Effect Of Nano-Titanium Dioxide and Amorphous Silica on Fresh and Hardened Concrete

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ABSTRACT

High-performance concrete structures to attain high strength and durability consume more cement, creating many environmental issues and is also uneconomical. Researchers have been addressing the issues by adding nanomaterials to the concrete. In the present investigation, trials are conducted to add Anatase Nano Titanium Dioxide (TiO_2) and Amorphous Silica (AS) nanomaterials at various combination proportions 0.5% & 2.5%, 1% & 5%, 1.5% & 7.5%, 2% & 10%, and 2.5% & 12.5% by weight of cement. The workability, mechanical, and durability properties and compared with conventional concrete of M25 grade. Concrete specimens were cast and cured. Mechanical properties obtained after 7, 14, and 28 days curing in normal water and durability properties after 90 days curing in acidic (5% of H_2SO_4) water. TiO_2 and AS combination at the proportions of **1.5% & 7.5%** produces better results than conventional concrete. Compressive, flexural, and split tensile strengths at 28 days increase from 28.01 to 42.04 N/mm^2 (50.09%), 3.51 to 3.99 N/mm^2 (13.68%) and 3.14 to 4.12 N/mm^2 (31.21%), respectively. TiO_2 and AS combination at the proportions of 1.5% & 7.5% recommended for M25 grade concrete for better strength and durability.

Keywords: Nano Titanium dioxide, Amorphous Silica, compressive strength, flexural strength, split tensile strength, Acid test.

1. INTRODUCTION

Many concrete buildings have been polluted by natural disasters. The use of titanium dioxide (TiO2) will make concrete structures less polluted. When these substances absorb UV radiation from the sun, hydroxyl radicals and superoxide anions are created with the ability to react with pollutant molecules such as NOX to convert them into less harmful substances and increase the strength of concrete. Concrete is the second most building material widely used for construction in the world. Concrete is made of cement, fine aggregate, and coarse aggregate mixed with water which makes time hard. In concrete mixtures, admixtures or super plasticizers are used to obtain performance.

Nanotechnology is the reorganization of matter by regulating matter at the atomic level. The key to nanotechnology is the measurement of particles in terms of how the properties of particles are affected under a nano-size [10 - 9 meter] scale [1]. Owing to a variety of notable features of nanotechnology, such as the late made of nano can reduce current constraints. Nanotechnology is the use of fragments of small things themselves or tricks them into making new great things [2]. Cementitious composites show excessive failure, low tensile strength and are prone to cracking. These features of cement Based materials are major flaws that not only pose a challenge to the structure of the building, but also affect the durability of the building in the long run [3].To overcome this inefficiency, nanoparticles have been added to the cement components. The addition of nanoparticles to cement concrete is gaining attention due to its high surface area and therefore high regeneration [4]. Recent experiments have shown that nanoparticles improve the mechanical properties of CSH, reduce porosity and alter the hardness of the cement matrix [5]. Application of Nanotechnology in construction and construction processes with unique properties, light and integrated lighting, sound insulation, fire resistance, water repellent, air purifiers, disinfectants, low maintenance coverings [6]. Titanium Dioxide (TiO2) is well known and well researched. The titanium number is 22 and the atomic weight is 47.86. The type of Anatase TiO_2 has a crystal structure corresponding to the tetragonal system, the Rutile TiO2 type and has a crystal tetragonal structure, the Brookite TiO_2 type has a crystalline structure that corresponds to an orthorhombic crystalline structure [7]. Titanium Dioxide is a flexible material that can be used in various products such as pig paint, sunscreen lotions, electrochemical electrodes, capacitors, solar cells and as a food colouring agent and on tooth pipes [8]. The manufactured concrete is named as self-cleaning concrete or photo catalytic concrete. This concrete is also known as Green Concrete because of its self-cleaning properties. The use of nano photocatalytic concrete includes biodegradable pollution and cleaning [9].Rich husk ash is an agricultural by product obtained from rice mill and then burned at very high temperature as fuel. This provides additional benefits when using cement [10].Rice husks can be burned to ashes that replenish the body's nutrients and chemical composition of minerals. The Pozzolanic function of rice husk ash (RHA) depends on (i) the silica content, (ii) the stage of silica crystallization, and (iii) the size and surface area of the ash particles. In addition, the ash should contain only a small amount of carbon. Well prepared RHA, with heat or grinding, used as a pozzolanic material in cement and concrete. Using it offers many benefits, such as improved energy and structural strength, as well as environmental benefits related to waste disposal and reduced carbon dioxide emissions [11].Rice husk is an agricultural residue widely available in major rice producing countries. The husk surrounds the paddy grain. During milling process of paddy grains about 78 % of weight is obtained as rice, broken rice and bran. Remaining 22 % of the weight of paddy is obtained as husk [12]. This husk is used as fuel in the various mills to generate steam for the parboiling process. This husk contains about 75 % organic volatile matter and the rest 25 % of the weight of this husk is converted into ash during the firing process, this Ash is known as rice husk ash [13]. The RHA contains around 85 % - 90% amorphous silica. Rice husks are produced in the rice processing industry as a major agricultural product in many parts of the world especially in developing countries [14]. About 500 million tons of pasture is produced worldwide each year after burning only about 20% of the rice husks are converted into RHA. There is still no effective use of RHA and it is often dumped in water streams or as dumping sites that cause air, water and soil pollution. RHA contains non-crystalline silicon dioxide with a high surface area of Surface and high Pozzolanic performance, so due to growing environmental concerns and the need to save energy and resources, the use of industrial waste and biogenic as additional cement-reinforcing materials has become an important component of concrete construction [15]. Pozzolanas improve strength because they are smaller than cement particles, and can pack between cement particles and provide a good pore texture. RHA has two roles in concrete construction, as part of Portland cement, to reduce the cost of concrete in the production of low-cost building blocks, and as an integral part in the production of high-strength concrete [16].

