International Journal of Scientific Research in Engineering and Management (IJSREM)
Volume: 04 Issue: 05 | May -2020 ISSN: 2582-3930

TITANIUM DIOXIDE-POTENTIAL USE IN PERMEABLE PAVMENTS

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Abstract-This study shows the results of a concrete containing titanium dioxide experimental investigation. The main aim of this study is to increase concrete structures' strength and durability. The favourable results are given by a small percentage of titanium dioxide (TiO2) addition. The concrete is mixed with different percentages of titanium dioxide (0%, 0.5%, 1%, 1.5% and 2%) of powder content. According to IS 10262:2009 and IS 415:2000, the permeable concrete mix proportions were obtained. In the laboratory, the permeable concrete was developed and the characteristics of both fresh and permeable concrete were examined using appropriate testing. There have been fresh permeable concrete tests like slump flow testing. The specimens such as cubes, cylinders and beam were casted and cured. After 28 days of curing, hardened concrete tests such as split tensile strength test, compressive strength test and flexural strength tests were experimentally done. At 1.5% replacement of titanium dioxide (TiO2) by weight of cement, the maximum strength was achieved.

Keywords-Titanium Dioxide (TiO2), aggregate, cement, sand, etc.

INTRODUCTION

1. NEED TO USE IN THE TiO_2 ECONOMICAL PAVEMENT

Today is the era of industrialization, globalization, and modernization. The green cover of earth is reducing hence the problems like global warming is arising. However in upcoming years these problems may arise more, hence proper steps need to be taken today. Some ecological and social problems in any metropolitan city are,

1. Increasing population.
2. Traffic and industrial pollution.
3. Storm water and drainage problems.
4. Road accident.
5. Health condition.
6. Living standard.

Directives were given by the Honorable Supreme Court of India to include Pune City, as one of the four cities, which further studies in order to prepare an action needed plan as per those directives for an air quality improvement. Detailed discussions were held by Maharashtra Pollution Control Board with the State Environment Department, Home (Transport), Public Sector Oil Companies, Municipal Commissioner, Pune to draw a plan of action. Member Secretary, MPCB has been appointed as a Convener to prepare the action plan for Pune city. Accordingly, a Plan was jointly drawn which was submitted to the Ministry of Environment & Forests, Government of India, vide MPCB letter No.BO/APAE/TB/B-3521, dated 05-09-2002.Government of India in Ministry of Environment & Forests further directed the State Government and MPCB vide their letter No.Q-16011/10/2002-CPA, dated 1st April, 2003 to revise the Plan taking into consideration of Industrial Pollution in Pune city and surrounding areas including Pimpri-Chinchwad Municipal Corporation area. Since Pimpri – Chinchwad is very close to Pune city, inter- city air pollution is bound to affect the air quality in both the cities. Hence, the pollution load of both vehicular and industrial area of PCMC has also been included in this report.

2. *TiO_2USE CONSTRUCTION INDUSTRY*

The photocatalyst, titanium dioxide (TiO_2), is a naturally occurring compound that can decompose gaseous pollutants with the presence of sunlight. Applying TiO_2 to pavement can help remove emission pollutants right next to the source, near the vehicles that drive on the pavement itself. However, surface coatings to traditional pavements may lose their effectiveness due to surface wear. When TiO_2 is applied to pervious pavement, this provides two sustainable benefits in one material; air will be purified on sunny days, and water will be infiltrated on rainy days, in addition to having a rougher surface, which may retain more TiO_2. With this innovative idea, this paper aims to identify the effectiveness of applying TiO_2 to the surface of pervious concrete pavement to produce a greener urban road environment.Several coating methods were compared for their influence on permeability, pollutant removal effectiveness, and their resistance to extreme environmental conditions.

3. PROBLEM STATEMENT

Air and water are vital to the existence of life on Earth. With their highly trafficked transportation systems, cities produce a significant amount of air pollution due to vehicle emissions, and they reduce the amount of groundwater recharge due to the extensive use of impermeable pavements. Impermeable pavements also contribute to the urban heat island effect. These problems are not natural, and the larger the cities grow, the more they are disrupting the quality of life on Earth by contributing more to these problems. It is important to keep the air clean and water charged to acceptable natural levels so that the Earth can stay sustained for future generations without becoming impoverished.

