EXPERIMENTAL EVALUATION ON USE OF TITANIUM DIOXIDE SLUDGE AS A PARTIAL REPLACEMENT OF CEMENT

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Abstract- The worldwide infrastructure development is growing rapidly with increase in the demand of construction materials. Due to this rapid growth in the sector of infrastructure, we are moving on to the situation of facing shortage in the supply of construction materials, as it urge to the exploitation of natural resources at different stages. The primary binding material of concrete is cement, in which its production is extremely energy intensive and production of cement releases large amount CO_2 gas, which results in global warming. Diversely, several industries are producing huge amount of sludge which were mostly dumped as waste and leads to polluting the environment. In that concern, this paper proposes an experimental evaluation on use of titanium dioxide (TiO_2) sludge as a fragmentary replacement of cement. It is partially replaced with different percetages of TiO_2 sludge with M25 grade concrete. The concrete specimen is cured for 24 hrs, and for 7, 14, and 28 days the compressive strength is determined.
Keywords: Cement, Mortar, Concrete, Partial replacement, Titanium di oxide.

1 INTRODUCTION

The worldwide growth in the infrastructural sector tends to increase the demand of construction materials. Because of this rapid development, we are facing shortage in supply of construction materials, which leads to huge exploratation of natural resources at different stages. The development in concrete technology aids in preserving the energy resources as well as natural sources and facilitates to reduce pollutions [1]. One of the least sustainable industries in the world is construction industry, so to reduce its environmental impact, available technologies need to be applied. Certain industrial waste materials have the ability to be used as an alternate for cement. The replacement of cement with these materials aids in reducing the CO_2 emission, thereby enhancing the environmental performance of the concrete [2].

The self compacting concrete is partly replaced with unprocessed calcareous fly ash to enhance the concretes workability. The fiber content addition after 50 %, results in worsening the concrete properties [3]. The cement is comparatively replaced with glass fiber and fly ash in fiber reinforced concrete in various fraction are tested. The glass fiber does not enhance the flexural strength and compression strength [4]. The fly ash and Cement Kiln Dust (CKD) are used in concrete to achieve significant effect on economical and environmental benefits [5]. The effect of meta kaolin and fly ash in concrete are determined by partially replacing the cement. It is revealed that, 10 % meta kaolin and fly ash in concrete attains favourable combinations for casting of concrete flexural members [6]. The by-product obtained from cement is CKD, which is used as a relative replacement of cement in lightweight construction material is analysed to produce sustainable products [7]. The 20% of cement is partially replaced with GGBS and fine aggregate of 25 % is replaced with robo sand to validate the strength of gardened concrete [8]. The OPC (Ordinary Portland Cement) is moderately replaced with GGBS and crushed sand as fine aggregate and it is observed that, the addition 10 % GGBS and 0 % crushed sand gains, 50 % strength [9]. The 20 % and 30 % addition of GGBS and silica fume are suitable concrete mix for OPC, because it keeps the shrinkage within the acceptable level [10]. The steel fiber reinforced concrete and quarry dust are used in concrete to study the concrete properties. From the results it is clear that, the quarry dust reduces the slump value, thus decreasing the concrete's workability and when volume of fiber added in concrete increases the workability decreases [11]. To determine the strength characteristics, the rice husk is partially replaced with cement and its efficiency improves, when cementitious content in mixture is not less than 20 % and 35 % respectively [12]. The polypropylene fiber and weld slag are added in concrete to boost the concrete strength. The weld slag of 0.2 % is the optimum percentage of fiber reinforced concrete [13]. The rice husk in concrete with various percentages are used as a comparative substitute for cement to attain improvement in conventional concrete [14]. To improve the concrete's tensile strength, steel fibers are used and silica fume is added in varied percentages

[15]. To prevent the concrete structures in coastal areas, the cement is relatively replaced with silica fume, fly debris and rice husk in M60 grade concrete. Even though they are getting less strength than concrete, the essential target strength is achieved [16].

The beaviour of bagasse ash with glass fibers in concrete is experimentally investigated. It is noticed that, bagasse ash addition improves the concret's workability and when fiber content increases the workability decreases [17]. In concrete, the sugarcane bagasse ash is used as a fragmentary replacement of cement in M20 and M15 grade concrete respectively [18]. To boost the concrete's workability, limited quantity of cement is replaced with coir, jute fibers and addition of admixtures with M25 grade concrete. When the percentage of jute fibers and coir increases, the concrete density decreased which reduces the dead weight of structure [19]. The lime and silica are used in concrete as total replacement of cement for producing paving blocks. They are economically feasible as compared to ordinary concrete paving blocks [20]. By using lime stone powder as relative replacement of cement, the mechanical properties of concrete is determined and it is observed that, due to reduction in OPC, the hydration process is reduced [21]. The behavior of bond and compressive strength of hydraulic lime concrete and mortar are investigated. The results indicate a change in physical properties of mortar and concrete. When the lime content amount in concrete is increased beyond 15 %, the lime concrete's compressive strength decreases [22].

