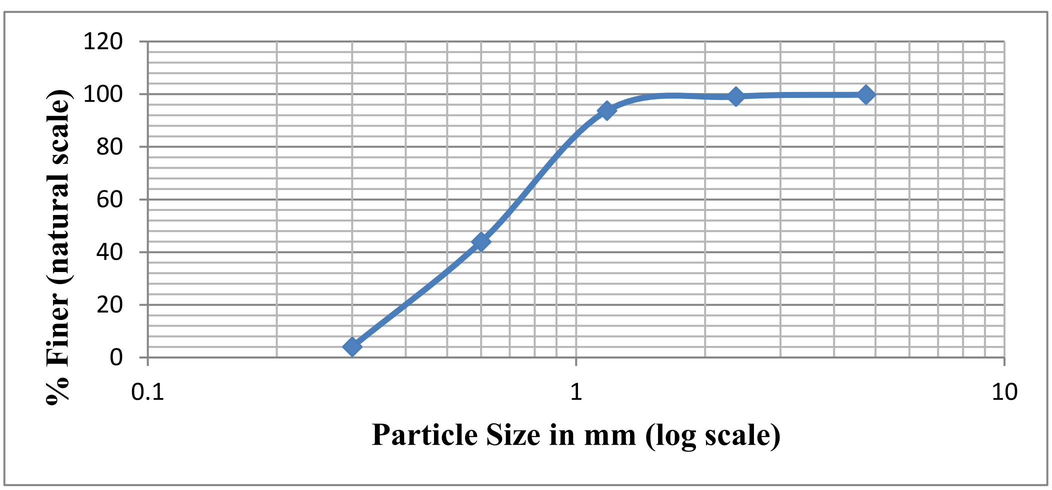

Figure 3.2.1 Particle size distribution curve

From the gradation curve, we find

Effective size, D_{10}=0.33mm and D_{30}=0.48mm, D_{60}=0.72mm

Coefficient of Uniformity, C_u= D_{60}/ D_{10} =0.72/0.33=2.18

Coefficient of Curvature, C_c= D_{30}^2/ (D_{10}*D_{60}) =0.48^2/ (0.33 x0.72)=2.02

Thus, the Sand is poorly Graded Sand.

3.2.2 Fineness Modulus:

Fineness modulus (FM) is an empirical equation which is calculated by adding the cumulative percentages weight of retained aggregate on each of the IS standard sieve varies from 80 mm to 150 µm and dividing it by 100.

Hence F.M. = (0.2+0.933+6.293+56.09+95.95+99.31)/100 = 2.587

As F.M. lies between 2.2 and 2.6. Therefore, the Sand is Fine Sand.

3.2.3 Specific gravity of sand:

The test is done by Pycnometer method. The observations are taken at 27^0 c are given below:

Weight of empty Pycnometer, W_1 = 0.692 kg

Weight of Pycnometer + Dry sample, W_2 =0.892 kg

Weight of Pycnometer + sample +water, W_3 =1.668 kg

Weight of Pycnometer + water, W_4 =1.544 kg

Specific gravity is given by the following formula:

G = (W2– W_1) / [(W2– W1) – (W3 - W_4)]

G = 0.2/ (0.2 -0.124)

G = 2.63

3.2.4 Specific gravity of coarse aggregates:

The test is conducted by Wire Basket Method at 27^0 C and the readings are as follows:

Weight of oven dry sample, W_1 =500 g

Weight of empty wire basket in water, W_2 =891g

Weight of basket and sample in water, W_3 =578.5 g

Specific gravity $G = W_1 / \{W_1 - (W_2 - W_3)\}$

$G = 500 / \{500-(891-578.5)\}$

G = 2.67

3.2.5 Standard Consistency test for cement:

Standard consistency test for a cement paste is used to determine the water content at which the cement paste will allow a Vicat's plunger of 10 mm diameter and 50 mm in length to penetrate to a depth of 33mm to 35 mm from the top of mould or 5mm to 7 mm form bottom of mould. The test is useful for finding out Initial setting time, Final setting time, Strength and Soundness of cement. The test is conducted using Vicat apparatus.

The observations obtained during the test are:

Weight of cement taken for each trial is 400 g.

Trial no.	Water content (%)	Penetration(mm)
1	25	15
2	27	20
3	29	32
4	30	34
5	31	35.5

Table 3.2.5 Standard Consistency Test on cement

The standard consistency of the cement is obtained as 30%.

3.2.6 Initial Setting Time of Cement:

Initial setting time of cement is defined as the time period between the experiment during which the water is added to the cement to the time when the cement paste start losing its plasticity. In Vicat apparatus, it is measured as the time period elapsed between the time in which water is added to the cement paste and to the time period at which the needle penetrates the test specimen to a depth equal to 33 mm to 35 mm from the top of mould at water content of 0.85 times the standard consistency.

The observations obtained at a temperature of 27^0 c are as:

Weight of cement =400 g

Weight of water =0.85 x 30/100 x 400 = 102 g.

Time at which water is added to the cement = 2:05 pm

Time at which needle penetrates to a depth of 33-35 mm = 2:45 pm.

Initial setting time is obtained as 0hr 40 min.