4. Objectives

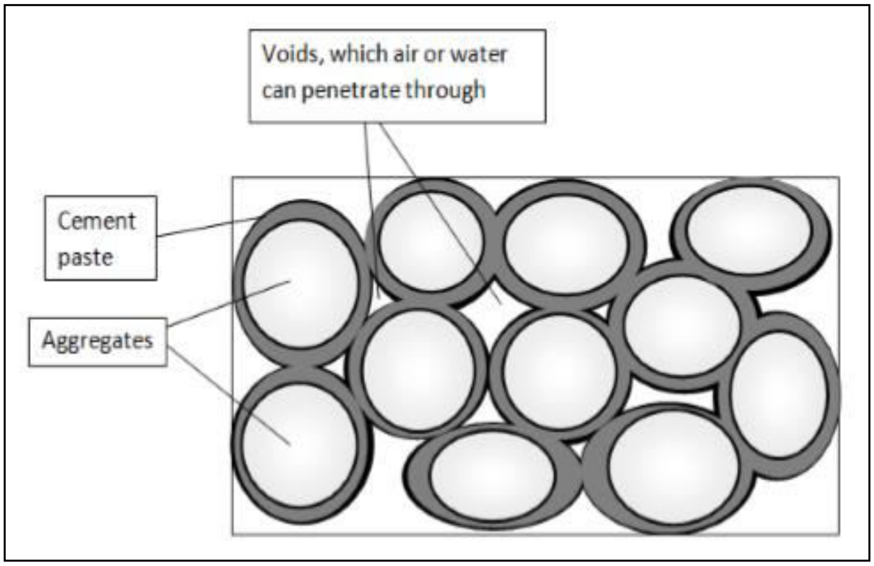
The objective of this study is to evaluate the effectiveness of TiO_2 treated pervious concrete for their capability of pollutant reduction, maintaining the infiltrating characteristic of the pervious concrete, and withstanding environmental damage.

TiO_2 distribution for each application method was analyzed using a setup to evaluate the pollutant removal efficiency due to the photocatalytic effect of the TiO_2.

Because a major focus of this application is in the transportation environment, three different gaseous pollutants that are present in automobile exhaust were tested: toluene, tri-methyl benzene, and NO. Infiltration was tested to ensure the surface treatments did not reduce the infiltrating characteristic of the pervious concrete.

5. PERMEABLE CONCRETE

Pervious concrete is concrete with high porosity, which allows water to infiltrate completely through it. It is composed of coarse aggregates, cement, and water. The high void content in pervious concrete is maintained by using aggregates that are generally all one size to avoid filling the voids with fines. The single-diameter aggregates form a framework for pervious concrete (Yang & Jiang, 2002), and the aggregates are bound together with cement paste, as shown in Figure 3.2.The voids maintained throughout the structure due to the single-diameter aggregates being held together with the thin cement paste allow air or water to penetrate through the pervious concrete. Because the cement paste that binds the structure together is thin, this reduces the strength of pavement. For this reason, pervious concrete would not be appropriate for highway use, as it would need to accommodate for a high volume of heavy vehicle traffic each day. It could however be implemented on the highway shoulders, which do not carry the repetitive loads of vehicle traffic each day. Also, because pervious concrete has numerous voids exposed to the surface, it is prone to clog with debris, which could hinder water from infiltrating through the structure. It can be prevented with proper maintenance techniques.Shown in fig no.1.1



1.1 A schematic diagram of pervious concrete structure

EXPERIMENTAL PROCEDURE/METHODOLOGY

MATERIAL USE-

Lab work consist various tests conducted on materials and specimens prepared for testing. For making of Eco-Social pavement we have designed pervious concrete pavement. In designing of pervious concrete pavement the materials confirming to IS 383 is taken. The materials required for pervious pavement are;

1. Cement
2. Aggregate
3. TiO_2
4. *Water*

1.2 Dry mix of concrete.

1.3 Wet mix of concrete.

1. Test on cement

The physical tests were conducted on ACC cement. The physical test was conducted by checking the expire date of cement, putting hand in to the cement which gives cooler sense if cement is fresh, checking the fineness of cement by taking the cement in the pinch of finger, checking the lumps formation etc.