The half of the cement is replaced with glass powder in concrete with various mixes of concrete to validate the concrete strength and stress-strain relationship. The compressive strength of concrete reduces when specimen with 25 % glass powder is used [23]. An experimental investigation is carried out to evaluate the effects of replacing cement with metakaolin and coarse aggregate with blast furnace slag. The air voids in concrete lowers the compressive strength beyond 30 % replacement of concrete [24]. The slight replacement of cement is made with metakaolin in concrete and the modified concrete has been validated using non-destructive tests [25]. The cement is partially replced with Palm Oil Fuel Ash (POFA) in concrete to determine the strength of concrete with M40 grade concrete. The strength properties are decreased when the POFA is increased beyond 10 %. [26]. The usage of partial cement replacement in concrete with POFA is determined and the results indicate that, with increased amount of POFA content in concrete, the workability decreases [27]. In nylon fiber reinforced concrete, the strength properties are determined by partially replacing cement with metakolin [28]. The properties relative to strength in polyester fiber reinforced concrete is determined with replacing the cement with fly ash partially. The results indicate that, when the fiber quantity content in concrete is increases, workability decreases accordingly with decrease in modulus of elasticity [29]. The effects of rubberized mortar has been investigated to determine its chemical and mechanical properties in which the mortar compoites are prepared from rubber waste from unstable tires and Portland blast furnace slag cement. When the rubber particles are incorporated in mortar with large quantity, it leads to materials mechanical property changes and decreases the compressive strength. The rubber properties also affects the permeable voids volume and apparent density.

This paper proposes to improve the compressive strength of concrete and to reduce the environmental impacts caused by various ascpects, half of the cement is replaced with titanium dioxide sludge. The cement is partially replaced by 5 %, 10 % and 15 % of TiO_2 sludge with M25 grade concrete. The concrete specimen is cured for 24 hrs and for 7 days, 14 days, and 28 days the compressive strength is tested.

2 EXPERIMENTAL DETAILS

The replacement of cement with various other components are essential in the construction sector to attain sustainable construction materials. The overall experimental details involves selection of materials and testing of materials, which are discussed below.

2.1 Materials used

The general material used for preparation of concrete are cement, water, coarse aggregate and fine aggregate. In this paper, cement is partially replaced with TiO_2 sludge to improve the concrete strength in structures, thereby reducing the consumption of cement. The chemical composition of TiO_2 sludge is tested and approved by the pollution control board. The titanium dioxide sludge is represented in figure 1.

Figure 1 Titanium dioxide sludge

The chemical contents of effluent treatment plant sludge of TiO_2 are presented in Table 1.

Table 1 Chemical Composition of Titanium

S.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_3	0.13
7	Cr_2O_3	0.1
8	Others	3.3

The chemical constituents of titanium dry sludge waste is represented in Table 1. The raw titanium dioxide is classified and surface treated with various chemials, filtered and washed.

2.2 Priliminary Tests

The preliminary tests conducted for the concrete materials are given in detail.

2.2.1 Tests for Cement

a) Fineness
b) Consistency
c) Setting time
d) Specific gravity

a) Fineness

A cement of 100 gram is weighed using weighing balance and is sieved continuously for 15 minutes using IS 90- sieve by circular and vertical motion. After 5 minutes of sieving, using the given brush the bottom of the sieve is brushed lightly. The residue's accurate weight is determined and thus the fineness of the cement is determined. They are generally expressed in percentage. The investigation is repeated with different samples and results are represented in Table 2.

Table 2 Fineness test for cement

S.No	sample weight taken (w_1)g	Residue weight (w_2)	Percentage weight of residue (w_2/w_1) x100
1	100	6	6
2	100	5	5
3	100	6	6

$$\text{Fineness of cement} = \frac{\text{Wt.of residue}}{\text{Wt.of sample taken}} \times 100$$

$$= \frac{5.6}{100} \times 100 = 5.6\%$$

The fineness requirement of cement for ordinary Portland cement must be below 10 %.

b) Consistency

A cement of 500g was taken and a cement paste with a weight quantity of water (25%) was prepared. Within 3 to 4 minutes the cement paste was filled in the mould. The mould is shaked to release the plunger of 50mm long and 10mm in diameter which are attached to the vicat's apparatus and made to contact with the surface of the cement paste. After that, it was immediately released to drop into the cement paste. The penetration depth of the plunger was noted and are tabulated in Table 3.

Table 3 Consistency test for cement

Trial no.	Cement weight (g)	Water percentage	Water added (ml)	Reading of pointer from bottom
1	500	25	125	38
2	500	27	135	35
3	500	29	145	29

By adding 28% of water, the second trial was done and the penetration depth was noted and various trials are conducted. The plunger penetration to a depth of 33mm to 35mm is the water percentage required to product the cement paste with standard consistency.

Consistency of cement, P= 27%

c) Setting time

The water is added to the cement paste to achieve standard consistency. At the moment water is added stop watch is started. The cement paste is completely filled in the vicat mould and this mould in the test block is the cement block thus prepared. The needle is allowed to prob the block and then, the final and initial setting time of the sample is determined. The vicat apparatus is represented in Figure 2.

Figure 2 Vicat apparatus

The test procedure for the cement in vicat apparatus is that, initially the vicat apparatus needle is replaced with an annular ring. Then it is lowered and released immediately. Until the annular ring makes a contact with the mould, this process is repeated. The final setting time and is recorded and the test values are represented in Table 4.

Table 4 Initial setting time for cement

S.No	Weight of cement (g)	Percentage of water added	Initial setting tine (min)	Depth of penetration (mm)
1	300	22.95	0	46
2	300	22.95	5	25
3	300	22.95	10	23
4	300	22.95	15	22
5	300	22.95	20	19
6	300	22.95	25	18
7	300	22.95	30	18

The values are obtained for the tests are presented in Table 4.