3.2.7 Final setting time of cement:

The final setting time is defined as the time period between the moment when water is added to the cement and till the time, when the cement paste lost its plasticity completely and has required enough hardness to resist against applied pressure. In Vicat apparatus, cement is considered fully set, when lowering of the attachment firmly cover the test block surface and the middle needle make a impression on paste, whereas, the circular cutting edge portion of the attachment fails to penetrate more than 0.5 mm into the cement paste.

The observations obtained are as:

Time at which water is added to the cement 2:05 pm

Time at which the circular edge fail to make an impression 7:25 pm

Final setting time is obtained as 5 hr 20 min

3.2.8 Trial mix design

A trial mix has been designed for an assumed compaction factor of 0.80 as per IS 10262 - 1982. The trial mix is obtained as 1:1.4:2.8 for water cement ratio of 0.45.

3.2.8.1 Compaction factor:

Compaction factor is defined as the ratio of density of concrete achieved when the concrete is allowed to fall through a standard height and the density of the same concrete fully compacted.

The observations obtained during the test are:

Weight of empty cylinder W_1 =18.7 kg.

Weight of cylinder + partially compacted concrete W_2 = 29.5 kg.

Weight of cylinder + fully compacted concrete W_3 = 31.3 kg.

C.F. = $(W_2 - W_1) / (W_3 - W_1)$

C.F. = (29.5-18.7) / (31.3-18.7)

C.F. = 0.85

3.3 Material Used:

3.3.1 Cement: Ordinary Portland Cement (OPC) of 43 grade is the most common type of cement used for general purpose. Specific Gravity is 3.15, available in local market.

Test	**Result**	**As per IS 4031-1998**
Consistency	30%	30-35
Initial setting time	0 hr 40 min	Not less than 30min.
Final setting time	5 hr 20 min	Not more than 600min

Specific gravity	3.15	3.10-3.15
Fineness	2.9%	Not exceed 10%

Table 3.3.1 Properties of cement.

3.3.2 Fine Aggregate: Fine aggregate is a type of aggregate with inert or chemically inactive material, that passes through a IS sieve size of 4.75 mm and contain less than 5 percent coarse material.

Test	Result	As per IS 4031-1998
Fineness Modulus	3.07	Grading zone II
Specific Gravity	2.63	2.6-2.8

Table 3.3.2 Properties of fine aggregates.

3.3.3 Coarse Aggregates: Coarse aggregate is defined as a vast category of coarse particles material used for construction application which includes stone, sand, gravel, slag and geo synthetic aggregates. Size of coarse aggregate used may vary from maximum of 20 mm to minimum size of 4.75 mm. The coarse aggregate are divided into two equal ratios having maximum size between 10-20 mm and between 4.75-10 mm.

Test	Result	As per IS 4031-1998
Specific Gravity	2.70	2.6-2.85
Fineness Modulus	7.3	6.5-8
Impact	18.18%	Strong (10-20%)

Table 3.3.3 Properties of coarse aggregates.

CHAPTER 4

EXPERIMENTAL PROGRAM

4.1 Mix Design

4.1.1 M-50 Design mix: IS 10262-2009

Characteristic strength required at 28 days =50 MPa.

- Target mean strength = f_{ck} +1.65 x S
  = 50+1.65 x 5
  = 58.25 MPa.
- The w/c ratio is obtained as 0.35 from the IS 456-2000.
- For 10mm maximum size aggregate and 20mm maximum size aggregate, sand conforming to grading zone II, w/c ratio of 0.35 and C.F. of 0.85.
  water content per cubic meter of concrete = (186+208)/2 = 197 kg
- Adjustments to water content.
  - Estimated water content for 100mm slump = 197 x 1.06 = 209 kg.
  - 14% Reduction for Super plasticizer = 0.86 x 209 = 179.74 kg.
- Cement content = 179.74/0.35 =513.5 kg.
- Proportion of volume of Coarse Aggregate content from Table-3 of IS:10262-2009 for water cement ratio of 0.5 is 0.62
  Volume of Coarse aggregate is increase by 0.01 for every decrease of 0.05 in water cement ratio.
  Now, Volume of Coarse Aggregate =0.62 + (0.01 x (0.5-0.35)) = 0.65
  For Pumpable concrete, this value is reduced by 10%
  Therefore, Volume of Coarse aggregate = 0.65x0.9 = 0.59
  And Volume of Fine Aggregate = 1-0.59 = 0.41
- MIX CALCULATION
  a) Volume of Concrete = 1 m^3
  b) Volume of Cement = $\frac{513.5}{3.10} \times \frac{1}{1000} = 0.166 m^3$

c) Volume of Water = $\frac{179.74}{1} \times \frac{1}{1000}$ =0.179 m^3

d) Volume of Super Plasticizer = $\frac{1.541}{1.09} \times \frac{1}{1000}$ = 0.00141 m^3

e) Volume of All in Aggregate = 1-0.166-0.179-0.00141 = 0.653

f) Mass of Coarse Aggregate = 0.653 x 0.59 x 2.7 x 1000 = 1040 kg per m^3

g) Mass of Fine Aggregate = 0.653 x 0.41 x 2.6 x 1000 = 696 kg per m^3

SUMMARY

Cement = 513.5 kg/m^3

Fine Aggregate = 696 kg/m^3

Coarse Aggregate = 1040 kg/m^3

Water = 179.74 kg/m^3

Super Plasticizer = 1.54 kg/m^3

Therefore, Final Design Mix Ratio:-

CEMENT : FA : CA : W/C : S P :: 513.5 : 696 : 1040 : 179.74 : 1.54

CEMENT : FA : CA : W/C : S P :: 1 : 1.36 : 2.03 : 0.35 : 0.003

4.2 Experimental Procedures:

Preparation of Fresh Concrete

The concrete components are ordinary cement (OPC-43 grade), fine aggregates (FA), coarse aggregates (CA), Titanium dioxide (TiO_2), Metakaolin (MK), Super plasticizer (SP) and water. For the casting of cube, four different proportions of TiO_2 and MK were taken.