The physical properties of cement-

1.1 Physical properties ofcement

No	Properties	Observedvalue
1	Standardconsistency	33%
2	Initialsettingtime	33min
3	Specificgravity	1.68%

1.4 quality of cement

2. Tests on aggregate:

This is very important material required to be tested in the lab for construction purposes, because the aggregate is not the packed factory product, it is the locally available natural material. Hence following test procedure have to be followed for testing of aggregate confirming to IS code 2386.

- Sieve analysis

1.2 Aggregate gradation chart

Sieve size in mm	Passing percentage of quality /%			
	Gradation 1	Gradation 2	Gradation 3	Gradation 4
31.5	100	100	-	-
25	-	-	100	100
20	76-87	76-87	90-100	-
16	-	-	-	25-60
10	0-5	50-71	20-55	-
6.3	-	0-5	0-10	0-10
4.75	-	-	0-5	0-5

- Water absorption test and specific gravity test

Weight of saturated aggregate suspended in water with the basket (w_1) = 4344gm

Weight of basket suspended in water (w_2) = 694 gm

Weight of saturated aggregate in water = (w_1-w_2) = 3414 gm

Weight of saturated surface dry aggregate in air (w_4) = 5258 gm

Weight of water equal to the volume of the aggregate= (w_3-w_S) gm

Result:

1. The Apparent Specific Gravity of given aggregate sample is found to be 3.27
2. The water absorption of given aggregate sample is found to be 1.55%.

- Impact test

1.5 Impact test

1.3Observation table of Aggregate impact test.

Sr. no.	Details of sample	Trail 1	Trail 2	Average
1	Total Weight Of Aggregate Sample Filling The Cylinder Measures = W_1 g	366	350	358
2	Weight Of Aggregate Passing 2.36 mm Sieve After The Test = W_2 g	50	48	490
3	Aggregate Impact Value = $(W_2/W_1)*100$ Percent.	13.6	13.7	13.65

Result: The mean A.I.V is 13.65%.

- Aggregate crushing strength test

1.6 Aggregate crushing strength test

Observation and Calculation:

1.4 Observation table for crushing test

Trials	Total weight of dry aggregate sample, w_1 gm	Weight of fines passing 2.36 mm IS sieve, w_2 gm	Aggregate crushing value in %	Average crushing strength
1	3080	450	14.61	14.7%
2	3085	458	14.34	

Result:

The mean (average) crushing value of the given aggregate sample is 14.7 %

- Los Angeles Abrasion Test

1.7 Los Angeles Abrasion Test

1.5 Observation and Calculation

Sr. No	Details of sample	Trial 1	Trial 2	Average
1	Weight of Specimen= W_1 gm	5000	5000	17.5%
2	Weight of specimen after abrasion test, coarser than 1.70 mm IS sieve= W_2 gm	4100	4150	
3	Percentage wear= $((W_1-W_2)/W_1)*100$	18%	17%	

Result**:**The average value of Los Angeles abrasion test on given aggregate sample is 17.5 %.

3. Titanium dioxide

The properties of titanium dioxide is shown below

1.6 PropertiesofTiO_2

No	Properties	Observedvalue
1	Appearance	White
2	Odour	No
3	Specificgravity	4.26
4	Density	3.82g/cc

Mix Design:

ACI Method for Mix Design:

The composition design of porous concrete should fulfil the demands of porosity, permeability coefficient and strength according to the material characteristics with the minimum cement dose. The design effective porosity should be 20%-30%, the coefficient of permeability shouldn't be less than 1.05 cm/s.

1.7 Summary table of concrete samples made

Sample	Sample type	Sample size	Aggregate size	Water-cement ratio
Commercial water based TiO2	Pervious	38cmx25cmx 6cm	4.75mm	0.28
Addition of TiO2 at the time of Mix design	Pervious	38cmx25cmx 6cm	6.3mm	0.29
The cement-tio_2 paste coating	Pervious	38cmx25cmx 6cm	6.3mm	0.30
Non pervious sample	Non pervious	38cmx25cm x 6cm	10mm	0.40

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1. EXPERIMENTAL PROGRAM AND RESULTS

- Slump cone test-

Slump test is the most usual method of measuring concrete consistency that can be used either in the laboratory or in the workplace. Slump is a measure that indicates cement concrete's consistency or workability. Bottom diameter= 200 mm, top diameter= 100 mm and height= 300 mm, however, it is conveniently used as a control test. The slump cone test value was found to be 78 mm for 0.43 water cement ratio. For this investigation, therefore, this ratio is used.