Amount of water added (0.85 P) = 68 ml
Initial setting time = 30 minutes
Final setting time = 10 hrs.

d) Specific gravity

The empty pygnometer is weighed initially with the top cover in the weighing balance. The top cover is then removed and 300 grams of cement sample pasing through 90 micron sieve is placed in pygnometer and weight is noted. Sufficient quantity of kerosene is added to the cement in the pygnometer and then shaked so as to remove the entrapped air and fill with kerosene completely and weight is noted. Then, the pygnometer is cleaned thoroughly and kerosene is added to it and weighed.

Observation and calculation

Empty pycnometer weight, W1(g) = 618
Pycnometer weight + cement weight, W2 (g) = 918
Pycnometer weight + weight of cement and kerosene, W3(g) =1678
Pycnometer weight + kerosene weight, W4(g) =1419

Specific gravity of kerosene = 0.79

$$\text{Specfic gravity, G} = \frac{(\mathrm{W_2} - \mathrm{W_1})}{(\mathrm{W_2} - \mathrm{W_1}) - (\mathrm{W_3} - \mathrm{W_4}) \times \text{Specfic gravity ofkerosene}}$$

$$= \frac{(918 - 618)}{(918 - 618) - (1678 - 1419) \times 0.79} = 3.15$$

2.2.2 Test for Fine Aggrgate

a) Specific gravity
b) Fineness modulus
c) Moisture content

a) Specific gravity test

The specific gravity bottle was dried thoroughly and weighed as W1(g).The measured quantity of coarse aggregate was taken in the specific gravity bottle, and weighed as W2(g).Then, to remove the entrapped air the was shaken well and with the glass rod it was stirred thoroughly. The bottle was filled with water completely up to the mark, after removal of entrapped air, and with a clean cloth outside of the bottle was dried and weighed as W_3 (g). Then, the bottle was filled with water up to the top and was weighed asW_4 (g).

Table 5 Specific gravity test for fine aggregate

S.No	Description	Weight (g)
1	Wt. of empty pygnometer, (W_1)	618
2	Wt. of pygnometer +sand, (W_2)	933
3	Wt. of pygnometer + sand + water (W_3)	1679
4	Wt. of pygnometer + water, (W_4)	1485

The values of specific gravity for fine aggregates are presented in Table 5.

$$\text{Specific gravity} = \frac{(\mathrm{W_2} - \mathrm{W_1})}{(\mathrm{W_2} - \mathrm{W_1}) - (\mathrm{W_3} - \mathrm{W_4})}$$

$$= \frac{(933 - 618)}{(933 - 618) - (1679 - 1485)}$$

$$= 2.603$$

b) Fineness modulus

A factor obtained by adding the total percentage of an aggregate sample retained on each of the following sieves and dividing the sum by 150μ, 300 μ, 600 μ, 1.18mm, 2.36mm &4.75mm is the measure of fineness of an aggregate. Before weighing and sieving of the samples, they are brought to an air dry condition. The schematic representation of the sieve is represented in Figure 3.

Figure 3 Sieve sets (M-Sand)

The air dry sample is weighed and sieved continously by using proper sieves starting with the largest size sieve. If sieving was carried out with the rest of sieves on and sieve shaker machine not less than 10 minutes. The weight of sample taken is 3kg.

Table 6 Test of sieve analysis for fine aggregate

S. No	IS sieve No	wt. retained (kg)	% wt. retained (kg)	% cumulative wt. retained (kg)	% weight passing	Sand conforming zone
1	4.75 mm	0.024	1.2	1.2	98.8	I,II,III,IV
2	2.36 mm	0.026	1.3	2.5	97.5	II,III,IV
3	1.18 mm	0.402	20.1	22.6	77.4	II,III,IV
4	600 µ	0.905	45.25	67.85	32.15	I
5	300 µ	0.463	23.15	91	9	I,II
6	150 µ	0.175	8.75	99.75	0.25	I,II,III,IV
7	pan	0.005	0.25	100	0	–

$$\text{Fineness modulus} = \frac{\text{Total percentage of cumulative weight retained}}{100}$$

$$= \frac{384.9}{100} = 3.849$$

The results of sieve analysis indicate that, the soil belongs to zone II of soil classification

c) Moisture content

The measured quantity of fine aggregateW_1 (g) was taken in the container. The sample was taken in the container and weighed W_2 (g) and placed it in oven for 24 hours. The fine aggregate was taken out and weighed as W(g) after 24 hrs. The results are mentioned in Table 7.

Table 7 Fine aggregates moisture content

S.No	Description	I Trial	II Trial	III Trial
1	Container weight, W_1 (kg)	0.79	0.79	0.79
2	Weight of container + sample, W_2 (kg)	2.79	2.80	2.84
3	Wt. of container + dry sample, W_3 (kg)	2.75	2.759	2.801
4	Moisture content of fine aggregate	2.04	2.08	1.93

$$\text{Percentage of moisture content} = \frac{(W_2 - W_1)}{(W_3 - W_1)}$$

$$= \frac{(2.81 - 2.77)}{(2.77 - 0.79)}$$

Average % of moisture content $= 2.0\%$

2.2.3 Test for Coarse Aggregate

a) Fine modulus
b) Specific gravity test
c) Moisture content test
d) Water absorption test
e) Aggregate impact test

a) Fineness modulus

Before weighing and sieving of the samples, they are brought to an air dry condition. Using sieves starting with the largest size, the samples are weighed and sieved. The sieving was carried out with the rest of sieves on and sieve shaker machine not less than 10 minutes. The values obtained for the fineness modulus for coarse aggregate is mentioned in Table 8.