The process for making fresh concrete is as follows.

- Proper mixing of all components of concrete in desired quantity is completed using a vertical mixer. All the dry aggregates are mixed for 2 minute to provide uniformity to the mix.

- Water is added in half quantity gradually during mixing operation of concrete and the remaining quantity of water is added with SP.
- However, TiO_2 and MK are mixed with water because they are available in very fine powder form which can easily blown away even with slight air.
- Proper mixing of constituting ingredients is continue for a duration of 2 minute and the quantity of SP and water are adjusted for each mixture to get the required workability of concrete without segregation of concrete particles.
- Mixing of the different proportion of TiO_2 and MK used in each sample is shown in Table 4.2.

MIX	TiO_2	MK
M-0	0	0
M-0.5	0.5	5
M-1	1	10
M-1.5	1.5	15

Table 4.2 Percentage variation of TiO_2 and MK in mix

4.3 Material Required For One Concrete Mould of Control Mix

Weight of Concrete = Density*Volume of mould

Weight of Concrete = 2400 kg per m^3*0.15 m^3

Weight of Concrete = 8.1 kg

Assume 5% wastage

Then, Weight of Concrete = 8.1*5 = 8.5 kg

Weight of cement = 8.5*1/ (1+1.36+2.03) = 8.5/4.39

Weight of cement = 1.93 kg

Weight of Fine aggregate = 8.5*1.36/4.39

Weight of Fine aggregate = 2.63 kg

Weight of Coarse aggregate = 8.5*2.03/4.39

Weight of Coarse aggregate = 3.9 kg

Weight of Coarse aggregate (10 mm) = 3.9/2 kg = 1.95 kg

Weight of Coarse aggregate (20 mm) = 3.9/2 kg = 1.95 kg

MATERIAL	WEIGHT (kg)
Cement	1.93
Fine aggregate	2.63
Coarse aggregate (10mm)	1.95
Coarse aggregate (20mm)	1.95

Table 4.3 Material for One Concrete Mould

4.4 Casting of Specimens

The cube of dimensions 150mm x 150mm x 150mm were put together on the concrete leveled floor. The internal surface of the mould was oiled properly. The concrete is poured in the mould in 3 layers and compacted using the vibrating table. After the moulds have been fill with concrete and compacted, the top surface of concrete is leveled and cubes are kept in laboratory conditions for 24 hours during which the top surface of moulds is covered using plastic plates. The moulds are de-molded after 24 hours of casting. There are four samples are prepared with different fraction ofTiO_2 and MK. Each sample has Twelve cubes..Total 48 numbers of cubes specimen were prepared. The figure 4.4 show's casting of specimens.

Figure 4.4 Casting of Concrete cubes

4.5 Curing of Specimen

After the casting of cubes, specimen were kept 24 hours in the room temperature around 27°C for initial setting and then immersed in water for curing operation. The age of the curing for three specimens of each sample is 7 days, 28 days and 90days before conducting the test. Fig 4.5 shows curing of specimens.

Figure 4.5 Curing of Concrete Cubes

CHAPTER 5

TEST RESULT

5.1 TESTS ON CONCRETE

5.1.1 Slump Cone Test

Slump cone test was conducted to get fresh concrete workability and consistency. Slump cone method is the most common tool used to test concrete workability and durability and can be done either in the laboratory or at the work site. This check doesn't fit for very wet and very dry concrete.

Apparatus details as per IS: 1199 — 1959

1. The typical hollow cone of size of the bottom diameter of 200 mm, the top diameter of 100 mm and the height of 300 mm is taken with the lifting handle fixed with a circle.
2. A 600mm long, 16mm diameter tamping rod with rounded bottom edge.

Figure 5.1.1 Slump Cone Apparatus

Procedure for Testing

1. The mould's internal surface is thoroughly cleaned and a light oil layer is applied.
2. The mould is placed on a surface that is smooth, flat, rigid and non absorbent.
3. Concrete is poured into the cone in four layers, each roughly one-quarter of the

mould height and each layer is tamped 25strokes.

4. Soon after the filling has been finished and excess concrete is strike off from the top layer, the slump cone is raised slowly and carefully upright as the unstable concrete slumps.
5. The slump is determined by inserting the cone just next to the slumped concrete and placing the temping rod over the cone, so that it can also move over the slumped concrete area.
6. The reduction in concrete height is calculated using the amount of fresh concrete, i.e. the slump value. Slump value for different concrete mix is given in table 5.1.1 below.

MIX	SLUMP VALUE (mm)
M-0	100 mm
M-0.5	95 mm
M-1	85 mm
M-1.5	80 mm

Table 5.1.1 Slump Value for Different Mix

NOTE: The aim is to keep slump value constant to maintain workability by increasing the amount of Super plasticizer used in concrete.