2. MATERIALS AND METHODS

The materials that are used in this study are as follows:

2.1.Portland Cement*:*

Cement is used in concrete as a binder. Cement is manufactured in the Zuari cement plant (Ordinary Portland Cement) brand, IS 12269-1987, which is used in this study. The physical properties of cement are mentioned in Table no 2.1.

Table No 2.1: **Physical Properties of Cement**

S. No	Particulars	IS Code used	Results
1	Specific Gravity	-	3.15
2	Normal Consistency	IS: 5513-1976	32%
3	Initial Setting Time	IS: 5513-1976	38min
4	Final Setting Time	IS: 5513-1976	310min
5	Soundness Test	-	8mm
6	Fineness of cement	IS: 460-1962	8.9%

2.2 Aggregates:

Aggregates play an important role in the mixing of concrete and mortar. Inevitably, it is a component that is located in one of these. A large proportion of the mass contributions of the major characteristics are to be linked to the fresh and hardened state. The IS codes are used 2386 part-I, part III, Part IV, part V of the study in this research process.

2.2.1 Fine Aggregate:

The aggregates most of which pass through 4.75 mm IS sieve are termed as fine aggregates. In terms of size, good combinations can be described as bright, medium, and fine sand. Depending on the distribution of particle size IS: 383-1970 divided the positive amount into four measuring areas (Grades I to IV). Measurement areas gradually improve from area I to IV planning. In this test program, a good combination was found in your area and was matched with General Data India: 383-1970. The sand was removed with a filter of 4.75 mm to remove any particles larger than 4.75 mm and aligned with the grading area I. It was light brown sand in colour. Sieve analysis and physical properties of good integration were assessed according to IS: 383-1970 and the results are shown in table below 2.2 &2.3.

Table No 2.2: **Properties of the Fine Aggregate**

S.No	Particulars	Result
1	Type	Fine Aggregate
2	Specific Gravity	2.52
3	Grading size	4.75mm
4	Water absorption	0.89%
5	Fineness modulus	2.66

Table No2.3: Sieve Analysis of Fine aggregates

Weight of sample taken = 1000 gm					
S. NO	**IS Sieve (mm)**	**Wt. retained (gm)**	**% Retained**	**% Passing**	**Cumulative % Retained**
1	4.75	14.5	1.45	98.55	1.45
2	2.36	37	3.70	94.85	5.15
3	1.18	246.5	24.65	70.20	29.80
4	600 µ	205.5	20.52	49.65	50.35
5	300 µ	287.5	28.75	20.90	79.10
6	150 µ	177	17.70	3.2	96.80
	Pan	32	3.2	-	
	Tot	1000		SU	262.65
	al			M	
				FM	2.62

2.2.2 Coarse Aggregate:

The aggregate which is retained over IS Sieve 4.75 mm is termed as coarse aggregate. The coarse aggregates may be the types crushed graves or stone obtained by crushing of gravel or hard stone. The physical properties and sieve analysis are shown in below table 2.4 & 2.5.