Table 8 Fineness modulus for coarse aggregate

S. No	IS Sieve size	Wt. retained (kg)	% Wt. retained	Cumulative wt. retained (%)	% Wt. passing
1	40mm	0.158	7.9	7.9	92.1
2	20mm	1.657	82.85	90.75	9.25
3	16mm	0.056	2.8	93.55	6.45
4	12.5 mm	0.08	4	97.55	2.45
5	10 mm	0.028	1.4	98.95	1.05
6	4.75 mm	0.002	0.1	99.05	0.95
7	2.36 mm	0.001	0.05	99.1	0.9
8	Pan	0.018	0.9	100	0

$$\text{Fineness modulus} = \frac{\text{Total \%of cumulative wet retained}}{100}$$
$$= \frac{686}{100} = 6.86$$

b) Specific gravity test

The pygnometer was dried thoroughly and weighed as W1(g).The measured quantity of coarse aggregate was taken in the specific gravity bottle, and weighed as W2(g).Then, the entrapped air is removed by stirring the bottle with glass rod. Then, up to the mark of the bottle, water was filled after removal of entrapped air and weighed as W3(g). Then, the bottle was completely filled with water up to the top and was weighed as W4 (g). The results are presented in Table 9.

S.No	Description	Sample 1
1	Empty pygnometer weight, W_1 (gm)	630
2	Pygnometer weight + coarse aggregate weight, W_2	1071
3	Pygnometer weight + coarse aggregate + water, W_3	1805
4	Wt. of pygnometer + water, W_4	1524

Table 9. specific gravity test of coarse aggregate

$$G = \frac{(W_2 - W_1)}{(W_2 - W_1) - (W_3 - W_4)}$$
$$= \frac{(1071 - 630)}{(1071 - 630) - (1805 - 1524)}$$
$$= 2.756$$

c) Moisture content

The sample was taken in the container and weighed as W1 (g). It was placed it on oven for 24 hours. The coarse aggregate was taken out and weighed as W2 (g) after 24 hours.

Weight of sample taken, $W_1 = 3$ kg

Oven dried sample weight, $W_2 = 3$ kg

$$\text{Moisture content} = \frac{(W_1 - W_2)}{(W_1)} \times 100 = 0\%$$

d) Water absorption

A coarse aggregate of 3000 g was taken as W1 (g). In the moisture content test, the oven dried sample was weighed as W2 (g). It was filled with water in the container and kept for 24 hours. The coarse aggregate was taken out after 24 hours and dried in air. Then, it was weighed as W3 g.

Weight of sample taken, $W_1 = 3$ kg

Oven dried sample weight, $W_2 = 3$ kg

Weight of wet aggregate after 24 hrs immersion,

$W_3 = 3.015$ kg

$$\text{Water absorption} = \frac{(W_1 - W_2)}{(W_1)} \times 100 = 0.5\%$$

e) Aggregate impact

This test is conducted to validate the aggregate impact value of the given aggregates. The Tamping rod, Cylinder, Impact testing machine, IS sieve of 2.36 mm, 10 mm and 12.5mm are used here. The 1/3 of the cylinder are filled with aggregate and using round ended tamping rod they are tamped 25 times continously. Then, the cylindrical measure left out are filled by two layers. By using the straight edge of tamping rod. After that, the aggregates that are in the cylindrical measure is weighed nearing to 0.01gm. The schematic representation of impact testing machine is represented in Figure 4.

Figure 4 impact testing machine

The base plate of the machine is firmly fixed in position to carefully transfer the aggregates from the cylindrical measure and are tamped 25 times. The hammer is allowed to fall freely on the aggregate in the cylinder. Then, the aggregates that are crushed are taken out from the cup and is sieved using a sieve of 2.36mm.

Weight of aggregate sample is taken as W_1

Weight of aggregate passing through 2.36 sieve is taken as W_2

$$\text{Aggregate impact value} = \frac{(W_2)}{(W_1)} \times 100$$
$$= \frac{111}{619} \times 100 = 17.9$$

2.2.4 Test for Titanium Dioxide

a) Specific gravity
b) Fineness modulus

a) Specific gravity

The empty pygnometer with top cover is weighed initially by using a weighing balance. The top cover is removed and 300gm of TiO_2 sludge sample passing through 90 micron sieve is placed into pygnometer and weight is noted. Then, sufficient quantity of kerosene is added to TiO_2 sludge in the pygnometer. Shake the pygnometer so as to remove the entrapped air and fill with kerosene completely and note the weight. Clean the pygnometer by weighing thoroughly with kerosene and the weight is determined.

Observation and calculation

Empty pycnometer wight, W_1(g) = 630
Pycnometer weight + titanium weight, W_2(g) =1048
Pycnometer weight + weight of titanium and kerosene, W_3(g) =1740
Pycnometer weight + kerosene weight, W_4(g) =1525

Specific gravity of kerosene = 0.79

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

$$= \frac{(1048 - 630)}{(1048 - 630) - (1740 - 1525) \times 0.79} = 2.059$$

b) Fineness

Titanium dioxide sludge of 100g is weighed and sieved continuously for 15 minutes using IS 90 micron sieve by circular and vertical motion. After every 5 minutes of sieving, with the given brush the bottom of the sieve is brushed lightly. The weight of the residue is determined and then the Titanium dioxide sludge's fineness is determined. The experiment is repeated with fresh samples.

