

# Study on Behaviour of TiO<sub>2</sub> and GGBS with Respect to Mechanical and Durability Properties of Sustainable Concrete

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**ABSTRACT:** Concrete is the abundant man made material in the world. The amount of CO<sub>2</sub> emission during the manufacturing of OPC is nearly one ton. The CO<sub>2</sub> emission is approximately 7% of the world's CO<sub>2</sub> emission. In order to decrease the CO<sub>2</sub> emission and create the sustainable environment we have to develop greener building material. In this the Titanium dioxide and Ground Granulated Blast furnace Slag are used in cement at mixing of concrete. In this TiO<sub>2</sub> act as a self cleaning material and the concrete with addition of TiO<sub>2</sub> is 1% by mass of the cement based on the previous experiments done by the researchers and GGBS with 5%, 10% and 15% by mass of cement were prepared. In these mechanical properties of concrete such as Compressive strength, Flexural strength, Split Tensile strength and durability properties like Water Permeability and RCPT were studied. The comparison of mechanical properties of normal concrete with TiO<sub>2</sub> and different percentages of GGBS were studied. The SEM (Scanning Electron Microscopy) analysis with EDS (Energy Dispersive X-Ray Spectroscopy) of concrete observations mixed with TiO<sub>2</sub> and GGBS for optimum content was studied.

**KEYWORDS:** Titanium dioxide, GGBS, Self cleaning material, SEM analysis with EDS.

## I. INTRODUCTION

Concrete is the most usable abundant material on the earth for infrastructure development. It is used in construction industry for buildings, roadways, dams, bridges and for developing infrastructure of a country. Generally normal concrete or conventional concrete is made up of cement, water and aggregates. But a modern concrete consist of two more components in addition to the above four components. The other materials are chemical and mineral admixtures. Mineral admixtures are the kind of materials which goes into the concrete and sometimes even in cement manufacturing like fly ash, silica fume, rice husk ash and other pozzolans or other similar materials. In the present study the admixture which is used is GGBS and the chemical compound TiO<sub>2</sub>. Now days the GGBS is mostly common used material in concrete.

The use of photo catalytic building materials to reduce atmospheric pollutants, which have a negative effect on health, particularly among children and the elderly, is becoming more necessary. Vehicular traffic emissions and contaminants caused by housing and industry are the main sources of atmospheric pollution in dense urban areas. Photocatalytic substances includes nano titanium dioxide (TiO<sub>2</sub>), with the presence of UV light (sunlight), can accelerate the photo catalytic process via the decomposition of organic and inorganic materials, such as air pollutants including NO<sub>x</sub>, SO<sub>x</sub>, and volatile organic compounds (VOCs).

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## II. LITERATURE REVIEW

In the literature the use of TiO<sub>2</sub> and GGBS are explained, the effect of admixtures in the fresh concrete and the hardened concrete are explained by the authors who are studied previously.

**Shihui Shen et al. (2012)**<sup>1</sup> has making use of TiO<sub>2</sub> to pavements would possibly enhance the elimination of emissions at road level. Not like conventional non-pervious pavements, the excessive porosity and surface roughness of pervious concrete pavement permit more TiO<sub>2</sub> particles to have direct contact with UV lighting and hence improve elimination performance. When DPM coatings were compared at different TiO<sub>2</sub> on concentrations (5%, 10%, 15%, and 18% TiO<sub>2</sub>), all four concentrations had similar results for NO reduction, maintaining between 94% and 98% static NO% reduction. This shows that the DPM coating can still work well with lower amounts of TiO<sub>2</sub>. The impact of the TiO<sub>2</sub> to the texture and friction properties of the pavement will need to be studied.

**Decheng Feng et al. (2013)**<sup>2</sup> has been investigated via experimental studies on the mechanical properties and microstructure of the cement pastes containing TiO<sub>2</sub> nanoparticles. The laboratory testing showed that the 28-day 3-point bend strength of the cement paste with a water/cement ratio of 0.4 improved with respect to 0.1%, 0.5%, 1.0%, and 1.5% TiO<sub>2</sub> nanoparticles by means of mass of cement had been included. Such upgrades inside the mechanical properties can be attributed to development of the paste microstructure by way of the addition of a small quantity (1.0% by means of mass) of TiO<sub>2</sub> nanoparticles and achievement of desirable dispersion, nano change increased the quantity of cementitious segment inside the paste, reduced the micro porosity and quantity of internal micro cracks and defects, acquired a denser microstructure with reduced nano roughness, and led to the formation of needle-shaped nano precipitates.

**Jitendra Patil et al. (2016)**<sup>3</sup> have studied that the compressive strength of Nano particles such as Alumina, Silica and Titania are reduced when compared to the normal concrete. The compressive strength of Titania is reduced by 63.31% for 7 days and 42.85% for 14 days. As the compressive strength of concrete and cement by using Nano products is not achieved up to the desired degree although workability is achieved up to some extent also the Nano products are not easily available in market at present, So the other alternatives which are easily available are preferable as compare to Nano products, in case 10 % replacement of cement is adopted. Nano Products used are costlier than other additives and admixtures, so use of Nano product increases the overall cost of the project.

**B.Mangamma et al. (2016)**<sup>4</sup> has carried out experiments on GGBS. It gives good strength when compared to normal mix. Partial replacement of GGBS decrease the environmental pollution such as ground pollution, water pollution etc. Partial replacements of GGBS increase the strengths at 10%, 20%, 30% as well as reduce the strength at 40%, 50%. It also reduces the cost of construction.