Table No 2.4: **Properties of the Coarse Aggregate**

S. No	Particulars	Result
1	Colour	Gray
2	Specific Gravity	2.68
3	Maximum size	20mm
4	Shape	Angular
5	Fineness modulus	6.95

Sieve analysis of Coarse aggregates:

Sieve Analysis of Coarse Aggregate (20mm)

Weight of sample taken = 3000 gm

Table No 2.5: Sieve Analysis of Coarse aggregates

S. NO	IS Sieve (mm)	Wt. retained (gm)	% Retained	% Passing	Cumulative % Retained
1	80	0	0	100	0
2	40	0	0	100	0
3	20	68.5	2.28	97.72	2.28
4	10	2776.5	92.55	5.17	94.83
5	4.75	113.5	3.78	1.38	98.62
6	Pan	0	0	0	-

	Total	300		Sum	195.73 + 500 = 695.73
				FM	6.95

2.3Titanium dioxide:

Titanium dioxide is a natural titanium oxide. TiO2 has its own chemical formula. When inserting nano (TiO2) particles with a standard particle size of 15nanometer (nm) in a variety of concrete, physical and mechanical properties were measured. These nanoparticles help to improve the penetration of concrete as a substitute of cement (up to 2% weight of cement). Rutile, Anatase and Brookite are the three most common types of titanium dioxide. Titanium dioxide is also called self-cleaning concrete or white concrete. It gives not only structural stability but also aesthetic appearance. Rutile is a very stable form of titanium dioxide Anatase and Brookite does not change, but is converted slowly when heated to rutile at normal temperatures. Nowadays, applications have become increasingly popular with anti-fog buildings. Titanium dioxide can be used in a variety of applications ranging from paint, sunscreen to food colouring.

Fig.2.1: Titanium Dioxide (Anatase Based)

The properties of titanium dioxide are shown below in table 3.4:

Table No2.6: Properties of titanium dioxide

Property	Value
Particulars	Anatase based
TiO_2	97-98 %
Specific Gravity	3.8-3.9
pH Content	6.5 – 8
Moisture	0.4% max
Oil Absorption	20 - 25 gm / 100 gm
Particle size	20-25μm

2.4 Amorphous silica:

Amorphous Rice Husk Ash (RHA) is produced from rice husks, which are the shells produced during the dehusking operation of rice. Rice husks are approximately 50% cellulose, 30% lignin and 20% silica. To reduce the amount of waste materials, rice husks are incinerated by controlled combustion to remove the lignin and cellulose, leaving behind an ash composed mostly of silica. RHA, produced by controlled incineration under oxidizing conditions at relatively low combustion temperatures and short holding time, is highly pozzolanic with high surface area (50 to 100 m^2 /g by nitrogen adsorption), and consists mainly of amorphous silica. By varying the temperature, RHA can be produced with a range of colours from nearly white to black. The chemical analysis of fully burnt RHA shows that it ranges between 90 and 96%. It is a highly active pozzolana, suitable for making high-quality cement and concrete products. In this project Rice husk was collected from nearby rice mill after collecting burned and sieved with 90microns IS sieve is shown in fig 3.9 and its properties were tabulated in table 3.5. RHA is the result of burning rice husks. A large part of the easily accessible parts of husk rice are lost slightly during the meal and the most important deposits are silicates. The characteristics of the waste are less than (1) the arrangement of the rice husks, (2) the heat, and (3) the time consuming. Each dose of 100 kg of consumed heater for example will produce approximately 25 kg of RHA.

Fig. 2.2: Fine powdered rice husk ash

Table No 2.7: Properties of Rice husk ash

Property	Value
Particulars	Amorphous based
Specific Gravity	2.14
pH Content	10.8
Moisture	0.6% max
Particle size	5 – 95 µm

2.5 Water:

Water is used to mix the solution must be free of dissolved contaminants, particulate matter, and should be suitable for drinking. According to the survey, it is found that several researchers to perform different types of tests on the water, such as pH of the test, alkalinity, turbidity and acidity test.