1.8 Trueslump

1.9Shear slump

2.0 Collapsed slump

- Compressive strength test

Compressive strength test is an important parameter to determine the performance of material during several weather conditions. Here, concrete mix of M35 grade is made with various proportions of titanium dioxide such as 0.5%, 1%, 1.5% and 2%. The size of concrete cube moulds are 15cm×15cm×15cm.Concrete cube specimens are made and cured for 28days.

1.8 Compressive strength value

No	Sample ID	Namingof Cubes	At7days (N/mm)	At28days (N/mm)
1	CC	0%TiO_2	23.5	43.25
2	C1	0.5%TiO_2	32.14	49.46
3	C2	1%TiO_2	34.08	52.32
4	C3	1.5%TiO_2	38.76	59.64
5	C4	2%TiO_2	30.92	47.54

- Split tensile strength test

Similar to compressive strength test of cube specimens split tensile strength test is done. Here, concrete mix of M35 grade is made with various proportions of titanium dioxide such as 0.5%, 1%, 1.5% and 2%. Samples of the cylinder are placed horizontally and testing is carried out. Using compressive testing machine, it is also tested.

1.9Splittensilestrengthtest

No	Sample ID	Namingof concrete Cylinders	At7days (N/mm)	At28days (N/mm)
1	0	0%TiO2	1.96	3.02
2	1	0.5%TiO2	2.24	3.46
3	2	1%TiO2	2.52	3.85

4	4	1.5%TiO2	2.67	4.12
5	5	2%TiO2	2.35	3.62

2.1 Split tensilestrengthtest

- Flexural strength test –

  Flexural strength is the amount of force an object can take without permanently breaking or deforming. The beams are made, one with conventional concrete and other beam with 1.5%replacement of titanium dioxide. The beam is being healed and tested.

2.0 Flexural strengthtest

No	Mix	At7days (N/mm)	At28days (N/mm)
1	0%TiO2	4.34	5.49
2	1.5%TiO2	6.24	7.82

2.2 Flexural strength of beam

- Estimate materials per batch of samples

After the total amount of mass to place in each sample mould had been calculated, it is necessary to determine the weight of each material (cement, water, and aggregates) to make a batch of pervious concrete samples. These materials-per-batch calculations were based on the same previous work used to perform the mass-per-mould calculations, which the samples had 22% porosity. To account for any material lost while mixing and handling the pervious concrete, 20% extra and an alternative estimate with 30% extra were added into the calculations. A summary of the material proportions used to make a 3-sample batch of the trial samples and a 3-sample batch of the final-evaluation samples.

2.1 Mix Proportion

Materials	Mass ratio to cement	Mass for 3 mold
Cement	1	748 Kg/m^3
Aggregate	1.58	1190 Kg/m^3
Water	0.30	202 Kg/m^3

2.3 Materials Proportions in Pervious Concrete

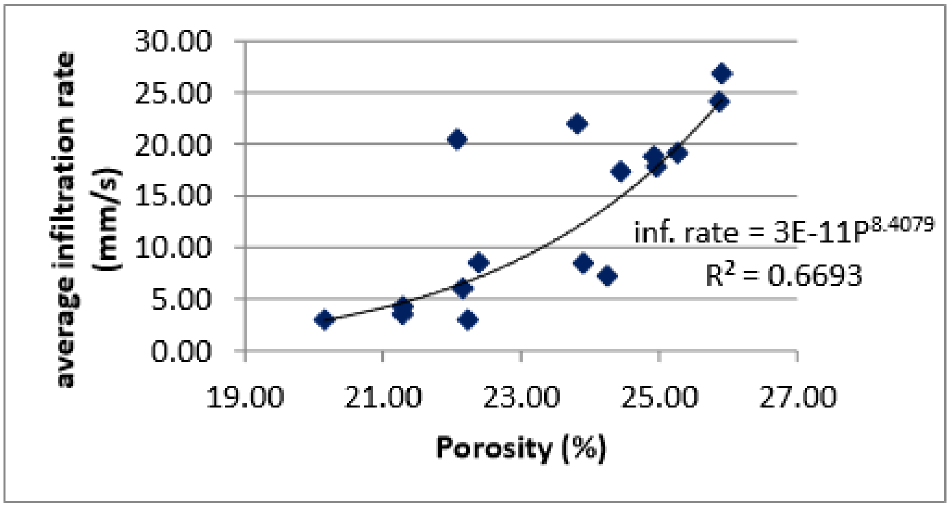
Infiltration Test:

Pervious concrete allows water to infiltrate completely through it. The infiltration characteristics of the pervious concrete were determined before and after the surface coating applications. The test followed the ASTM Standard C1701 (2009), but was applied to the smaller scale samples by using a smaller 4-inch diameter pipe. The pipe was attached to the sample surface using plumber's putty at two locations, centered at 3 inches (76.2 mm) from the left and right sides of the sample. 2000 mL of water was poured through the pipe and timed. Each side (left and right) of each sample was tested 3 times, and the overall average infiltration rate for each sample was calculated. The infiltration rate was calculated as shown in Equation below, where d is the diameter of the pipe and t is the infiltration time.

$$\text{Infiltration rate} = \frac{\text{Volume of water infiltrated}}{\text{Area of surface infiltration through Time to fully infiltrate}}$$

2.4 Pouring water through the pipe a

The infiltration rates of the 10mm samples were acceptable, with fast rates ranging from 17.37-26.86 mm/s. The infiltration rates of the 4.75mm samples were not so fast, with rates ranging from 3-8.55 mm/s. It is possible that the two samples with the same porosity had different infiltration rates because of differences in connectivity of the voids within the internal structure of the samples. The high degree of variability in infiltration exists because the void connectivity variability is not accounted for by porosity. infiltration rate vs porosity for sample
of 10mm and 4.75mm aggregate.



2.5 Infiltration rate VS porosity for sample of 10mm and 4.75mm

Infiltration rate and porosity:

2.2 Observation table of infiltration test.

Pavement type	Size of block (in cm)	W/C ratio	Result obtained in mm /s	Standard result in mm/s
10mm pervious	35×25×6	0.28	22.22	17.37-26.86
6.3mm pervious	35×25×6	0.29	15.27	15.00- 20.00
4.75mm pervious	35×25×6	0.30	7.14	3.00- 10.00

Discussion:

There is linear relationship between porosity and infiltration rate, if porosity increases infiltration rate also increases proportionately and vice versa. The infiltration may be affected on field due to chocking of voids, TiO_2 coat on pavement, smoking and splitting on the pavement, aggregate size etc. The different aggregate sizes are used for obtaining infiltration rate for the respective rainfall in the locality. 4.75mm size aggregate gives good strength and infiltration rate for heavy traffic. Instead of 10mm and larger size 4.75mm aggregate have good surface texture and gives good comfort while driving.

CONCLUSION

Based on the results and analysis,the following conclusions have been arrived.

- The concrete cube specimen of grade M35 with a 1.5% replacement of TiO2 provides a higher compressive strength.
- Similarly,concrete cylinder splittensile strength with1.5% replacement of TiO2 shows a higher value compared to conventional concrete.
- The values has been gradually increased at 0.5%,1%,1.5% replacement of titanium dioxide and at 2%of replacement the value decreases.
- As the value of concrete cubes and cylinder increases by 1.5% replacement of TiO_2,the flexural strength of the beam was found for 1.5% replacement of TiO_2.
- Hence the use of smaller percentage of titanium dioxide gives the valuable results.

FUTURE SCOPE

In this project we did all the basic test and we come to the conclusion that we can added titanium dioxide TiO2 upto 1.5% in the permeable pavement which is very useful for reducing the harmful gases mixed in the environment and also to reduce the storm water at time of high flood.

ACKNOWLEDGEMENT

We would like to special thanks to Principal Prof. K CSalunke for providing valuable time to go through our report and providing helpful suggestions.

We also thanks to honorable HODMrs. M S Jadhav for being very helpful are we will appreciate the support to provide us with whichever we appreciate him. We would also like to thanks to our project guide Mrs. P M khatavkar who gave proper guidance, continuously encouraging and help carrying work presented in this report.

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