**Chetan A. Rajgor1 et al. (2017)**<sup>5</sup> has made studies on mechanical properties of concrete with GGBS and Fly ash. The compressive strength concrete increased by a maximum of 8.75% at 28 days with (0% of fly ash + 30% of GGBS) replacement. The compressive strength of other mixes is less than the nominal mix. The pozzolanic material gives the less early strength. The flexural strength concrete increased by a maximum of 4.43% at 28 days with (0% of fly ash + 30% of GGBS) replacement. The split tensile strength concrete increased by a maximum of 4.39% at 28 days with (0% of fly ash + 30% of GGBS) replacement. In the Rapid Chloride Penetration Test (RCPT) the mix of 5% of Fly Ash and 25% GGBS is replacement of cement is gives the less effect of Chloride Penetration than the others mixes. Also the effect of Chloride on mixes of 0% Fly Ash and 30% GGBS the then normal concrete.

## III. MATERIALS

The materials used in the present study are:

- 1. Cement:** Cement is used as a binding material in concrete. The Cement used in the present study is manufactured by **Zuari Cement** Company of 53 grade OPC (Ordinary Portland Cement) confirming to IS 12269-1987 is used in this study. The properties of cement are given below.

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**Table 1:** Properties of Cement

S.No.	Particulars	Results
1	Specific Gravity	3.0
2	Initial Setting Time	34 min
3	Final setting Time	450 min
4	Fineness modulus	250 m <sup>2</sup> /kg

2. **Aggregates:** Aggregates represent a skeleton of concrete. More or less three-quarters of the amount of conventional concrete is occupied by aggregate. It's inevitable that a constituent occupying one of these large percentages of the mass have to make a contribution of essential properties to both the fresh and hardened product.

a. **Fine aggregates:** Aggregates passing through 4.75 mm sieve and predominately retained on 75 µm sieve are classified as fine aggregate. River sand is the most commonly used fine aggregate. In addition, crushed rock fines can be used as fine aggregate. However, the finish of concrete with crushed rock fines is not as good as that with river sand. In the present study we are using River sand for the good finishing and to fill the voids between the coarse aggregate. It is taken from Cheyyeru River near Nandalur. The properties of sand are given in below.

**Table 2:** Properties of Fine Aggregate

S.No.	Particulars	Results
1	Type	River Sand
2	Specific gravity	2.62
3	Size	4.75 mm
4	Water absorption	1%
5	Grade of sand	Zone II

b. **Coarse Aggregates:** Aggregates predominately retained on 4.75 mm sieve are categorized as coarse aggregate. Usually, the size of coarse aggregate is from 5 to 150 mm. For normal concrete which is used for structural members including beams and columns, the maximum size of coarse aggregate is about 25 mm. For mass concrete which is used for dams or deep foundations, the maximum size may be as large as 150 mm. In this study the size of the aggregate is 20 mm and it is taken from the quarry Akepadu village near Rajampet. The physical properties of coarse aggregate are listed in below table.

**Table 3:** Properties of Coarse Aggregate

S.No.	Particulars	Results
1	Type	Crushed stone
2	Specific Gravity	2.64
3	Size	20mm
4	Water absorption	0.8%

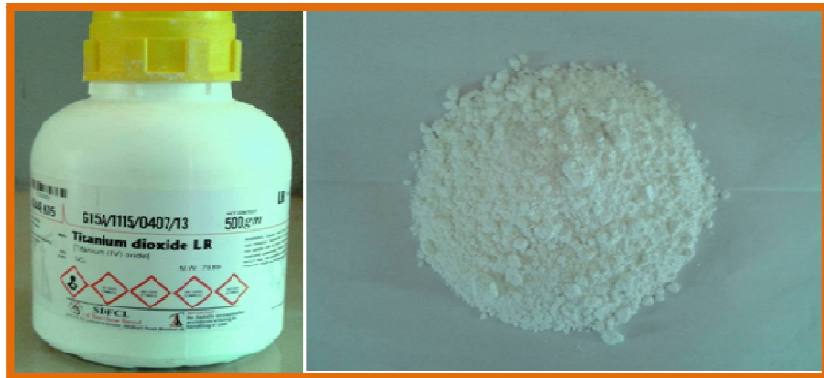
3. **Titanium Dioxide:** The main reason TiO<sub>2</sub> was loaded with cementitious materials because only water, oxygen and solar light required for photo catalysis reaction. In addition, TiO<sub>2</sub> is a photo catalyst that can break down almost any organic compound with the presence of sunlight. If any dirt present on the surface, the water will penetrates under the dirt and removes it. The specific gravity of TiO<sub>2</sub> is 3.7.

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**Fig.1** Titanium dioxide in anatase form

4. **GGBS:** Ground granulated blast furnace slag is a mineral admixture which have the chemical components similar to that of Portland cement. Due to hydraulicity, therefore, it contributes not only improvement of concrete performance, but also in resource and energy savings. The specific gravity of GGBS is 2.9.
- 5.



**Fig.2:** GGBS in Nano form

From XRD test results for GGBS,

By using Debye – Scherer equation Nano particle size can be obtained.

$D = \frac{K\lambda}{\beta \cos\theta}$  where  $\lambda = 1.54 \text{ \AA}$ ,  $\beta$  = full width at Half maximum intensity (FWHM) of the peak in radians,  $\theta$  = angle, K is constant, i.e.0.9.