Table No 2.8: Properties of Water

S.NO	PARTICULARS	RESULTS
1	pH Value	6.8
2	Alkalinity	95 mg/lit
3	Turbidity	12.6 NTU
4	Acidity	138.67 mg/lit

3. EXPERIMENTAL PROGRAM

1. Mix Proportions:

M25 grade of concrete is considered. The concrete is mixed with different percentages of titanium dioxide and amorphous silica (0% - 0%, 0.5% – 2.5%, 1% - 5%, 1.5% - 7.5%, 2% - 10% and 2.5% - 12.5%) of powder content as a replacement by the weight of cement. The mix design for concrete is carried out as per IS 10262 – 2019 and IS 456 – 2000.

Table No 3.1: Representing Mix number with respected to titanium dioxide and amorphous silica

S. No	Titanium dioxide % - Amorphous silica %	Mix No.
1	0% - 0%,	M1
2	0.5% – 2.5%	M2
3	1% - 5%	M3
4	1.5% - 7.5%	M4
5	2% - 10%	M5
6	2.5% - 12.5%	M6

2. The casting of specimens:

In this study, a cube with dimensions of 70.6X70.6X70.6 mm is used to determine compressive strength, a cylinder with dimensions of 150mm diameter and 300mm height is used to determine split tensile strength, and a beam with dimensions of 100X100X500 mm is cast to determine flexural strength of cement mortar specimens at 7, 14, and 28 days. .

To find the durability properties of cement mortar cube of size 70.6X70.6X70.6 mm are used to find the acid resistant test and salt resistant test at 90 days.

3. Mix Design:

The aspect ratio of the mixture used in this study is listed in Table 3.1.

Table No 3.2: **Mix Design for M25 Concrete**

Material	Quantity
Cement	438.13 Kg/m^3
Fine Aggregate	645.67 Kg/m^3
Coarse Aggregate	1074.06Kg/m^3

Water	197.16 lit/m^3

4. EXPERIMENTAL RESULTS

4.1. Workability Test:

4.1.1 Slump Test:

The Slump test was performed on the Titanium dioxide and amorphous silica-based concrete to check the workability. The following results were obtained, according to which it can be concluded that with the increase workability when Titanium dioxide and amorphous silica added to the concrete. The results obtained for Slump test are shown below in Table 4.1.

Table No4.1: Results of Slump test

Mix No	Slump value (cm)
M1	96
M2	102
M3	115
M4	121
M5	125
M6	128

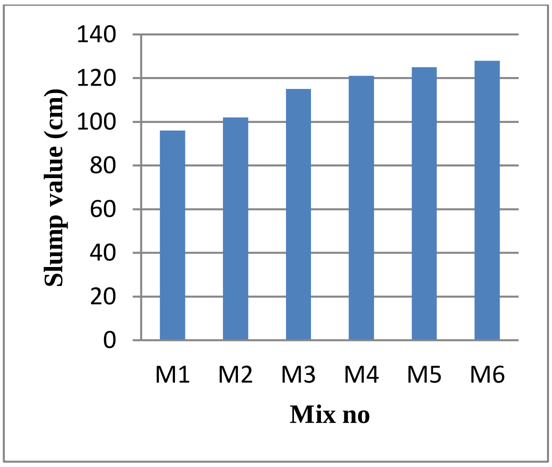

Fig. 4.1: Slump test results

The above figure 4.1 shows the slump results. It was observed that, the slump was increases with the increasing Titanium dioxide and amorphous silica content in the concrete.

4.1.2 Compaction factor test:

The compaction factor test was performed on the Titanium dioxide and amorphous silica-based concrete to check the workability. The following results were obtained, according to which it can be concluded that with the increase workability when Titanium dioxide and amorphous silica added to the concrete. Theoretical maximum value of compaction factor can be 0.96 to 1.0. The results obtained for Slump test are shown below in Table 4.2.