Weight of residue = 59g
Weight of sample taken = 100g

$$\text{Fineness of titanium} = \frac{\text{weight of residue}}{\text{weight of sample taken}} \times 100$$
$$= \frac{59}{100} \times 100 = 5.9\%$$

2.3 Mix design

The process of Mix design involves selection of ingredients which are suitable for concrete and establishing their relative proportions.

a) Design stipulation

The characteristics compressive strength at 28 days is 25 Mpa with maximum aggregate size of 20mm and degree of workability is 0.9. The degree of workability control is good and type of exposure is mild.

b) Test data of material

The specific gravity of cement is 3.15, Specific gravity of coarse aggregate is 2.756 and Specific gravity of fine aggregate is 2.603

c) Water absorption

The water absorption for fine aggregate is 1 % and for coarse aggregate is 0.5 %

d) Free moisture

The free moisture for coarse aggregate is wet and for fine aggregate is 2 %

e) Sieve analysis

The sieve analysis for fine aggregate is 3.849 and coarse aggregate is 6.86.

f) Target mean strength of concrete (ft)

ft = fck+ts
Fck = 25 + (1.6x4)
Fck = 33.745 Mpa

g) Selection of water cement ratio

The required water ratio for target mean strength is 33.745 N/mm^2

Therefore, water cement ratio adopted is 0.43.

h) Water and sand content selection

The maximum size of aggregate is 20mm, water content per cubic meter is 186 kg, sand content as percentage of total and aggregate by absolute volume is 35 %.

Table 10 Water cement ratio and compacting factor

Change in condition of water cement ratio	Percentage alteration in water	Percentage adjustment in sand
The water cement ratio for 0.17	0	-3.4
The compacting factor of 0.1	3	0
The sand confirming for zone-II	0	-1.5
Total	3	-4.9

Required sand content = 35-4.9
= 30.1 %
Water content required = 186 + (186x3/100)
= 191. 6 lit/m^3

i) Determination of cement content

The adopted water cement ratio is 0.43

- water = 191.6 lit/m^3
- cement content = 191.6/0.43
  = 445.58 kg/m^3

j) Calculation for fine and coarse aggregate

- Size of aggregate = 20mm
- Entrapped air in wet concrete = 2 %

$$V = \left(W + \frac{C}{SC} + \frac{F_a}{P \times SF_a}\right) \times \frac{1}{1000}$$

$$0.98 = \left(191.6 + \frac{445.58}{3.15} + \frac{F_a}{0.301 \times 2.603}\right) \times \frac{1}{1000}$$

$$F_a = 507.01\ K_g/m^3$$

$$\boldsymbol{C_a} = \frac{1-P}{P} \times F_a \times \frac{SC_a}{SF_a}$$

$$= 1 - \frac{0.301}{0.301} 507.01 \times \frac{2.756}{2.603}$$

$$= 1246.61 K_g/m^3$$

Table 11 Mix proportion

Water	cement	fine aggregate	coarse aggregate
191.6	445.58	507.01	1246.61
0.43	1	1.137	2.797

Table 12 Mix proportion for titanium

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

The mix proportion for titanium and concrete has been tabulated in Table 11 and 12.

3 RESULTS AND DISCUSSION

The cement is a fundamental material of concrete, in which its production is highly energy intensive and cement production emits CO_2 gas, which causes global warming. Consequently, several industries are producing huge amount of sludge which were mostly dumped as waste and leads to polluting the environment. In that aspect, this paper proposes an experimental analysis of concrete using titanium dioxide (TiO_2) sludge as a partial replacement of cement. The tests conducted on the concrete and the results are discussed below.

3.1 Test on Concrete

3.1.1 Test on fresh concrete

The following are the test conducted on fresh concrete

A) Slump cone
B) Compaction factor
C) Veebee consistometer
D) Flow table

A) Slump cone

The internal surface of mould in slump cone is cleaned and applied with oil. In 4 subsequent layers, the concrete is filled in the mould and placed on a smooth horizontal non- porous base plate. By using a round ended tamping rod, each layer is tamped with 25 strokes uniformly. The tamping penetrated the bottom layer after tamping of subsequent layers.

Mould height = 300mm
Diameter of bottom = 200mm
Diameter of top = 100mm
Slump value = 300 190 = 210 mm

B) Compaction factor

The concrete sample is placed in the upper hopper and the cylinder is covered. The bottom of the upper hopper consists of a trapdoor and it is opened so that concrete fall into the lower hopper. Using the steel rod, the concrete remaining on its sides are pushed down. After opening the trapdoor at the lower hopper, the concrete is then allowed to fall into the cylinder. The excess concrete is cut using a trowel.

Calculation Empty weight of cylinder ,W =8.5Kg
Weight of partially compacted concrete,W1 =17.5g
Weight of fully compacted concrete,W2 =19.5g
Compaction factor = (W1 W)/(W2 W) = 0.9

C) Veebee consistometer test

The consistometer consists of sheet metal slump cone, which is placed inside the cylinder and in four subsequent layers the concrete is filled inside the cone. Each concrete layer is one fourth the height of the cone and using a strandard round ended tamping rod, each layer is tamped 25 times after pouring of concrete. In an uniform manner the strokes are distributed and in the second layers and subsequent layers, the concrete penetrates the bottom layer.

Calculation

Initial reading, before unmolding (a) = 21mm
Final reading, after removing the mold (b) =15mm
Slump = 6mm
The time required for complete remolding = 4sec

D) Flow table test

The diameter of the flow table about 76 cm in total and concentric circles are marked over it. A mould is used as a frustum of cone, with base as 25cm, diameter of upper hoop as 17cm and height of the cone as 12cm.