By using Debye – Scherer equation,  $K=0.9$ ,  $\lambda= 0.154 \text{ nm}$ ,  $\beta = \frac{\pi}{180} \times \text{FWHM} = \frac{\pi}{180} \times 8.14 = 0.142$ ,

$$2\theta = 30.45^\circ \gg \theta = 15.225$$

$$\text{Particle Size of GGBS, } D = \frac{K\lambda}{\beta \cos\theta} = \frac{0.9 \times 0.154}{0.142 \times \cos 15.225} = 1.011 \text{ nm.}$$

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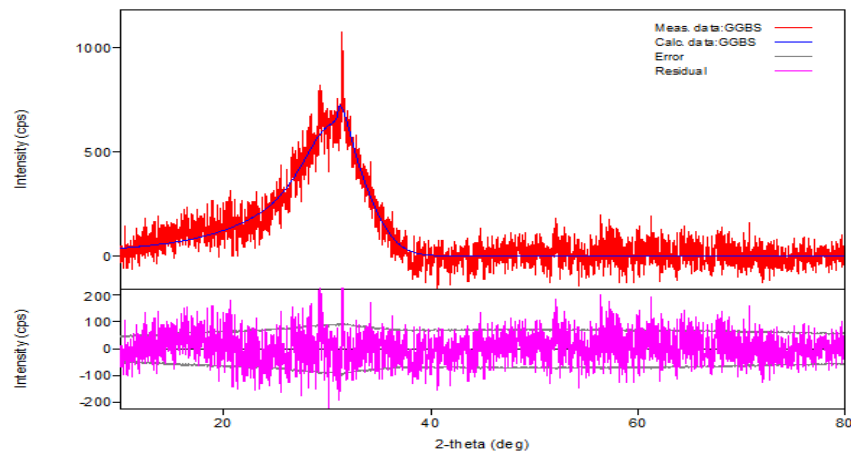


Fig.3: XRD Graph for GGBS

The chemical components of the GGBS which are obtained from the XRD data are shown in the below table.

Table 4: Chemical components of GGBS

S.NO.	Compound	Content by % wt.
1	SiO <sub>2</sub>	38.56
2	Al <sub>2</sub> O <sub>3</sub>	9.75
3	Fe <sub>2</sub> O <sub>3</sub>	3.52
4	CaO	34.35
5	MgO	7.03
6	K <sub>2</sub> O	0.3

6. **Water:** Water is an essential ingredient of concrete, and a well designed concrete mixture, normally with 15 to 25% water with the aid of quantity, will possess the desired workability for fresh concrete and the specified durability and strength for hardened concrete. The entire quantity of water in concrete and the water-to-cement ratio can be the most important factors in the production of good-quality concrete.

## IV. EXPERIMENTAL PROGRAM

- a. **Mix Proportions:** In the present investigation M30 concrete is prepared with the water cement ratio 0.5. Concrete mixes are prepared by different proportions of cement replacing with TiO<sub>2</sub> (1%) and GGBS (0%, 5%, 10% and 15%). i.e. the percentages with different combinations of 1% TiO<sub>2</sub> with 0% GGBS, 1% TiO<sub>2</sub> with 5% GGBS, 1% TiO<sub>2</sub> with 10% GGBS and 1%TiO<sub>2</sub> with 15% GGBS along with normal concrete without TiO<sub>2</sub> and GGBS. The mix designations are follows:

1. CM refers to the Control Mix
2. G<sub>0</sub>T<sub>1</sub> refers to 1% TiO<sub>2</sub> and 0% GGBS
3. G<sub>5</sub>T<sub>1</sub> refers to 1% TiO<sub>2</sub> and 5% GGBS
4. G<sub>10</sub>T<sub>1</sub> refers to 1% TiO<sub>2</sub> and 10% GGBS
5. G<sub>15</sub>T<sub>1</sub> refers to 1% TiO<sub>2</sub> and 15% GGBS

- b. **Casting of Specimens:** The specimens are casted in the present study are cubes of size 150X150X150 mm, Cylinders of size 150 mm diameter and 300 mm height, Beam specimens of size 150X150X700 mm for 7 days, 14 days and 28 days. RCPT of size 10 mm diameter and 5 mm height and water permeability of 200mm diameter and 120 mm height are used for 28 days and 60 days. The SEM analysis was also done for 28 days specimens of optimum content.

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**c. Mix Proportions:**

Mix Proportions for M30 Control Mix concrete.

**Table 5:** Mix Proportions of Concrete

Material	Quantity
Cement	363.16 Kg/m <sup>3</sup>
Fine Aggregate	730.45 Kg/m <sup>3</sup>
Coarse Aggregate	1104.05 Kg/m <sup>3</sup>
Water	181.58 lit/m <sup>3</sup>

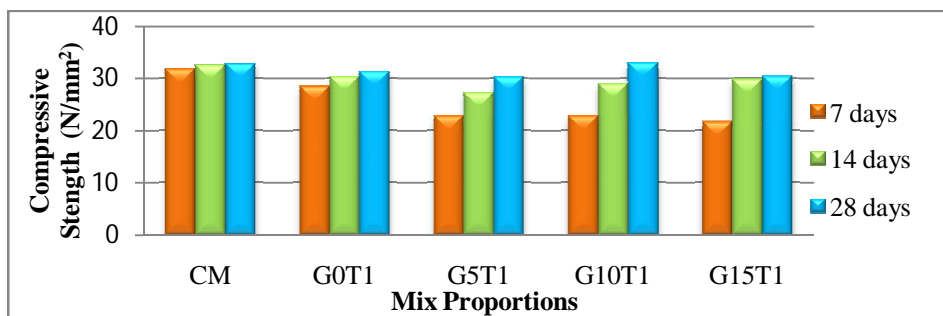
## V. EXPERIMENTAL RESULTS

**A. Compressive strength:** The compressive strength of concrete with different proportions are increased up to 1%TiO<sub>2</sub> and 10% GGBS concrete, then it is decreased for 1% TiO<sub>2</sub> and 15% GGBS.