Table No 4.2: Results of compaction factor test

Mix No	Compaction factor (%)
M1	0.87
M2	0.89
M3	0.9
M4	0.93
M5	0.94
M6	0.96

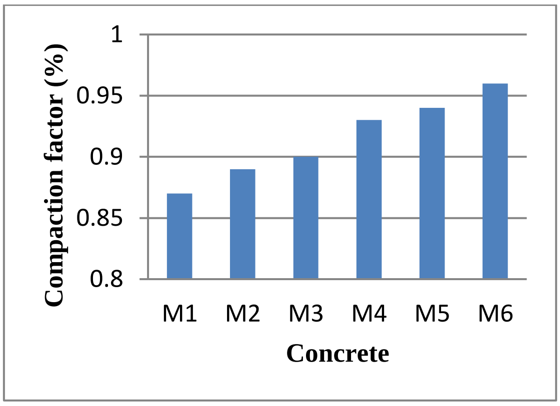

Fig. 4.2: Compaction factor test results graph

4.2 Hardened Properties of Concrete:

4.2.1 Compressive strength test:

The compressive strength test was performed on Titanium dioxide and amorphous silica-based concrete the cubes of size 15 cm x 15 cm x 15 cm to check the compressive strength of concrete and the results obtained are given in Table 4.3.

Table No4.3: Compressive strength test

Mix No.	Compressive strength (N/mm^2)		
	7days	**14days**	**28days**
M1	14.82	23.67	28.01
M2	18.92	29.53	33.12
M3	20.61	32.75	36.43
M4	24.25	37.32	42.04
M5	20.89	32.92	37.98
M6	16.68	27.39	31.27

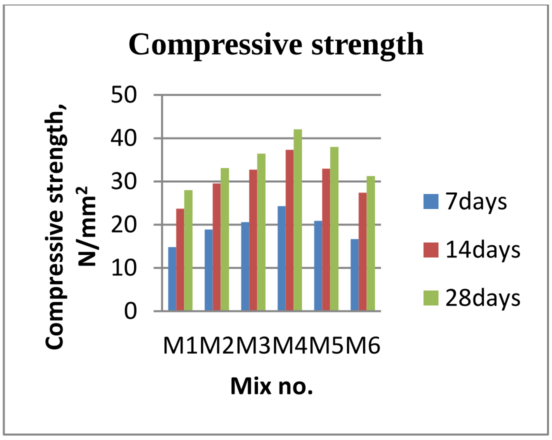

Fig. 4.3: Compressive strength test results graph

From the above graph the Titanium dioxide and amorphous silica based concrete compressive strength **50%** more than Conventional concrete for 28days curing.

4.2.2 Flexural Strength test:

The flexural strength test was performed on the cubes of size 10 cm x 10 cm x 50 cm to check the flexural strength of Titanium dioxide and amorphous silica-based concrete and the results obtained are given in Table 4.4.

Table No4.4: Flexural Strength test

Concrete	Flexural strength (N/mm^2)		
	7days	**14days**	**28days**
M1	2.23	3.24	3.51
M2	2.34	3.37	3.73
M3	2.41	3.48	3.81
M4	2.57	3.64	3.99
M5	2.39	3.5	3.86
M6	2.17	3.18	3.43

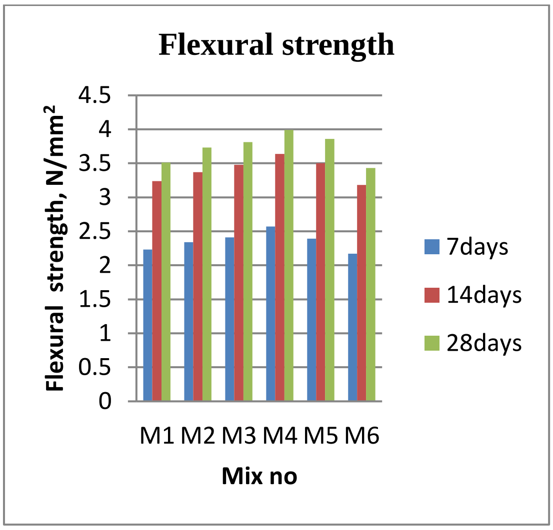

Fig. 6.4 Flexural strength test results graph

From the above graph the Titanium dioxide and amorphous silica based concrete flexural strength **12%** more than Conventional concrete for 28days curing.