5.1.2 Rebound Hammer Test

Rebound Hammer method is used to determine the concrete compressive strength with the help of rebound hammer as per IS code: 13311 (Part-2) - 1992. The primary principle of the rebound hammer method is:

The mass striking against the surface rebounds due to elastic spring which helps in determining the rebound value. The spring controlled mass gets rebound when plunger of rebound hammer is pushed against the surface of concrete specimen and the amount of rebounding is depend on hardness of concrete surface. The surface hardness and rebound number is used to relate with compressive strength of concrete cube.

The rebound value is determined using the rebound index or graduated scale. The compressive strength of concrete specimen is determined directly from the given graph on the body of rebound hammer.

Figure 5.1.2 Proceq Rebound Hammer Apparatus

Procedure for Testing

1. For testing of concrete specimen, it is cleaned and surface dried. If loose adhering scale is available then it needs to be scraped off with the help of grinding stone. Surface roughness due to improper compaction, grout loss, a spall surface does not give satisfactory results and needs to be avoided.
2. The impact point of rebound hammer is minimum 20 mm away from any end or shape discontinuity in concrete specimen.
3. For measurement purpose, the rebound hammer is to be hold at perpendicular to the surface of the concrete specimen. The test is conducted in horizontal position on vertical surface and vertical upwards position or downward position on horizontal surface. As per the requirement of situation, the rebound hammer can also be aligned at intermediate angles; also the rebound value varies for the same concrete specimen.

4. On each concrete cube surface, five observations of rebound indices are noted and mean value of these readings after omitting outliers as per IS code 8900 : 1978 indicates the rebound index for the point under observation.
5. The test result of Rebound Hammer and quality of concrete specimen for different average rebound value is given in table 5.1.2 and table 5.1.2.1 below.

MIX	AVERAGE REBOUND VALUE
M-0	42
M-0.5	45
M-1	46
M-1.5	51

Table 5.1.2 Test Result of Rebound Hammer

AVERAGE REBOUND VALUE	QUALITY OF CONCRETE
More than 40	Very Good
30-40	Good
20-30	Fair
Less than 20	Poor
0	Delaminated

Table 5.1.2.1 Concrete quality for Average rebound

5.1.3 Ultrasonic Pulse Velocity Test

UPV Apparatus is used for testing in situ strength of concrete specimen. It determines the travel time for an ultrasonic wave travelling inside the concrete specimen. The apparatus include a pulse generator and receiver. Pulses are produced using shock exciting piezo electric crystal with same crystal use in receiver. The time duration for pulse to travel through the concrete specimen is determine by electronic measuring circuits.

The working principal of determining the concrete quality is based on the fact that higher velocity is obtained when concrete quality is determined in term of density, uniformity and homogeneity is better. Low velocity is obtained in case of low quality concrete. Due to presence of crack, flaw or void in the concrete specimen which interrupts in the path of pulse transmission, the pulse intensity is decreased and it will travel around the crack, by increasing the path length which results in lower velocities. The original pulse velocity determined depends primarily on the material and mix proportion of concrete specimen. Density and Young's modulus of aggregate has significant impact on the velocity of pulse. The Table 5.1.3 and Table 5.1.3.1 gives the Test result of UPV and quality of concrete for different values of pulse velocity as per IS code.

CONCRETE MIX	**PULSE VELOCITY (KM/Second)**
M-0	3.64
M-0.5	4.23
M-1	4.60
M-1.5	4.91

Table 5.1.3 Test Result of UPV

PULSE VELOCITY (KM/Second)	**CONCRETE QUALITY (Grading)**
Above 4.5	Excellent
3.5-4.5	Good
3.0-3.5	Medium
Below 3.0	Doubtful

Table 5.1.3.1 Velocity criterion for Concrete quality grading

Figure 5.1.3 UPV Test Apparatus

5.1.4 Compressive Strength Test

Concrete strength is usually defined and determined by the 150 mm x 150 mm x 150 mm dimensions of cube crushing strength during the age of 7, 28 and 90 days. This is the most commonly performed test on hard concrete cubes because of its simplicity to perform and because most of the attractive properties of concrete are calculated from its compressive strength. This test is conducted for cube after the curing age has been completed, and cubes are taken out from the curing tank and dried under room temperature. Now keep the specimen in the compression test machine and determine the dimensions of load bearing area of concrete cubes. Load is applied uniformly till the concrete cube fails to take additional load and write down the maximum load intensity taken by cubes. Compressive strength of cube is calculated from load applied divided by load bearing area and similarly, compressive strength of concrete is determined for each specimen and average value is determined. This is given as:

Compressive strength (σ) = P / A

P = Maximum applied load

A = Bearing surface area of cube

Figure 5.1.4 Compressive Strength Test Apparatus

Figure 5.1.5 Failure of Concrete cubes

5.2 CASTING OF MIX DESIGN (kg/m^3)

MIX NO	TiO_2	METAKAOLIN	S.P	CEMENT	FINE AGGREGATE	COARSE AGGREGATE	WATER
M-0	0	0	1.54	513.5	696	1040	179.74
M-0.5 (0.5/5)	2.57	25.7	2.54	513.5	696	1040	179.94
M-1 (1/10)	5.13	51.3	3.54	513.5	696	1040	179.94
M-1.5 (1.5/15)	7.7	77	4.54	513.5	696	1040	179.94