**Table 6:** Compressive Strength Test Results

Mix designation	Compressive strength (N/mm <sup>2</sup> )		
	7 Days	14 Days	28 Days
CM	31.85	32.6	32.86
G <sub>0</sub> T <sub>1</sub>	28.47	30.33	31.33
G <sub>5</sub> T <sub>1</sub>	22.83	27.33	30.3
G <sub>10</sub> T <sub>1</sub>	22.9	29	33
G <sub>15</sub> T <sub>1</sub>	21.77	29.9	30.46

The concrete with TiO<sub>2</sub> (G<sub>0</sub>T<sub>1</sub>) of compressive strength is decreased by 10.61%, 6.96% and 4.65% with respect to normal OPC Concrete (CM) in 7 days, 14 days and 28 days. When compared with normal OPC concrete, the compressive strength is decreased by 28.32%, 16.16% and 7.79% for 1% TiO<sub>2</sub> + 5% GGBS (G<sub>5</sub>T<sub>1</sub>) in 7, 14 and 28 days respectively. It is decreased by 28.1% in 7 days, 11.04% in 14 days and increased by 0.42% in 28 days for 1% TiO<sub>2</sub> + 10% GGBS (G<sub>10</sub>T<sub>1</sub>). It is decreased by 31.65% in 7 days, 8.28% in 14 days and 7.30% in 28 days for 1% TiO<sub>2</sub> + 15% GGBS (G<sub>15</sub>T<sub>1</sub>). When compared with normal concrete (CM) the compressive strength is decreased while adding with TiO<sub>2</sub> and GGBS in concrete with respect to 7 days, 14 days and 28 days curing. The test results of the concrete with different proportions are listed in above table. The comparison of conventional OPC concrete (CM) and concrete with TiO<sub>2</sub> and GGBS are represented in below chart.



**Fig.4:** Compressive Strength of different Proportions



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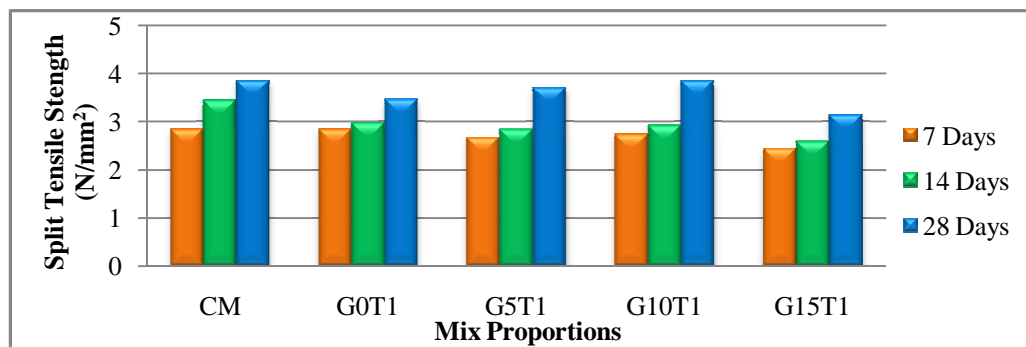
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**B. Split Tensile Strength:** The Split tensile strength of the concrete tested for M30 concrete with 0%, 5%, 10% and 15% are tested and the results discussed in below and normal concrete also will be discussed.

**Table 7:** Split Tensile Strength test Result

Mix Designation	Spit Tensile Strength (N/mm <sup>2</sup> )		
	7 Days	14 Days	28 Days
CM	2.85	3.44	3.86
G <sub>0</sub> T <sub>1</sub>	2.84	2.98	3.47
G <sub>5</sub> T <sub>1</sub>	2.67	2.85	3.71
G <sub>10</sub> T <sub>1</sub>	2.74	2.93	3.85
G <sub>15</sub> T <sub>1</sub>	2.45	2.59	3.14

The Split tensile strength of the concrete is decreases up to G<sub>15</sub>T<sub>1</sub> from CM. The split tensile strength of OPC Concrete (CM) is more compared to the all mix combinations of the concrete G<sub>0</sub>T<sub>1</sub>, G<sub>5</sub>T<sub>1</sub>, G<sub>10</sub>T<sub>1</sub> and G<sub>15</sub>T<sub>1</sub>. The tensile strength decreases by 0.35% in 7 days, 13.37% in 14 days and 10.10% in 28 days for concrete with 1% TiO<sub>2</sub> (G<sub>0</sub>T<sub>1</sub>) when compared with conventional OPC concrete (CM). When compared with Conventional OPC concrete, the tensile strength of concrete is decreased while adding GGBS to the concrete, by 6.32% in 7 days, 17.15% in 14 days, 3.88% in 28 days for 1% TiO<sub>2</sub> + 5% GGBS (G<sub>5</sub>T<sub>1</sub>), Decreased by 3.86% in 7 days, 14.82% in 14 days, 0.26% in 28 days for 1% TiO<sub>2</sub> + 10% GGBS (G<sub>10</sub>T<sub>1</sub>), Decreased by 14.03% in 7 days, 24.71% in 14 days and 18.65% in 28 days for 1% TiO<sub>2</sub> + 15% GGBS (G<sub>15</sub>T<sub>1</sub>), while adding GGBS to the concrete the tensile strength decreases in 7, 14 and 28 days of curing. The maximum compressive strength is obtained at G<sub>10</sub>T<sub>1</sub> among the concrete with GGBS. The graphical representation of the tensile strength of concrete is shown in below chart.