Flow percentage = ((spread diameter 25)/25)× 100
= ((18.5171917.51717.5)2/6 25/25)× 100
= 42%

3.2 Casting of Specimen

To calculate the strength of concrete, the specimens are prepared and casted on a steel mould of standard size. The concrete filled in the mould was perfectly compacted. After 24 hours of casting, the moulds are demoulded and cured,. The curing of specimens are shown in Figure 5, 6 and 7 respectively.

Figure 5 Cubes

Figure 6 cylinder

Figure 7 prism

The concrete was casting into moulds with different layers of conventional concrete. The size of cube moulds are 150x150x150 mm, cylinder mould is 150 dia and height of 300 mm is used, since the size of aggregate is 20mm. The compression test is done with cube specimens and split tensile test is done with cylinder specimens. To obtain sharp corners and to help demoulding easily, the moulds inner area was applied with oil in thin layers. In three subsequent layers, the concrete is filled and the layers are compacted using a standard tamping rod and strokes of the rod were uniformly distributed.

3.3. Curing of Concrete Specimens

The molds were filled with concrete and after 24 hours the moulds are removed and allowed to cure throughout the curing period. The cured concrete specimens are Presented in Figure 8.

Figure 8 Curing of specimen

The concrete specimens were tested on 7,14,28 days as per IS 456-2000 after 28 days.

3.4 Test om Hardened Concrete

The following are the test conducted on concrete,

A) compressive strength
B) split tensile strength
C) flexural strength

A) Compressive strength

The test on compressive strength of concrete is conducted to measure different properties of the hardened concrete. In practical, as the specimen size decreases, the concrete's compressive strength increases. The schematic representation of compression testing machine is presented in Figure 9.

Figure 9 Compression testing machine

Compressive stress = Ultimate load / Bearing area

Table 13 Test result of compressive strength for 7 days

Grade of concrete	No. of days	Compressive strength			
		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

Table 14 Test results of compressive strength for 14 days

Grade of concrete	No. of days	Compressive strength			
		Conventional concrete	Titanium 5 %	Titanium 10 %	Titanium 15 %
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

Table 15 Test results of compressive strength for 28 days.

Grade of concrete	No. of days	Compressive strength			
		Conventional concrete	Titanium 5 %	Titanium 10 %	Titanium 15 %
M25	28	40.4	28.88	33.33	30.56
M25	28	28.44	28.44	33.33	30.21
M25	28	29.9	29.33	35.55	31.55

The compressive strength of concrete for 7, 14 and 28 days are tested using compression testing machine, and the obtained values are tabulated in Table 12, 13 and 14 respectively.

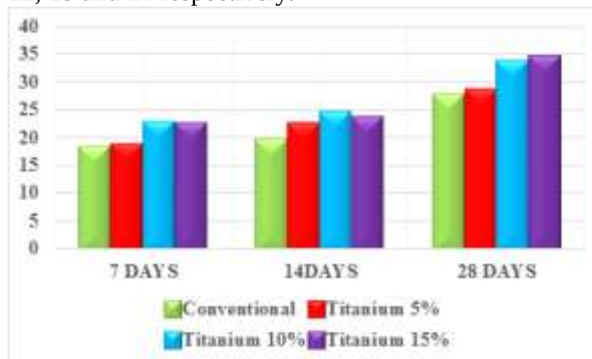

Figure 10 compression test result

The compression strength test result are compared with conventional concrete and titanium at 5 %, 10% and 15 % are represented as a graph in Figure 10.

B) Split tensile strength

The tensile strength of concrete is calculated by the split tensile strength test. The schematic representation of split tesile testing machine is represented in Figure 11.

Figure 11 Testing machine for split tensile strength

The split tensile strength is determined from the following formula,

Split tensile strength , ft 2p/πDL

Where,
P - Maximum load,N
D - Diameter of the specimen, mm

Table 16 split tensile strength test result for 7 days

Grade of cocrete	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

Table 17 Test results of split tensile strength for 14 days

Grade of cocrete	No. of days	Split tensile strength (N/mm^2)		
		Conventional concrete	Titanium 5%	Titanium 10 %
M25	14	2.05	2.19	2.26
M25	14	2.19	2.14	2.29
M25	14	2.11	2.21	2.33

Table 18 Split tensile strength for 28 days

Grade of cocrete	No. of days	Split tensile strength (N/mm^2)		
		Conventional concrete	Titanium 5%	Titanium 10 %
M25	28	2.405	2.405	2.62
M25	28	2.22	1.98	2.40
M25	28	2.15	2.15	2.54

Using split tensile testing machine, the split tensile strength for 7, 14 and 28 days are tested and the values are tabulated in Table 16, 17 and 18 respectively.

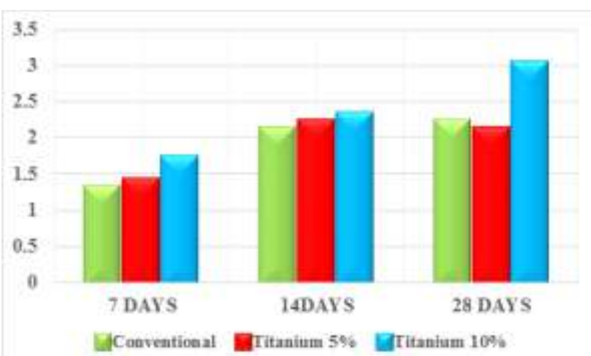

Figure 12 Test result of split tensile strength

The tensile strength test results are compared with conventional concrete and titanium at 5 % and 10% are represented as a graph in Figure 12.