Table 5.2 Casting of Mix Design

5.3 Test Results of M-50 Conventional Concrete

Table 5.3 Test results of M-0 mix

S.No.	7 days Strength (N/mm^2)	28 days Strength (N/mm^2)	90 days Strength (N/mm^2)
1	37.8	61.8	71.5
2	38.4	62.9	71.6
3	39.3	64.1	72.3
AVERAGE	**38.5**	**62.9**	**71.8**

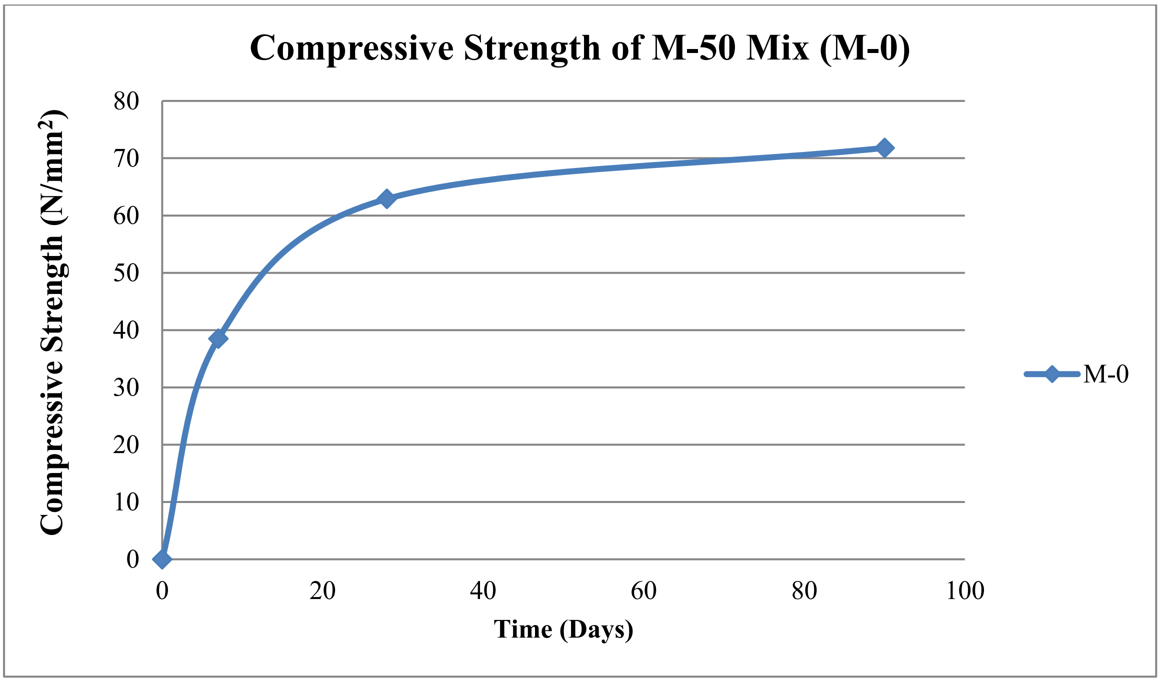

Figure 5.3 compressive Strength of M-0 mix.

Table 5.4 Test results of M-0.5 mix

S.No.	7 days Strength (N/mm^2)	28 days Strength (N/mm^2)	90 days Strength (N/mm^2)
1	44.1	71	81.4
2	46.4	71.1	82.1
3	46.9	73.7	82.9
AVERAGE	**45.8**	**71.9**	**82.1**

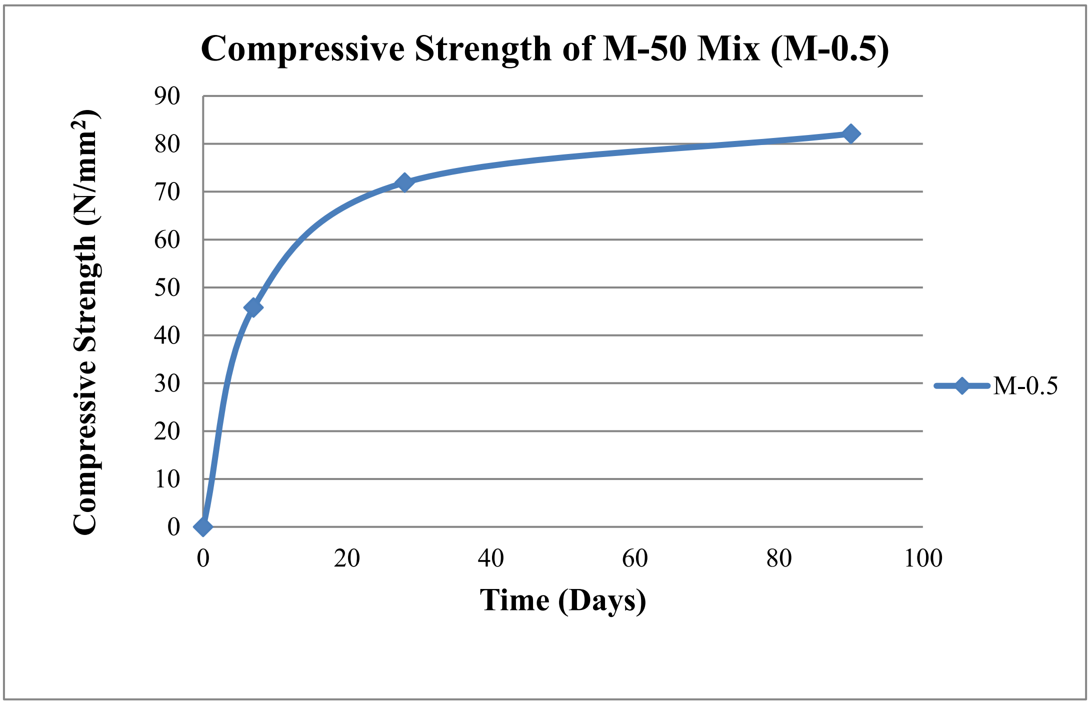

Figure 5.4 |Compressive Strength of M-0.5 mix.