4.2.3 Tensile strength test:

The tensile strength test was performed on the cylinder of size 15 cm dia30cm height to check the tensile strength of Titanium dioxide and amorphous silica-based concrete and the results obtained are given in Table 4.5.

Table No4.5: Tensile strength test

Concrete	Tensile strength (N/mm^2)		
	7days	**14days**	**28days**
M1	1.83	2.89	3.14
M2	2.24	3.21	3.46
M3	2.52	3.53	3.85
M4	2.67	3.86	4.12
M5	2.34	3.42	3.62
M6	1.81	2.84	3.27

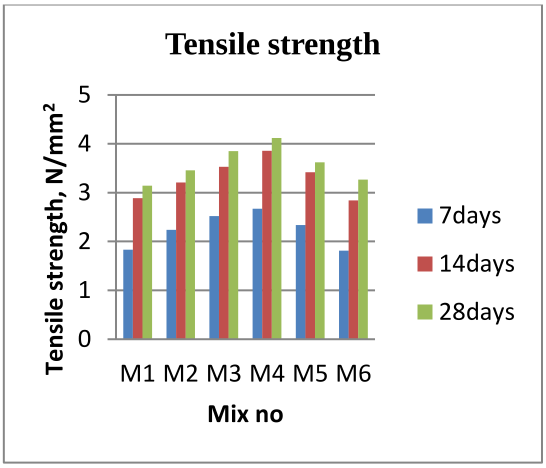

Fig. 4.5: Tensile strength test results graph

From the above graph the Titanium dioxide and amorphous silica based concrete tensile strength **23.78%** more than Conventional concrete for 28days curing.

4.2.4 Water absorption:

The water absorption of the Titanium dioxide and amorphous silica based concrete surface has improved when compared with conventional concrete.

Table No 4.6: Water absorption test

Mix No.	28days
M1	3.62
M2	3.56
M3	3.43
M4	3.12
M5	2.97
M6	2.92

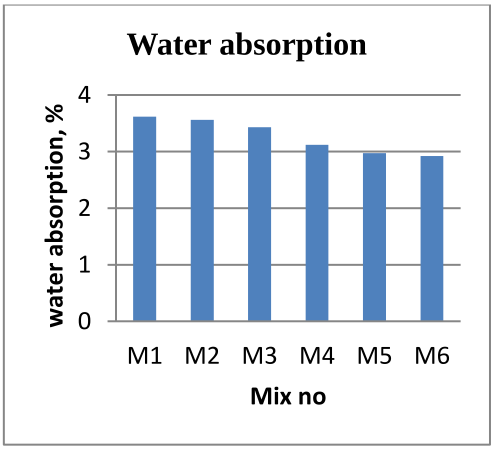

Fig. 4.6: Water absorption test results graph

From the above graph the Titanium dioxide and amorphous silica based concrete water absorption value lesser than Conventional concrete for 28days immersion.

4.2.5 Loss of weight due to Sulphate acid attack after 90 days curing:

After 28 days curing of Titanium dioxide and amorphous silica based concrete cubes those specimens were soaked in chemical water solution made with 5% of H2SO4 at 90 days, and the test was conducted. The test results are shown in table 6.7 and graphical representation in fig 4.7.

Table No 4.7: Sulphate acid attack test results

Mix No.	Weight of the specimen before curing in chemical water solution (W1) (kg)	Weight of the specimen after curing in chemical water solution (W2) (kg)	% of loss in weight of the specimen
M1	8.820	8.789	0.31
M2	8.830	8.800	0.30
M3	8.851	8.826	0.25
M4	8.863	8.848	0.15
M5	8.853	8.650	0.24
M6	8.783	8.463	0.32

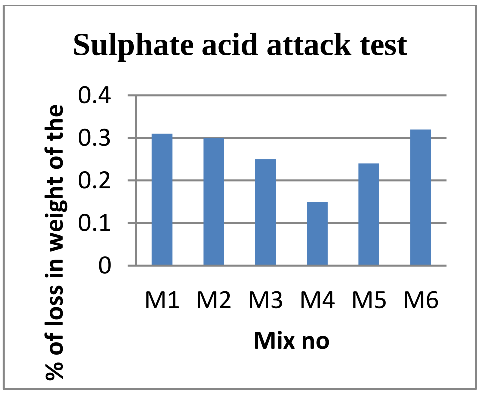

Fig. 4.7:Sulphate acid attack test results

4.2.6 Loss in compressive strength of concrete after 90 days curing in chemical water solution:

After 28 days curing of Titanium dioxide and amorphous silica based concrete cubes in portable water, those specimens were soaked in chemical water solution made with 5% of H2SO4 at 90 days, and the test was conducted. The test results are shown in table 4.8 and graphical representation in fig 4.8.