**Fig.5:** Split tensile Strength for different Proportions

**C. Flexural Strength:** The Flexural strength of M<sub>30</sub> grade concrete mixes replacing OPC by TiO<sub>2</sub> and GGBS at 0%, 5%, 10% and 15% is investigated. The tabular column represents the flexural strength at 28 days results CM, G<sub>0</sub>T<sub>1</sub>, G<sub>5</sub>T<sub>1</sub>, G<sub>10</sub>T<sub>1</sub> and G<sub>15</sub>T<sub>1</sub> concrete mixtures tested at 28 days are represented in table.

**Table 8:** Flexural Strength test Results

S.No.	Mix Proportion	Flexural Strength
1	CM	6.10
2	G <sub>0</sub> T <sub>1</sub>	6.74
3	G <sub>5</sub> T <sub>1</sub>	5.9
4	G <sub>10</sub> T <sub>1</sub>	7.67
5	G <sub>15</sub> T <sub>1</sub>	6.325

The bending strength of concrete is more in 1% TiO<sub>2</sub> and 15% GGBS concrete when compared with all mix proportions. The bending strength of concrete is more for 1% TiO<sub>2</sub> + 10% GGBS (G<sub>10</sub>T<sub>1</sub>) increases by 25.73%

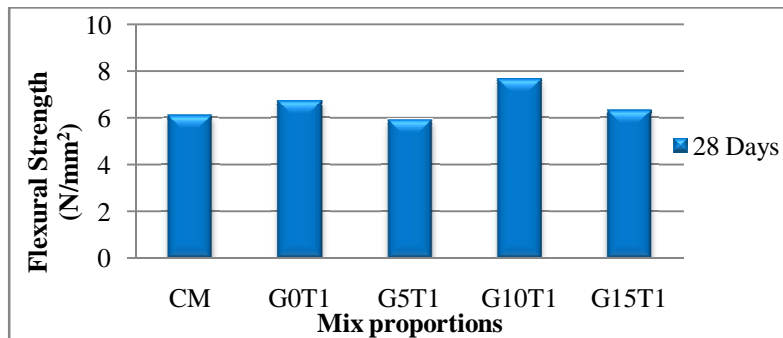
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compared to normal concrete (CM). 10.49% increases for 1% TiO<sub>2</sub> + 0% GGBS (G<sub>0</sub>T<sub>1</sub>), 3.28% decreases for 1% TiO<sub>2</sub> + 5% GGBS (G<sub>5</sub>T<sub>1</sub>), 3.68% increases for 1% TiO<sub>2</sub> + 10% GGBS (G<sub>10</sub>T<sub>1</sub>) concrete when compared with conventional OPC concrete (CM). The bending strength of concrete is less in 1% TiO<sub>2</sub> and 5% GGBS concrete while compared with normal conventional OPC concrete.



**Fig.6:** Flexural Strength test for different proportions

**D. Rapid Chloride Permeability Test:** The chloride permeability of M<sub>30</sub> grade concrete mixes replacing OPC by TiO<sub>2</sub> by 1% and GGBS at 5%, 10% and 15% is investigated. The results of chloride permeability of concrete mixtures tested at 28 days and 60 days are presented in table.

**Table 9:** RCPT Results

Mix proportions	Charge Passed (Coulombs)	
	28 Days	60 Days
CM	1532.6	1286.7
G <sub>0</sub> T <sub>1</sub>	1858.7	1173.6
G <sub>5</sub> T <sub>1</sub>	1799.1	953.55
G <sub>10</sub> T <sub>1</sub>	1085.41	787.5
G <sub>15</sub> T <sub>1</sub>	1058.5	735.87

The chloride permeability of concrete increases by 21.27% for 1% TiO<sub>2</sub> concrete (G<sub>0</sub>T<sub>1</sub>), increases by 17.38% for 1% TiO<sub>2</sub> + 5% GGBS (G<sub>5</sub>T<sub>1</sub>), decreases by 29.18% for 1% TiO<sub>2</sub> + 10% GGBS (G<sub>10</sub>T<sub>1</sub>), decreases by 30.93% for 1% TiO<sub>2</sub> + 15% GGBS (G<sub>15</sub>T<sub>1</sub>) in 28 days of curing, decreases by 8.79% for 1% TiO<sub>2</sub> concrete (G<sub>0</sub>T<sub>1</sub>), decreases by 25.89% for 1% TiO<sub>2</sub> + 5% GGBS (G<sub>5</sub>T<sub>1</sub>), decreases by 38.79% for 1% TiO<sub>2</sub> + 10% GGBS (G<sub>10</sub>T<sub>1</sub>), decreases by 42.8% for 1% TiO<sub>2</sub> + 15% GGBS (G<sub>15</sub>T<sub>1</sub>) in 60 days of curing while compared with Conventional OPC concrete. The graphical representation of the RCPT result is shown in below graph.