Table 5.5 Test results of M-1 mix

S.No.	7 days Strength (N/mm^2)	28 days Strength (N/mm^2)	90 days Strength (N/mm^2)
1	48.4	74.8	84.3
2	49.2	75.3	86.2
3	49.4	75.9	87.1
AVERAGE	**49**	**75.3**	**85.9**

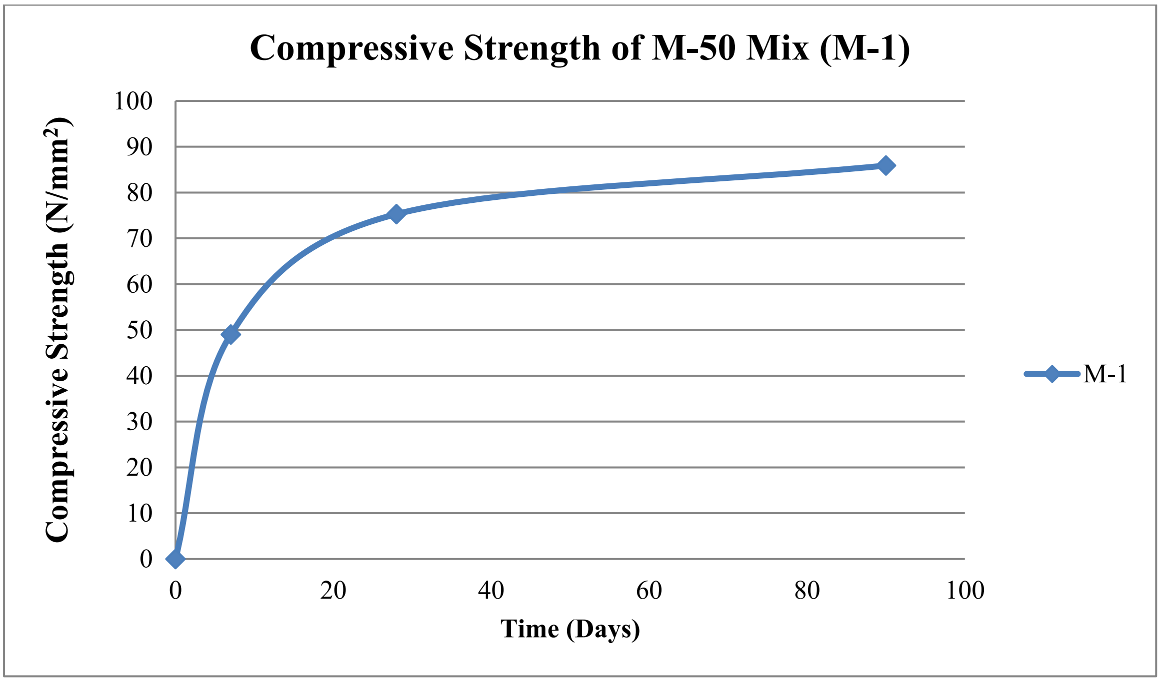

Figure 5.5 Compressive Strength of M-1 mix.

Table 5.6 Test results of M-1.5 mix

S.No.	7 days Strength (N/mm^2)	28 days Strength (N/mm^2)	90 days Strength (N/mm^2)
1	52.3	78.5	86
2	53.7	79.3	87.1
3	54	79.8	87.5
AVERAGE	**53.3**	**79.2**	**87**

