An Investigation of the Effects of Using Titanium Dioxide Sludge as a Partial Replacement of Cement in Concrete

J. Jesumanen

Department of Mechanical Engineering, DMI Engineering College, Aralvoimozhi.
jesumanenj@gmail.com

ABSTRACT

In the construction industry concrete is employed as a most significant material which is made up of composite material. Humans are moving towards a situation which involves in facing a shortage in the production of construction products, which will lead to huge exploitation of natural resources at varying stages, as a consequence of the sudden rise in demand for construction products is due to the massive growth in the sector of infrastructure boost-age worldwide at different levels. On the other side, a number of companies produce enormous amounts of sludge, which is frequently dumped as garbage and contributes to the planet's severe pollution. To identify a different approach or reduce the impact of this issue. A partial replacement of cement by titanium dioxide sludge using M25 grade concrete is discussed in this paper. At various phases, various tests were conducted, and it was determined that the replacement is a very good one in terms of strength and other factors. Waste sludge is used to replace cement by 5%, 10%, and 15%, respectively. These tests include compression, tensile and flexural strength tests.

Keywords: Concrete, waste sludge, Compressive strength, Flexural strength, Split tensile strength.

1 Introduction

Concrete is a substance which essentially served as the foundation for our modern history. It is the most significant building material, producing more than 15 billion tonnes yearly. To hold between two sections into a smaller mass, concrete might be conceived as a substance with cement-like qualities [1-3]. Since, the manufacture of cement generates a significant amount of greenhouse gas emissions and carbon dioxide. An amount of carbon dioxide and other greenhouse gases produced by 1 tonne of Portland cement clinker. Considering that one tonne of clinker emits one tonne of CO2 into the atmosphere and it observed that the carbon dioxide is a major atmospheric pollution released by the cement manufacturing sectors. As a result, there is a growing scarcity of cement and pollution has been produced by the cement factories [4-5]. Certain industrial by products including as FA, RHA, GGBS and SF are employed as secondary cementitious materials to reduce pollution caused on by the cement manufacturing process [6]. By partially substituting fly ash and metakaolin for cement, the unit cost of concrete can be as reduce as possible. A useful mineral additive for concrete is fly ash. In both the fresh and hardened states of concrete, it affects a number of qualities [7]. With a use of fly ash, cement content can be decreased while maintaining the strength of concrete [8]. Waste by products from the iron industry and thermal power plants, include industrial wastes such as FA and GGBS. These by products have been used in concrete in the current investigation at varying percentages to partially replace of cement. As concrete's compressive strength grows, GGBS and FA mixed concrete can be designed for medium strength concrete due to analysis. [9-10]. In this research work titanium dioxide sludge is employed as the replacement of cement and determine its strength of the concrete when the replacement of Tio2 is obtained. Several tests are taken out at various stages and determine the better alternative in the case of strength and other terms has been discussed in this paper. As a result, the suggested work demonstrate that the replacement of cement with TiO2 attained better result in 15% of compression and 10% of tensile properties.

2 Recent Works

Dr. N. Arunachalam et al. [2016] [11] have suggested to examine the materials which might be utilised in concrete to partially replace a Portland cement**.** Sixteen cement replacements are studied with five different kinds of Portland cement. Among the sixteen replacement materials are four distinct types of oxide sludge. Permeability, heat rise, resistance to freezing and thawing, Bleeding, elasticity, compressive strength to an age of ten years, and flexure strength comprised the 10 properties were evaluated. Fly ash concrete with a water cement ratio of range over 0.5 to 0.8 has never reached the compressive strength of Portland cement concrete.

Abdullah shahbaz khan et al., (2014) [12] have introduced that when using ilmenite (FeTiO3) and hematite coarse aggregates, heavy weight high performance concrete (HPC) has prepared. High-performance and effective radiation shielding qualities are required in this technique. Compared to concrete prepared using 18 dolomite and air cooled slag aggregates, these concretes have greater density. The study demonstrated that coarse ilmenite aggregate provides superior mechanical qualities to other aggregate. The study additionally demonstrated that concrete produced with crushed hematite and ilmenite has poor mechanical qualities to concrete produce with crushed air-cooled slag. Also, it was found that high density concrete with fine ilmenite and air-cooled slag particles was efficient in preventing gamma radiation.