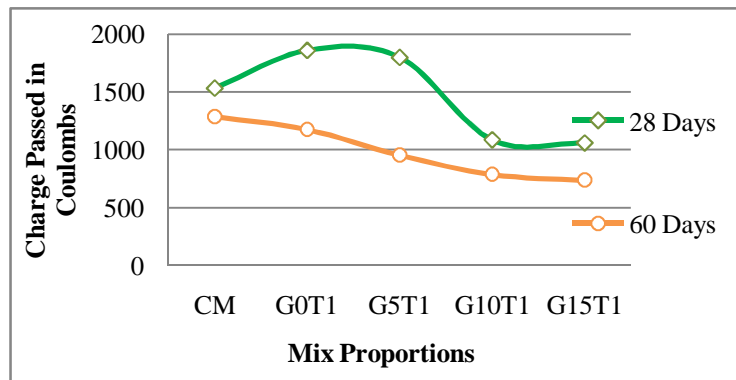


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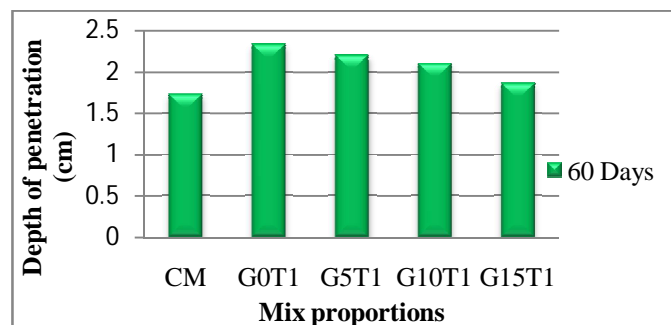
**Fig.7:** RCPT for different Proportions

**E. Water Permeability Test:** The water permeability of the concrete is done for 60 days for all proportions of CM, G<sub>0</sub>T<sub>1</sub>, G<sub>5</sub>T<sub>1</sub>, G<sub>10</sub>T<sub>1</sub> and G<sub>15</sub>T<sub>1</sub>. The water permeability of the concrete is increases with respect to the proportions from CM to G<sub>15</sub>T<sub>1</sub>.

**Table.10:** Water Permeability results

Mix Proportion	Weight gain (M in gm)	Depth of penetration (d in cm)	Coefficient of permeability (K in m/sec)
CM	50	1.73	$2.88 \times 10^{-13}$
G <sub>0</sub> T <sub>1</sub>	70	2.33	$9.42 \times 10^{-13}$
G <sub>5</sub> T <sub>1</sub>	50	2.2	$6.35 \times 10^{-13}$
G <sub>10</sub> T <sub>1</sub>	40	2.1	$4.85 \times 10^{-13}$
G <sub>15</sub> T <sub>1</sub>	60	1.86	$6.45 \times 10^{-13}$

The permeability of concrete is more in 1%TiO<sub>2</sub> + 0% GGBS (G<sub>0</sub>T<sub>1</sub>) for 60 days of curing, less in normal concrete. The depth of penetration of water increases 34.68% for G<sub>0</sub>T<sub>1</sub>, increases 27.17% for G<sub>5</sub>T<sub>1</sub>, increases 21.38% for G<sub>10</sub>T<sub>1</sub> and increases 7.51% for G<sub>15</sub>T<sub>1</sub> while compared to conventional concrete (CM). The water permeability is less for 1% TiO<sub>2</sub>+15% GGBS concrete among the GGBS and TiO<sub>2</sub> concrete. The graphical representation of water permeability is shown in figure 8.



**Fig.8:** Water Permeability for different mix proportions

**F. SEM with EDS of Concrete:** The SEM (Scanning Electron Microscopy) of the concrete with EDS is tested in Department of Physics, SV University, Tirupathi. The test was conducted for optimum compressive strength mix proportions of 7 days, 14 days and 28 days. The SEM Analysis with EDS (Energy Dispersive X-Ray Spectrometry)

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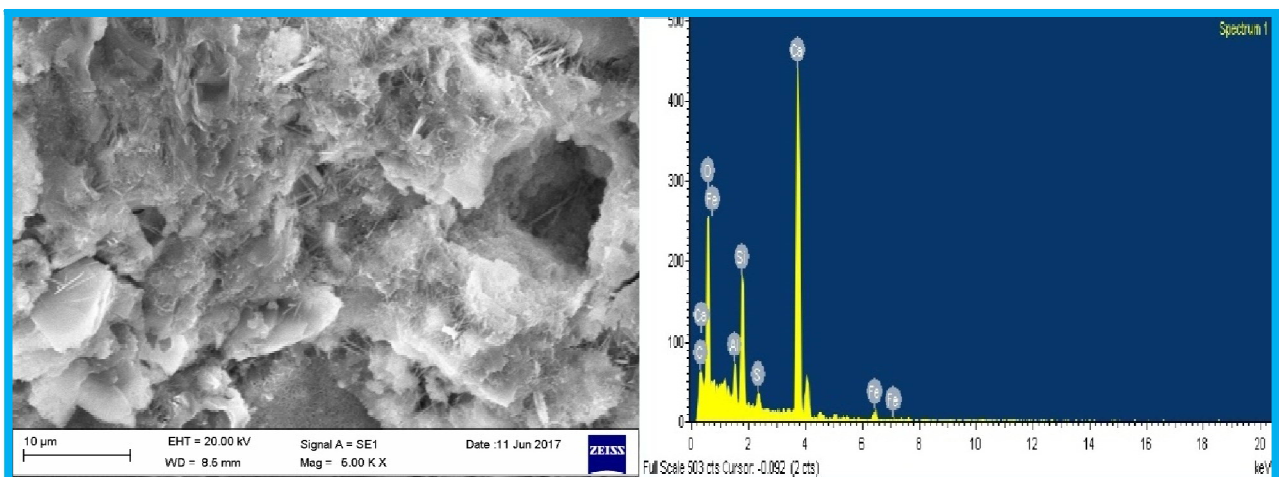
equipment is shown in the fig. which is obtained from the concrete surface. The concrete surface was scanning with microscope under 10µm scale in concrete.