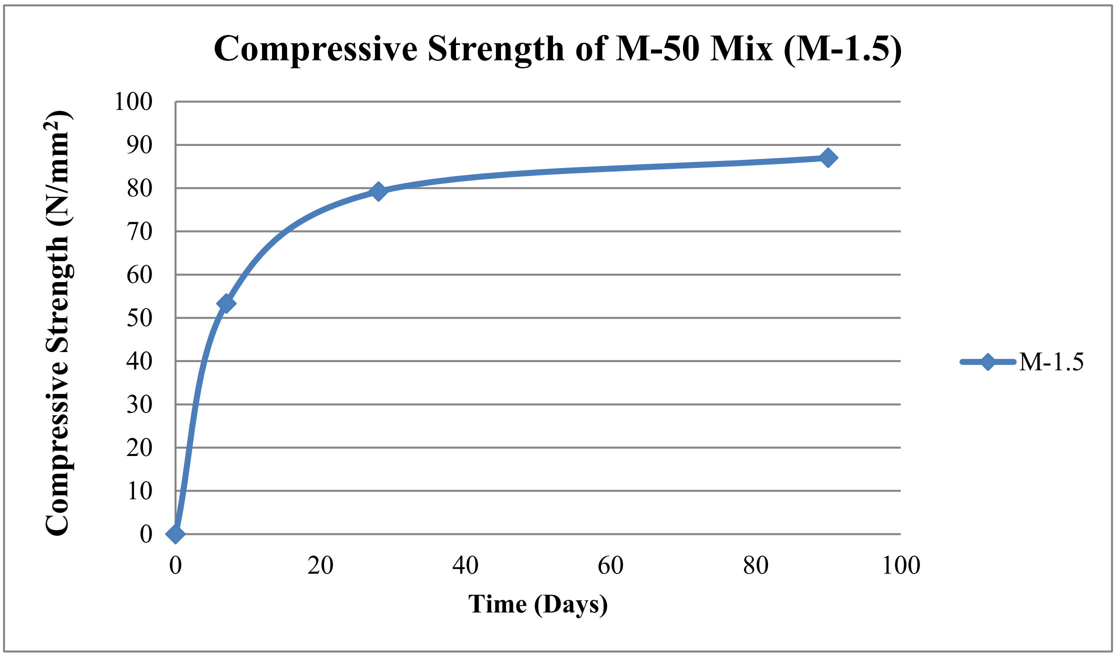

Figure 5.6 Compressive Strength of M-1.5 mix

Table 5.7 Test results of Different mix

MIX	7 days Strength (N/mm^2)	28 days Strength (N/mm^2)	90 days Strength (N/mm^2)
M-0	38.5	62.9	71.8
M-0.5	45.8	71.9	82.1
M-1	49	75.3	85.9
M-1.5	53.3	79.2	87

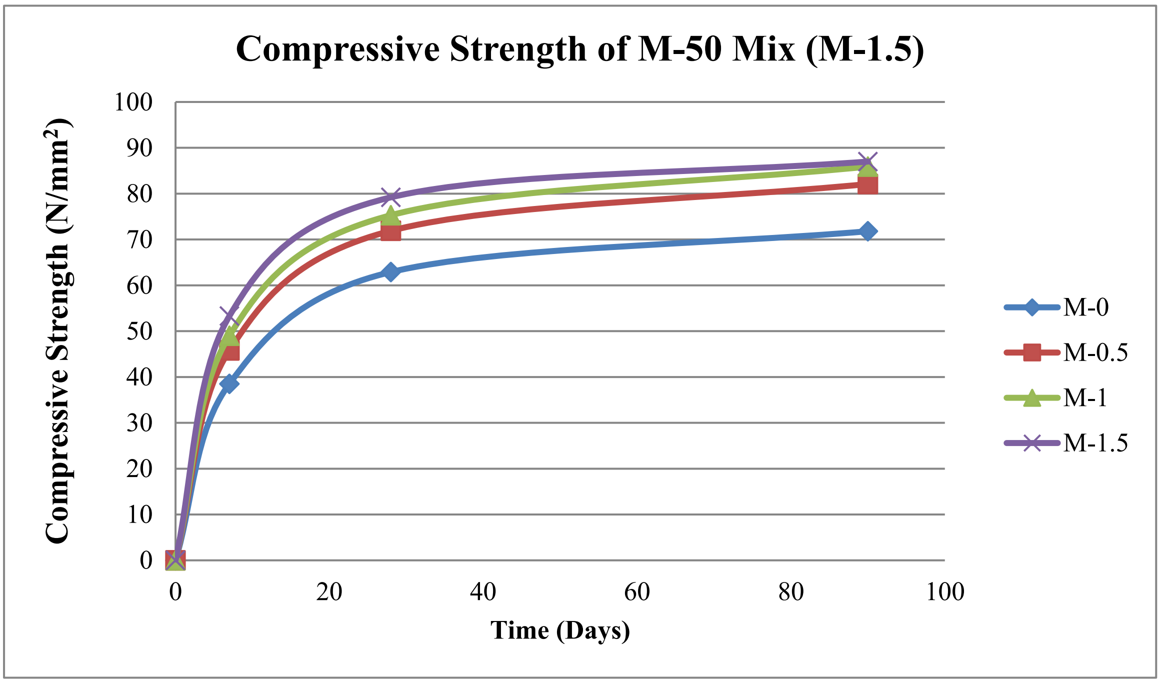

Figure 5.7 Compressive Strength of Different mix.