A. V. Kulkarni, Aslam Hutagi (2013) [13] have suggested an experimental investigation into the gamma ray shielding abilities of regular and high performance concretes. A few low water to cementitious materials ratios (w/cm) were employed to generate HPCs, and they were subsequently tested for the radioactive source energy. It was found that a strong HPCs' compressive strength significantly contributes to the attenuation of gamma rays. With heavy weight HPCs, there was an almost linear relationship between compressive strength as well as attenuation of gamma rays. An analysis revealed that an absorption coefficient improved linearly for HPCs as the density raised.

Amirabadi, E.A., et al., (2013) [14] have developed that the materials like as iron, lead, graphite, polyethylene, water, and concrete are employed to make nuclear radiation protective shields, with concrete being one of the best and most popular. Protects against gamma and neutron radiation. This is due to the fact that concrete is formed into any shape and can have a variety of densities at a relatively affordable price, in addition to having enough strength and structural qualities. This technology has a significant possibility of contributing to the sustainable fulfilment of the enormous infrastructure demand. Regarding gamma radiation shielding qualities, concrete is not more effective than metal.

Demo Yang et al (2012) [15] have introduced that the better compressive strength and good flow are obtained by silica fume at lower water to cement ratios. Polycarboxylic ether yields better concrete mixture at water cement ratios as low as 0.22, although conventional super plasticizers like sulphonated naphthalene formaldehyde (SNF) and sulphonate melamine formaldehyde (SMF) demand for larger water/cement ratios. When compared to the water/cement ratio it achieved using the additive Polycarboxylic ether, the flow of conventional concrete with SMF and SNF at a water/cement ratio of 0.3 that is relatively extremely high (PCE).

3 Proposed Work

Titanium dioxide (TiO2) is also known as Titania, which is a chemical compound produced from selected minerals by the chloride process at KTPL it is the first and only supplier of rutile grade titanium dioxide in India. Titanium Tetra Chloride (TiCl4) is produced by removing the chlorides of impurities metals using a number of different procedures. To achieve pure Titanium Tetra Chloride in liquid form, it's then purified by using distillation. The Oxidation Plant evaporates, preheats, and oxidises titanium tetra chloride with oxygen to create raw titanium dioxide at a high temperature. The table below lists the compounds found in TiO2 wastewater treatment plant sludge and figure 1 represent the titanium dioxide sludge.

Table 1: *Chemical Composition of Titanium Dry Sludge Waste*

Sl.NO	Constituent	Concentration(%)
1	TiO_2	22.5
2	Carbon	33.5
3	Fe_2O_3	38.3
4	SiO_2	0.87
5	Al_2O_3	1.6
6	V_2O_5	0.13
7	Cr_2O_3	0.1
8	Others	3.3

Figure 1: *Titanium dioxide sludge*

3.1 Test for Titanium Dioxide

- Specific gravity test
- Fineness modulus test

Specific Gravity Test

Use the weighing balance to weigh the empty pycnometer while it is covered by the top. Lift the top cover, add 300 grams of cement sample which has passed through a 90-micron sieve to the pycnometer, and record the weight. Fill the pycnometer with sufficient kerosene to mix with the cement. After shaking the pycnometer to release any trapped air, completely fill it with kerosene, and then weigh it. First weigh the pycnometer well with kerosene to clean it, then determine its weight.

$$G = \frac{(W_2 - W_1)}{(W_2 - W_1) - (W_3 - W_4) \text{ X Specific gravity of kerosene}} \quad (1)$$

Fineness Test

Accurately weighing 100g of titanium dioxide sludge, placing it on an IS 90-micron sieve and constantly sieving it in a circular and vertical motion for 15 minutes. After every five minutes of sieving, lightly brush the underside of the sieve with the provided brush. The ratio of the weights of the residual and the sampled weights, which is expressed as a percentage, which allows to determine the fineness of a titanium dioxide sludge. Results are tabulated after the experiment is repeated with new samples.

Fineness of titanium= Wt. of the residue Wt. of sample taken X 100 %

3.2 Mix Design

Characteristics compressive strength at 28 days	=25Mpa
Max size of aggregate	= 20mm
Degree of workability	= 0.9
Degree of workability control	= Good
Type of exposure	= Mild

Table 2: *Mix Proportion of Titanium*

Proportion	Cement (%)	Titanium (%)
1	95	5
2	90	10
3	85	15

3.3 Test on Fresh Concrete

The following are the test conducted on fresh concrete

- Compaction factor test
- Flow table test
- Slump cone test
- Veebee consistometer test

3.4 Casting of Specimens

Using several layers of typical concrete, the concrete was cast into the moulds. Cube moulds measuring 150 x 150 x 150 mm and cylinder moulds measuring 150 mm dia and 30mm in height is utilised because the aggregate's maximum size is 20 mm.