C) Flexural strength

The test specimen for flexural strength test is prepared by filling the concrete in 3 layers into the mould with equal thickness. As mentioned above, each layer is tampered 35 times. The specimen for testing is placed in the machine perfectly and for 15 cm specimens, the loading is applied at 400 kg/min and for 10 cm specimens, the loading is applied at 180 kg/min. The schematic representation of flexural testing machine is represented in Figure 13.

Figure 13 Flexural testing machine

Calculation

The Flexural Strength (fb) is given by, **fb = pl/bd2** when 'a' is greater than 20cm for 15cm specimen or greater than 13cm for 10cm specimen, **fb = 3pa/bd2** when 'a' is lesser than 20cm but greater than 17 for 15cm specimen or lesser than 13.3 cm but greater than 11cm for 10cm specimen.

Table 19 Test results of flexural strength for 7 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

Table 20 flexural strength test result for 28 days

Concrete grade	Number of days	Flexural strength (N/mm^2)	
		Conventional concrete	Titanium 5 %
M25	28	7.32	6.99
M25	28	6.55	6.95
M25	28	6.99	7.54

The flexural strength of concrete for 7 and 28 days are tested using flexural testing machine and the obtained values are tabulated in Table 19 and 20 respectively.

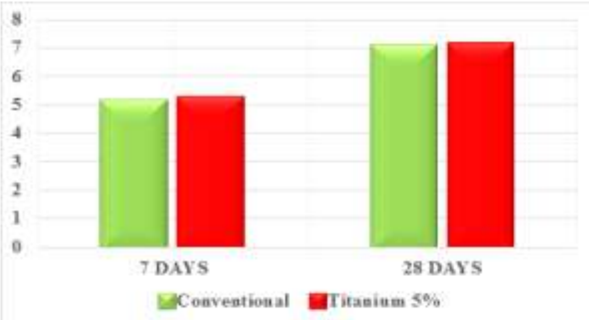

Figure 14 Flexural strength test result

The test results of flexural strength are compared with conventional concrete and titanium at 5 % is represented as a graph in Figure 14.

4 CONCLUSION

In this paper, an experimental analysis of concrete is done as half of the cement is replaced using titanium dioxide (TiO_2) sludge. The cement is partially replaced with titanium dioxide sludge of 5 %, 10 % and 15 % respectively. The concrete specimens with titanium dioxide sludge is cured for 28 days with percentages mentioned above and they are tested using compression testing machine. The specimens strength is checked as per the day process of curing for 7, 14 and 28 days. The partially replaced TiO_2 sludge in concrete is compared with conventional concrete. It is observed that, the partial replacement of cement with TiO2 shows good compression and tensile properties result when 15% of TiO2 is added in concrete.

References

[1] M.V. Patil, Y. D. Patil, G. R. Vesmawala, “A study on properties and effects of copper slag and marble dust in concrete”, International Journal of Structural Engineering, Vol. 9, no. 2, pp. 91-100, 2018.

[2] Matea Flegar, Marijana Serdar, Diana Londono-Zuluaga, Karen Scrivener, "Regional Waste Streams as Potential Raw Materials for Immediate Implementation in Cement production”, Materials, Vol. 12,no. 23,pp. 5456, 2020.

[3] Adnan mujkanovic,Dzenana becirhodzic, Ilhan busatlic, Marina jovanvovic, “Unprocessed calcareous fly ash as a partial cement replacement in self-compacting concrete" , Journal of Sustainable Construction Materials and Technologies, Vol. 6, no. 2, pp. 44-55, 2021.

[4] Sakshi Gupta, Aakash, Abhimanyu Ramola, Jatin Arora, Anand Saini, “Partial Replacement of Cement by Flyash & Glass Fibre in Light Weight Fibre Reinforced Concrete." International Journal Of Engineering Research and Technology, Vol. 6, pp. 24-7, 2017.

[5] A. A. Elbaz, A. M. Aboulfotoh, A. M. Dohdoh, A.M.Wahba, “Review of beneficial uses of cement kiln dust (CKD), fly ash (FA) and their bmixture”, Journal of Materials and Environmental Sciences, Vol. 10, no.11, pp. 1062-1073, 2019.

[6] M. Siva Parvathi , K.Yogesh , M. NikhilSuhas , Henloi L. Aventh, “ Evaluation of Strength of PCC with Partial Replacement of Cement by Meta Kaolin and Fly Ash”, International Journal of Scientific Development and Research (IJSDR), Vol. 4, no. 6, 2019.

[7] Saleh HM, Faheim AA, Salman AA, E Sayed AM, “A Review on Cement Kiln Dust (CKD), Improvement and Green Sustainable Applications”, International journal of nuclear medicine and radioactive substances, Vol. 4, no. 1, 2021.

[8] Mallesh M, Sajidulla jamkhani, Nandeesh M, “Experimental Study on Partial Replacement of Cement by GGBS and Fine Aggregate by Robo Sand for M25 Grade Concrete”, International Research Journal of Engineering and Technology (IRJET), Vol. 06 no. 08, 2019.

[9] Shelke, Shalaka, Rm Jadhav, “Partial Replacement of Cement by Ggbs and Fine Aggregate by Crusher Dust”, International Journal of Innovations in Engineering Research and Technology, Vol. 7, no. 10, pp. 174-179, 2020.

[10]Das, Kunal K., Eddie SS Lam, Ho H. Tang, “Partial replacement of cement by ground granulated blast furnace slag and silica fume in two- stage concrete (preplaced aggregate concrete)”, Structural Concrete, Vol. 22, pp. E466-E473, 2021.