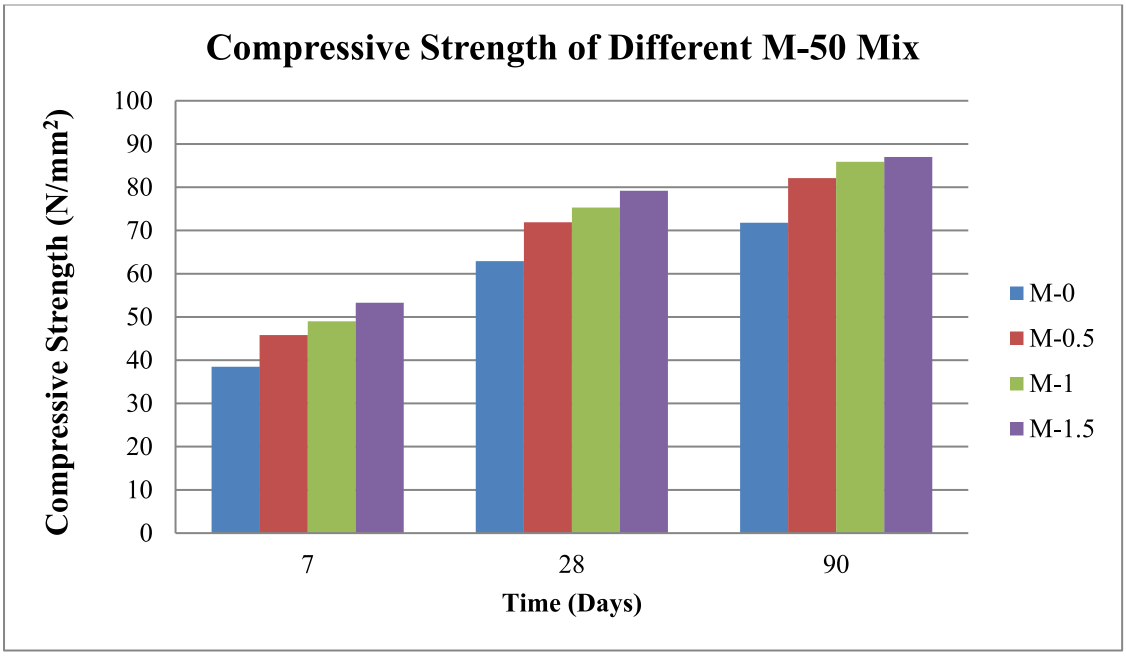

Figure 5.8 Compressive Strength of Different mix.

MIX	7 DAYS	28 DAYS	90 DAYS
M-0.5	18.9 %	14.3 %	14.3 %
M-1	27.3 %	19.7 %	19.6 %
M-1.5	38.4 %	25.9 %	21.2 %

Table 5.8 Percentage increase of strength of different mix

CHAPTER 6

CONCLUSION AND FUTURE SCOPE OF WORK

6.1 CONCLUSION

After experimental investigations and analysis of the test results, the following conclusions can be drawn.

- In the current experimental work, it has been found that the compressive strength of Different concrete mix increases with increase in percentage content of TiO_2 and MK.
- The percentage increase of compressive strength for Mix-0.5 is 18.9, 14.3 and 14.3 for 7, 28 and 90 days respectively.
- The percentage increase of compressive strength for Mix-1 is 27.3, 19.7 and 19.6 for 7, 28 and 90 days respectively.
- The percentage increase of compressive strength for Mix-1.5 is 38.4, 25.9 and 21.2 for 7, 28 and 90 days respectively.

6.2 FUTURE SCOPE OF WORK

- Research can be carried out to investigate the different properties of concrete with nano particles by varying the percentage addition up to acceptable limits and to calculate the split tensile strength of such partially additive nano particles.
- Investigation can be extended to check the other properties of hardened concrete such as impact resistance and propagation of cracks.
- Combination of nano particles such as TiO_2, Silica, alumina for future experiment.
- Analysing the seismic behaviours of frame members of concrete made from addition of nano particles.

REFERENCES

[1] Dr K Srinivasu, MLN Krishna Sai, Venkata Sairam kumar, 2014," A Review on Use of Metakaolin in Mortar and cement", Published in IJIRSET, Vol-3, ISSN: 2319-8753.

[2] Jiping Bai, Stan Wild, Albinas Gailius, 2004,"Accelerating early strength development of concrete using metakaolin as an admixture", Material Science, Vol. 10(4), 338-344.

[3] B B Patil, PD Kumbhar, 2012," Strength and durability properties of high performance concrete incorporating high reactivity metakaolin", IJMER, Vol. 2(3), 1099-1104.

[4] Sanjay N Patil, Anil K Gupta, Subhash S Deshpande," Metakaolin-Pozzolanic material for cement in high strength concrete", SICETE, 46-49.

[5] Farzad Khamchin Moghaddam, Rasiah Sri ravindrarajah, Vute Sirivivatnanon," Properties of Metakaolin Concrete- A Review", ICSSC, 15-18 sept 2015.

[6] Jian Tong Ding, Zongjin Li," Effects of Metakaolin and silica fume on Properties of Concrete", ACI Materials Journal, Title no 99-M3.

[7] Jitendra Patil, Dr Umesh Pendharkar, 2016," Study of Effects of Nanomaterials as Cement Replacement on Physical Properties of Concrete", IRJET, Vol. 3(1), 2395-0056.

[8] AK Rana, SB Rana, A Kumari, V Kiran," Significance of nanotechnology in construction engineering, IJRTE, Vol. 1(4), pp. 46-48.

[9] AS Kushwaha, Rachit Saxena, Shilpa pal, 2015," Effect of Titanium Dioxide on the compressive strength of concrete", JCEET, Vol. 2(6), ISSN: 2349-8404.

[10] Bureau of Indian Standards: IS -10262:2009," Concrete Mix Proportioning - Guidelines (first revision) ".

[11] Bureau of Indian Standards: IS -456:2000, "Plain and Reinforced Concrete - code of practice (fourth revision)".

[12] Bureau of Indian Standards: IS - 383:2004, "Specification for Coarse and Fine aggregate from natural sources for Concrete (second revision)".

[13] Bureau of Indian Standards: IS - 1199:2004, "Methods of Sampling and Analysis of Concrete".

[14] Bureau of Indian Standards: IS - 516:2004, "Methods of Tests for Strength of

Concrete".

[15] Jay Sorathiya, Dr Siddharth Shah, Mr Smit Kacha,2017" Effect of Nano Titanium dioxide on Compressive Strength of concrete", ICRISET, Vol. 1.