Figure 2: *(a) cubes (b) cylinder (c) prism.*

3.5 Curing of Specimens

After casting for 24 hours, all of the moulds were demoulded and then cured. The specimens' curing process is depicted in Figure 3. As per IS 456-2000, cubes are tested on days 7, 14, and 28**.**

Figure 3: *Curing of specimen*

4 Results and Discussion

Titanium dioxide sludge are used to enhance the compressive strength of concrete for 7, 14, 18 days in M25 grade as well as to improve a durability of concrete when compared to the cement material as demonstrated in Table 3. As a result, the proposed work is attained when the concrete which uses TiO2 as a cement replacement has good results in its 15% compression and 10% of tensile properties are demonstrates in the following metrics.

Table 3: *Compressive strength test for 7, 14, 28 days*

Grade of concrete	No. of days	Compressive strength (N/mm²)			
		Conventional concrete	Titanium 5%	Titanium 10%	Titanium 15%
M25	7	17.77	18.1	22.2	21.88
M25	7	19.11	17.55	20.46	19.56
M25	7	17.1	18.18	21.74	21.44
M25	14	20	20	24.07	24.99
M25	14	20	20.44	23.14	21.24
M25	14	19.11	24.44	23.76	21.22
M25	28	40.4	28.88	30.33	30.56
M25	28	28.44	28.44	30.33	30.21
M25	28	29.9	29.33	30.55	31.55

In M25 grade concrete, a compressive strength test for 7, 14, and 28 are represent in Table 3. It demonstrate that the high strength concrete are achieved by the replacement of titanium in 15% at 28 days.

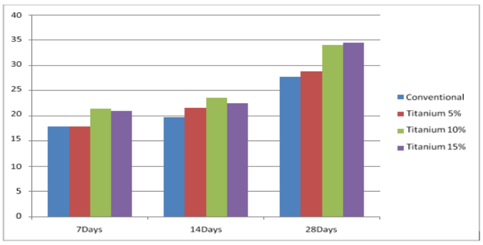

Figure 4: *Compressive strength for 7, 14 and 28 days*

Figure 4 specifies that the 15% replacement of titanium oxide sludge is attained the peak strength in 28 days when compared to other conventional concrete as shown in the above graph.

Table 4: *Split tensile strength test for 7, 14, 28 days*

Grade of concrete	No.of days	Split tensile strength (N/mm^2)		
		Conventional concrete	Titanium 5%	Titanium 10%
M25	7	1.42	1.42	1.69
M25	7	1.44	1.48	1.7
M25	7	1.49	|1.51	1.67
M25	14	2.05	2.19	2.26
M25	14	2.19	2.14	2.29
M25	14	2.11	2.21	2.33
M25	28	2.405	2.405	2.62
M25	28	2.22	1.98	2.40
M25	28	2.15	2.15	2.54

Table 4 denotes that the split tensile strength for 7, 14 and 28 days are tested. Where the M25 grade concrete, the test is achieved by the replacement of titanium at 10% in 28 days of curing.

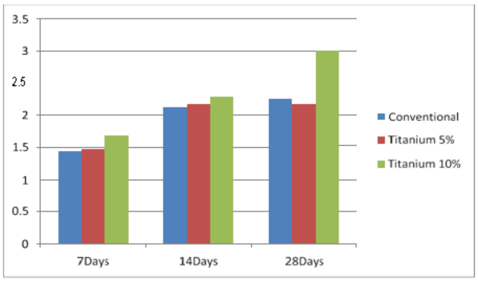

Figure 5: *Split tensile test for 7, 14 and 28 days*

The split tensile strength for 7, 14 and 28 days are displayed in Figure 5. Which shows that in M25 grade concrete the partial replacement of titanium oxide achieves its peak strength at 10% of mix in 28 days of curing.

Table 5: *Flexural strength test for 7, 28 days*

Grade of concrete	No.of days	Flexural strength (N/mm^2)	
		Conventional concrete	Titanium 5%
M25	7	5.45	4.65
M25	7	4.95	5.33
M25	7	5.27	5.99
M25	28	7.32	6.88
M25	28	6.55	6.95
M25	28	6.99	7.54

In M25 grade, the flexural strength test for 7 and 28 days are illustrated in table 6. Which demonstrated that the replacement of 5% titanium oxide in the concrete with cement. When compared to the conventional concrete flexural is achieved its high strength in 28 days.