[11]Hanumesh B. M, Vinay V Benakanakonda, Veeresh N Shirabadagi, Vedashri U Chakravarti, Banu S Gangayikoppa, Dr. shivakumara B, “The Mechanical Properties of Steel Fibre Reinforced Concrete with Quarry Dust as a Partial Replacement of Fine Aggregate”, International Journal for Research in Applied Science & Engineering Technology (IJRASET), Vol. 6, no. 5, 2018.

[12]Pornkasem Jongpradist, Watee Homtragoon, Raksiri Sukkarak, Warat Kongkitkul, Pitthaya Jamsawang , Hindawi, “Efficiency of Rice Husk Ash as Cementitious Material in High-Strength Cement-Admixed Clay”, Advances in Civil Engineering, https://doi.org/10.1155/2018/8346319, 2018.

[13]Nivedhan R, Nivedhitha V, Rifakkathullah A, Sowmiya S, Mr. P. Gopalsamy, “An Experimental Study on Fibre Reinforced Concrete Using Polypropylene Fibre and Partial Replacement of

Coarse Aggregate by Weld Slag Material", International Journal of Engineering Research & Technology (IJERT), Vol. 6, no. 07, 2018.

[14]Bhushan, Ravi, "Partial Replacement of Cement by Rice husk ash", International Research Journal of Engineering and Technology, Vol. 4, no. 10, pp. 251-256, 2017.

[15]Akshatha K, "Experimental Study of Concrete using Silica Fume", International Research Journal of Engineering and Technology (IRJET), Vol. 05, no. 05, pp. 769, 2018.

[16]Vijaya, Sathi Kranthi, Kalla Jagadeeswari, Karri Srinivas. "Behaviour of M60 grade concrete by partial replacement of cement with fly ash, rice husk ash and silica fume", Materials Today: Proceedings, Vol. 37 pp. 2104-2108, 2021.

[17]B.Aravind Yadav, M. Harinadh, V.Sree Lakshmi, L.Siv Kishore, "Experimental Study On Partial Replacement Of Cement Ash In Concrete Mix With Gl", International Journal of Civil Engineering and Technology (IJCIET), Vol. 8, no. 4, pp. 2104-2109, 2017.

[18]Sajjad Ali Mangi , Jamaluddin N , Wan Ibrahim M H , Abd Halid Abdullah , A S M Abdul Awal , Samiullah Sohu, Nizakat Ali, "Utilization of sugarcane bagasse ash in concrete as partial replacement of cement", IOP conference series: materials science, Vol. 271, no. 1, 2017.

[19] K.N. Lakshmaiah, S. Nikhilendra , A. Nagarjuna Reddy, "Investigation on Partial Replacement of Cement with Coir Fiber (CF) & Jute Fiber (JF) and with Addition of Admixture", International Journal for Research in Applied Science & Engineering Technology (IJRASET), Vol. 6 no. 3,2018.

[20]Mohini R. Shelke, Ganesh Wakchure, Akshay Pagire, Shweta Dehere,) "Eco-Efficient Concrete: Total Replacement of Cement", Journal of Emerging Technologies and Innovative Research (JETIR), Vol. 4, no. 12, 2017.

[21]Mikhlif, Abdul-Ghani Hamad, Ibrahim Ahmed Al-Jumaily, Bayan Salim Al-Numan, "Mechanical Properties of Sustainable Concrete Using Local Limestone Powder as Partial Replacement of Cement.", 12th International Conference on Developments in eSystems Engineering (DeSE), IEEE, 2019.

[22]Mixes Hemanshu Verma, Narendra Kumar Maurya, Smeet Faldu, Rambha Thakur, "The Influence of Lime as Partial Replacement of Cement on Strength Characteristics of Mortar and Concrete", Journal of Emerging Technologies and Innovative Research (JETIR), Vol. 6, no. 5, 2019.

[23]Mahmoud, Akram Shakir, Mohamed Mahir Yassen, Sheelan Mahmoud Hama, "Effect of Glass Powder as Partial Replacement of Cement on Concrete Strength and Stress-Strain Relationship", 12th International Conference on Developments in eSystems Engineering (DeSE), 2019.

[24]Rahman, Shaik Fazlur, Smt K. Chandrakala, "A Experimental Study on Partial Replacement of Cement with Metakaolin and Coarse Aggregate with Blast Furnace Slag", Int. J. Eng. Res., Vol. 8, pp. 341-347, 2019.

[25]Malagavelli, Venu, "Influence of metakaolin in concrete as partial replacement of cement", Int J Civil Eng Technology, Vol. 9, no. 7, pp. 105-111, 2018.

[26]Aiswarya, V. S., "Palm oil fuel ash as partial replacement of cement in concrete" International Journal of Engineering Research & Technology, Vol. 6, no. 3, pp. 544-546, 2017.

[27]Pone, Jonida, "Palm oil fuel ash as a cement replacement in concrete" Modern Approaches on Material Science, Vol. 1, no. 1, 2018.

[28] Ali, Akaram, Mohammad Arsalan Aleem Aijaz, "A study on nylon fibre reinforced concrete by partial replacement of cement with metakaolin: a literature review", International Research Journal of Engineering and Technology (IRJET), pp. 2367-2369, 2018.

[29]Sreekumar, S., A. V. Aparna, "Strength Characteristic Study of Polyester Fiber Reinforced Concrete", Vol. 6, pp. 1-7.

[30] Moreno, Diego David Pinzón, Sebastião Ribeiro, Clodoaldo Saron, "Rubberized Mortar from Rubber Tire Waste with Controlled Particle Size", Journal of Sustainable Construction Materials and Technologies, Vol. 6, no. 1, pp. 1-11, 2021.