Table No 4.8: Loss in compressive strength of concrete after 90 days curing in chemical water solution

Mix No.	Compressive strength before soaking in the chemical water solution (N/mm^2)	Compressive strength after soaking in the chemical water solution (N/mm^2)	% of loss in compressive strength
M1	28.01	23.04	4.97
M2	33.12	29.56	3.56
M3	36.43	33.82	2.61
M4	42.04	40.42	1.62
M5	37.98	33.74	4.24
M6	31.27	26.37	4.90

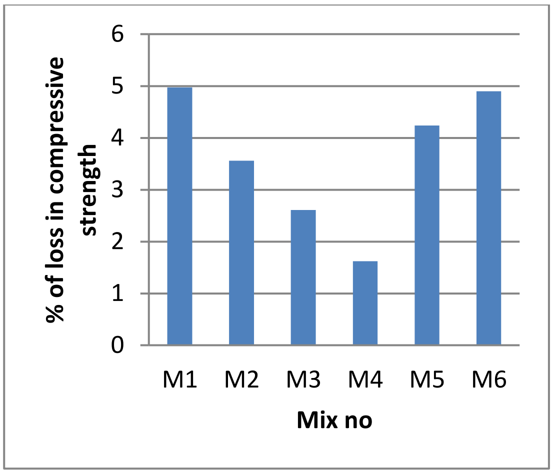

Fig. 4.8: Loss in compressive strength of concrete after 90 days curing in chemical water solution

5. CONCLUSION

Anatase Nano Titanium Dioxide (TiO_2) and Amorphous Silica (AS) nanomaterials added to the cement at various combination proportions 0.5% & 2.5%, 1% & 5%, 1.5% & 7.5%, 2% & 10%, and 2.5% & 12.5% by weight of cement, and concrete specimens are made, and tested, and compared with the conventional concrete of M25 grade, and the following are the outcomes from the experimental investigation are

- The workability of concrete is going on increasing with an increase of TiO_2 and AS proportions.
  - Slump increased from 96 to 121cm (26.04%) and compaction factor increased from 0.87 to 0.93% (6.90%) at 1.5% & 7.5% combination proportions of TiO_2 and AS
- Better mechanical properties (compressive, flexural, and split tensile strengths) were found at 1.5% & 7.5% proportions of TiO_2 and AS. It is also observed that the increase in initial strengths is more than at 28 days strength.

- Compressive, flexural, and split tensile strengths at 7 days increases from 14.82 to 24.25 N/mm^2 (63.63%), 2.23 to 2.57 N/mm^2 (15.25%), and 1.83 to 2.67 N/mm^2 (45.90%), respectively
- Compressive, flexural, and split tensile strengths at 14 days increases from 23.67 to 37.32 N/mm^2 (57.67%), 3.24 to 3.64 N/mm^2 (12.35%), and 2.89 to 3.86 N/mm^2 (33.56%), respectively
- Compressive, flexural, and split tensile strengths at 28 days increases from 28.01 to 42.04 N/mm^2 (50.09%), 3.51 to 3.99 N/mm^2 (13.68%), and 3.14 to 4.12 N/mm^2 (31.21%), respectively

➢ Better durability was found at 1.5% & 7.5% proportions of TiO_2 and AS.

- Loss of weight in concrete decreases from 0.48% to 0.19% (67%)
- Compressive strength decreases from 42.04% to 40.04% (3.34%)

TiO_2 and AS combination at the proportions of 1.5% & 7.5% recommended for M25 grade concrete for better strength and durability.

FUTURE SCOPE

➢ In this research only on strength properties of concrete, in this future work can be extended on permeability test, Sulphate attack test and Salt attack etc.

➢ Further study can be extended on various properties of concrete by changing the particles size of titanium dioxide and various grade of concrete.

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