5 Conclusion

In the construction industry concrete is utilized as the most significant material which is made up of composite material. The manufacture of cement generates a significant amount of greenhouse gas emissions as well as carbon dioxide. And it observed that the carbon dioxide is a major atmospheric pollution released by the cement manufacturing sectors. To overcome this issue, this paper demonstrate that the cement is partially replaced by the titanium oxide sludge using M25 grade to avoid the atmospheric pollution from the cement. Several tests like compressive strength, split tensile strength, flexural strength are made in this work to found the accurate strength of the concrete. As part of the curing process, the strength of the cube will be evaluated after 7, 14, and 28 days. The proposed method achieve better strength when compared to conventional concrete. As a result, the proposed work illustrate the replacement of cement with TiO2 attained better result in 15% of titanium oxide in 28 days of compression and 10% of tensile properties.

Reference

1. Girish P; Bajamma SK, Year: 2022, "Experimental Study on Concrete & Mortar by Partial Replacement of Cement with Red Mud", Journal of Engineering Sciences, Vol: 13, no: 12.

2. Gaur Monu; Arun Pandey; Amit Ashish, Year: 2018, "Performance of concrete utilizing red mud as a partial replacement of cement with hydrated lime", Int. J. Res. Eng. Sci. Manag, Vol: 1, no: 12.

3. Kumar Ede Naveen; Jayasree Raghavendran, Year: 2022, "Concrete Utilization of Red Mud as A Partial Replacement of Cement with Hydrated Lime", Journal of Engineering Sciences, Vol: 13, no: 6.

4. Prajapati Dhruvkumar B, Year: 2020, "Experimental Study on Mechanical Properties of Concrete Containing Metakaolin and Red Mud as Partial Replacement of Cement", Vol: 7, no: 6.

5. Manikanta, Manda Goutam V. Sai; P. Krithika, Year: 2017, "Determination of Mechanical and Durability Properties of Ultrafine Sludge Concrete", International Journal of Civil Engineering and Technology (IJCIET), Vol: 8, no: 3, pp. 913–920.

6. Venkatesh Chava; Madduru Sri Rama Chand; Ruben Nerella, Year: 2019, "A state of the art on red mud as a substitutional cementitious material", In Annales de Chimie: Science des Materiaux, Vol: 43, no: 2, pp. 99-106. 2019.

7. Lakshmi, AK; AIS Reddy; Kumar SAVS, Year: 2016, "Strength characteristics of concrete with partial replacement of cement with fly-ash & metakaolin", Int. J. Innov. Res. Technol, Vol: 1, no: 7, pp. 18-22.

8. Yamini G; Siddiraju S, Year: 2016, "An experimental research on strength properties of concrete by the influence of fly ash and nanosilica as a partial replacement of cement", International Journal of Civil Engineering and Technology, Vol: 7, no: 3.

9. Ashish Deepankar Kumar, Year: 2018, "Feasibility of waste marble powder in concrete as partial substitution of cement and sand amalgam for sustainable growth", Journal of Building Engineering, Vol: 15, pp. 236-242.

10. Panda Rachita; Tanmaya Kumar Sahoo, Year: 2021, "Effect of replacement of GGBS and fly ash with cement in concrete", In Recent Developments in Sustainable Infrastructure: Select Proceedings of ICRDSI 2019, pp. 811-818.

11. Arunachalam N; Mahesh V; Dileepkumar P; Sounder V, Year: 2014, "Development of innovative building blocks", Journal of Mechanical and Civil Engineering (IOSR- JMCE), Vol: 1, no: 1.

12. Abdullah shahbaz khan; Ram panth; Gagan Krishna R.R; Suresh G. Pati, Year: 2014, "Structural Performance of Concrete by Partial Replacement of Cement with Hypo Sludge (paper waste)", International Journal of Emerging Technologies and Engineering (IJETE), Vol: 1, no: 7.

13. Aijaz Ahmad Zende; Kulkarni AV; Aslam Hutagi, Year: 2013, "Comparative Study of Analysis and Design of Pre-Engineered- Buildings and Conventional Frames", IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE), Vol: 5, no: 1, pp. 32-43.

14. Gang Shi; Cuocuo Lin, Year: 2013, "Local Buckling Behavior of Welded Stub Columns with Normal and High Strength Steels", Journal of Constructional Steel Research, Vol: 119, pp.144-153.

15. Demo Yang; Huiyong Ban; Yuanqing Wang, Year: 2012, "Compression Test Stub Columns', Journal of Constructional Steel Research", Vol: 74, pp.140-150.