**Fig.9:** SEM with EDS Equipment

Backscattered electron images in the SEM displays compositional contrast that result from different atomic number elements and their distribution. Energy Dispersive Spectroscopy (EDS) allows one to identify what those particular elements are and their relative proportions (Atomic % for example). Initial EDS analysis usually involves the generation of an X-ray spectrum from the entire scan area of the SEM. Below is a secondary electron image of a polished geological specimen and the corresponding X-ray spectra that was generated from the entire scan area.

The surface morphology of concrete with 1% TiO<sub>2</sub> and 10% GGBS is observed in the following figure, the surface has shown in the figure is after 7 days the formation of bonding is like a needle shaped structure.



**Fig.10:** SEM with EDS of Concrete for 7 days Curing

The EDS data after 7 days curing represents the chemical compounds which are formed in the concrete with hydration of cement in concrete. The compounds which are formed in the concrete are shown below. The components which are formed in the concrete after 7 days curing are C (CaCO<sub>3</sub>) – 7.56%, O (SiO<sub>2</sub>)–56.47%, Al (Al<sub>2</sub>O<sub>3</sub>)–2.01%, Si (SiO<sub>2</sub>)–5.53%, S (FeS<sub>2</sub>)–0.89%, Ca (CaSiO<sub>3</sub>)–26.03%, Fe–1.51% by the weight of the concrete.

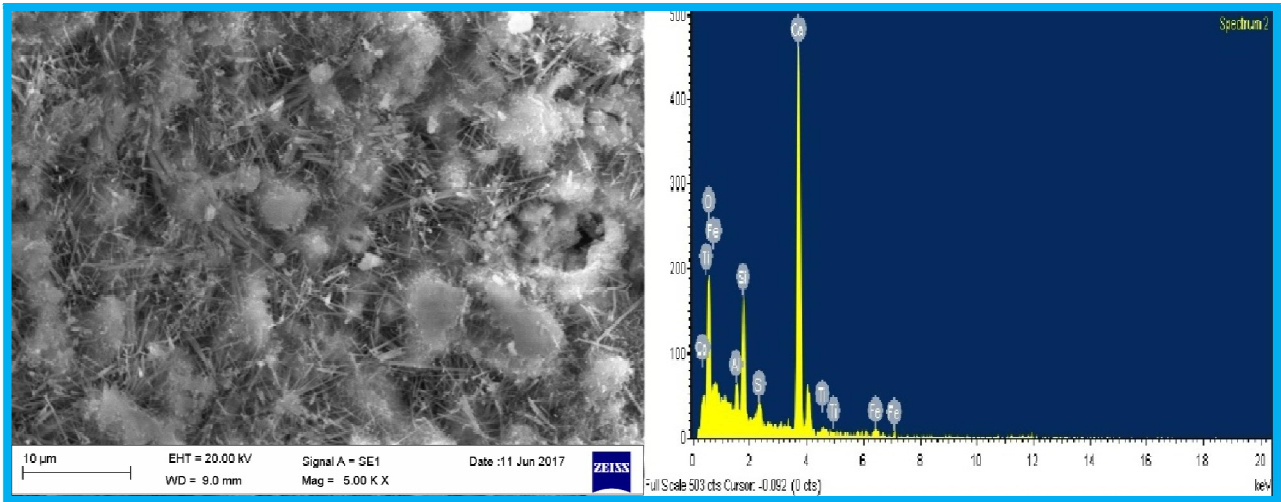
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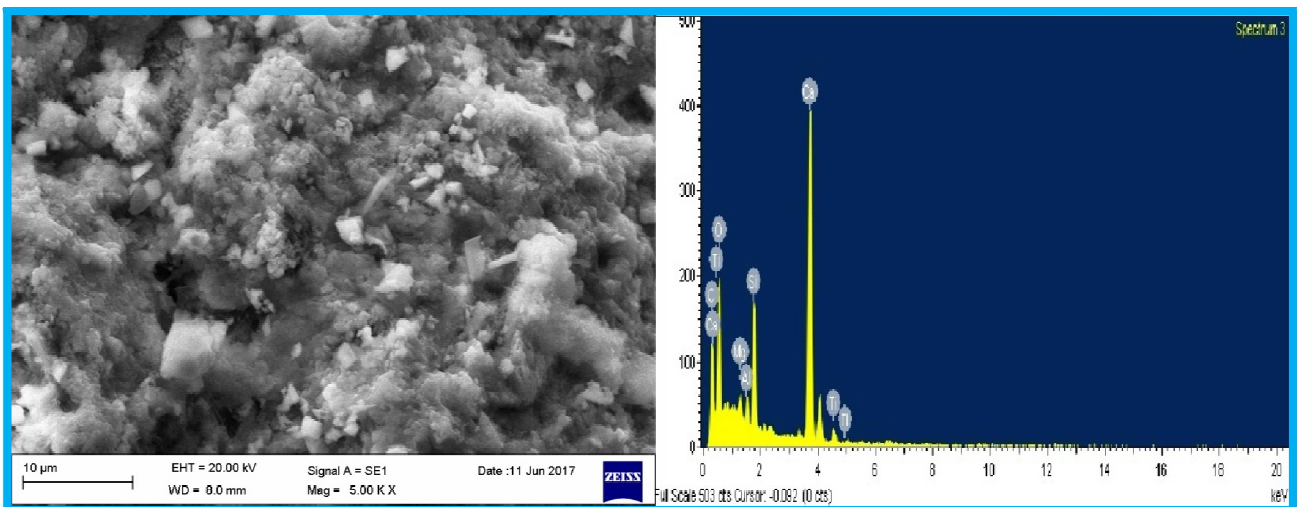
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The concrete fracture surface after 14 days of curing is filled with the needle shaped formation in micro pores of the concrete. The SEM image of the concrete after 14 days with 10µm length display fracture surface as shown in below.



**Fig.11:** SEM with EDS of concrete for 14 days curing

The SEM image of the concrete shown in figure is closely filled with needle shaped compound which formed in the hydration process. The chemical components which are formed in the hydration process are obtained from EDS data. The chemical components which are formed in the process of hydration are O (SiO<sub>2</sub>)-56.04%, Al (Al<sub>2</sub>O<sub>3</sub>)-2.03%, Si (SiO<sub>2</sub>)-6.66%, F (FeS<sub>2</sub>)-1.08%, Ca (CaSiO<sub>3</sub>)-31.86, Ti-0.7%, Fe-1.61% by weight of concrete, the graphical representation of these materials are shown in above fig.



**Fig.12:** SEM with EDS of Concrete for 28 days curing

The concrete fracture surface after 28 days of curing is filled with the needle shaped formation of hydration product in micro pores of the concrete. The SEM image of the concrete after 28 days with 10µm length display fracture surface as shown in figure.

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The figure represents the needle shaped hydration product was filled closely in micro pores and covered entire concrete with this product. The chemical components formed in the hydration process in the concrete are C ( $\text{CaCO}_3$ )-19.09%, O ( $\text{SiO}_2$ )-48.52%, Mg ( $\text{MgO}$ )-1.31%, Al ( $\text{Al}_2\text{O}_3$ )-1.14%, Si ( $\text{SiO}_2$ )-5.72%, Ca ( $\text{CaSiO}_3$ )-23.06% by weight of concrete, Ti-1.15%. In all the components Silica content is more shown graphically represented in above figure.

## VI. CONCLUSION

The work presented was focused on the consequences of introducing a photo catalytic component, i.e.,  $\text{TiO}_2$  and GGBS in the form of nano powders, in the mix proportion of concrete. An effect of  $\text{TiO}_2$  and GGBS on concrete fresh and hardened properties was identified, with a decrease in workability and a slight reduction of compressive strength.

The compressive strength of concrete with  $\text{TiO}_2$  is decreased while compared with the conventional OPC concrete. The compressive strength of concrete is decreased while adding GGBS up to 10% of concrete. The compressive strength of concrete with 10% GGBS and 1%  $\text{TiO}_2$  is increased and is optimum when compared to all the mix proportions. The compressive strength of concrete with 15% GGBS and 1%  $\text{TiO}_2$  is decreased. The Tensile strength of conventional OPC concrete is more compared with the all proportions. By adding  $\text{TiO}_2$  to the conventional concrete the Split tensile strength is reduced and then adding GGBS 5%, 10%, 15% the split tensile strength is decreased up to 10% of concrete. The Tensile strength of the concrete with 1%  $\text{TiO}_2$ +10% GGBS is more compared with all proportions of the concrete including conventional OPC concrete. The flexural strength of concrete with 1%  $\text{TiO}_2$  is slightly increased by adding in conventional OPC concrete without GGBS. By adding 5%, 10%, 15% GGBS and  $\text{TiO}_2$ , the bending strength is increased up to 10% GGBS + 1%  $\text{TiO}_2$ , then it is decreased. The chloride ingress is more in conventional concrete compared with all proportions at 28 days of curing. The chloride ingress is decreases by adding GGBS continuously with the 5%, 10% and 15% of GGBS for 28 days of curing, the chloride permeability is more in case of 1%  $\text{TiO}_2$ +0% GGBS, then it is decreased while adding GGBS 5%, 10%, 15% to the concrete for 60 days of curing. The chloride permeability of concrete with 1%  $\text{TiO}_2$ +15% GGBS is less while compared with the all proportions. The water permeability of concrete is increases while adding  $\text{TiO}_2$  to the concrete and then decreases while adding GGBS to the concrete after 60 days of curing. Finally it is concluded that the properties of concrete are better for the proportions of 1%  $\text{TiO}_2$  and 10% GGBS. By adding the small amount of  $\text{TiO}_2$  (1% by mass) concrete achieves good dispersion, decreased the microscopy and amount of internal micro cracks and obtain a denser micro structure which can be observed by SEM analysis and the chemical composition of the concrete obtained by EDS data. Improvement of the paste micro structure can be observed by adding nano  $\text{TiO}_2$  particles.

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