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Effect of Titanium di-oxide in Pervious Concrete

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Abstract: In many developed countries, the use of pervious concrete for the construction of pavements, car parks and driveways is becoming popular. The pervious concrete is produced by using conventional cementitious materials, aggregates, water and chemical admixtures – titanium-di-oxide (TiO_2)[1] and super plasticizer. This concrete is tested for its properties, such as compressive strength, split tensile and water permeability. The most important property of pervious concrete is its drainage facility[2] through permeability.
Currently, there is no standard experimental procedure to determine this property. A method was therefore developed to determine the water permeability. The use of titanium di oxide is found to be enhanced the permeability in pervious concrete by oxidizing the pollutants and helping in washing down the clogged particles from the pores during rainy season. To improve the drainage facility and to restore of ground water table, the pervious concrete is blended with 2% of Titanium oxide (TiO_2) of grade M35 and experimentally investigated on samples with aggregate ratios[3] (course aggragate : fine aggregate) 80:20 and 90:10. After studying the mechanical properties of control mix pervious concrete and TiO_2 blended pervious concrete mix in the form of cubes and cylinders, the performance of TiO_2 concrete is found to be enhanced its in terms of compressive strength and drainage facilities.
Keywords: pervious concrete, titanium di-oxide, permeability, chemical admixture.

Introduction

Pervious Concrete is a special type of concrete in which little or no fine aggregates are used. Pervious Concrete is a homogeneous mixture of cement, aggregate, water and any chemical admixture. The concrete cubes of size 150 mm x 150 mm and cylinders of size 150 mm diameter and 300 mm height are made for experimental investigation of pervious concrete. Pervious concrete is a gap-graded, permeable, or enhanced porosity concrete. When used in pavement applications, pervious concrete can effectively collect and store the storm water runoff, thereby allowing the runoff to percolate into the ground and recharge the groundwater table. Pervious concrete contains little or no fine aggregate (sand) and carefully controlled amounts of water and cementations materials. The paste coats and binds the aggregate particles together to create a system of highly permeable, interconnected voids that promote the rapid drainage of water.

Drainage facility in pervious concrete :

Titanium oxide is used in pervious concrete for cleaning the air pollutants and volatile organic compounds by oxidising them[1]. As a result, the dust particles clogged in the pores of concrete are easily washed down during rains by maintaining the infiltration rate in pervious concrete.

Production of Titanium dioxide (TiO_2)[4]:

The most common method for the production of titanium oxide utilizes the mineral limonite. Limonite is mixed with sulfuric acid. This reacts to remove the iron oxide group in the limonite. This titanium tetrachloride is distilled, and re-oxidized in a pure oxygen flame. One method for the production of titanium oxide with relevance to nanotechnology is solvothermal Synthesis of titanium oxide.

Experimental

Physical Properties of Titanium Oxide:

The physical properties of titanium dioxide are

Appearances	-	White crystalline powder
Density	-	4.23 g/cm^3
Specific gravity	-	3.77
Particles size	-	3 nm - 8 μm
Surface area	-	33.3 m^2/g

Concrete Mix:

The concrete mix for pervious concrete was arrived for M35 grade. The number of mixes prepared was four. The titanium dioxide was added at 0% and 2% by weight of cement in these mixes. The CA : FA ratio[3] adopted was 90:10 and 80:20 among these mixes to compare the infiltration rates and strengths.

Infiltration in pervious concrete:

The voids maintained throughout the structure due to the single-diameter aggregates i.e., 10 mm size 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.

Benefits of TiO_2 pervious concrete:

The construction of low traffic roads with pervious concrete may reduce costs in installing drainage and storm water systems, reduce the urban heat island effect and noise, improve roadway skid resistance, and prevent hydroplaning. In summary, TiO_2 treated pervious concrete pavement can be widely used for pedestrian sidewalks, bike lanes, parking lots, roadway shoulders, and urban low traffic streets for its storm water benefits and air quality purification, resulting in a greener urban living environment. TiO_2 particles are protected in the pervious concrete pores against traffic abrasion.

Compressive Strength Test:

The compressive strength test[6] will be carried out on the pervious concrete specimens at the end of 7 days, 14 days and 28 days of curing. After cleaning the bearing surface of the compression testing machine, the concrete block will be placed on its face side having dimension 150 mm × 150 mm. The axes of the specimen are to be carefully aligned with the center of the lower pressure plate of compression testing machine. Then an upper pressure plate is to be lowered till the distance between the pressure plate and the top surface of the specimen achieved. No packing used between the face of the pressure plates and block. The load will be applied without shock and increased gradually at the rate of 35kg/cm until the specimen was crushed. The compressive strength calculated in N/mm^2 from the maximum load sustained by the cube before failure. An average of three values was taken for determining compressive strength of concrete.

Split Tensile Strength Test:

Due to the difficulty in applying uniaxial tension to a concrete specimen, the tensile strength of the concrete is determined by split cylinder test[6], it is standard to determine the tensile strength of concrete in an indirect way. The test could be performed in occurrence in IS : 5816-1970 the cylinder size 150 mm diameter and 30mm length it is casted and tested to determine the split tensile strength on 7th, 14th and 28th days.

Permeability Test :

To determine the permeability[5] of the pervious concrete mixes, cubes of 150x150 mm size were casted using iron material as mold. Compaction method used was same as described in IS codes to prepare cube samples to determine compressive strength. The samples were soaked for 28 days in highly polluted run off water collected after first rain of a monsoon at Chennai city. Then the samples are dried at laboratory temperature for 2 days. These samples are tested under constant head permeameter. The outflow pipe in the inlet chamber of the permeameter was so placed that a constant water head of 50 mm is maintained above the top of sample. Amount of water percolated through the sample within known time interval (60 seconds) were recorded to determine the permeability in mm/hour.

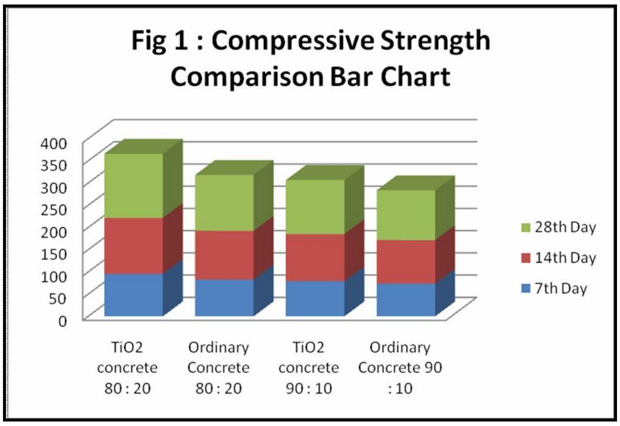
Results :

Compressive Strength :

The compressive strength of the samples of all the four mixes are tabulated in the table 1 and graphically compared in fig 1.

Table 1: Compressive Strength Result

Pervious concrete Aggregate Ratio	Samples of Specimens	Compressive Strength		
		7th Day	14th Day	28th Day
80:20	TiO_2 concrete	32.8	43.5	49.7
		31.9	42.6	48.3
		30.6	40.8	46.5
	Ordinary concrete	27.5	35.7	42.1
		26.6	35.5	40.4
		28.8	38.4	43.2
90:10	TiO_2 concrete	26.5	35.5	40.4
		27	34.8	41.0
		26.1	35.9	40.1
	Ordinary Concrete	23.5	31.3	38.6
		25.7	34.1	36.8
		24.4	32.6	36.6



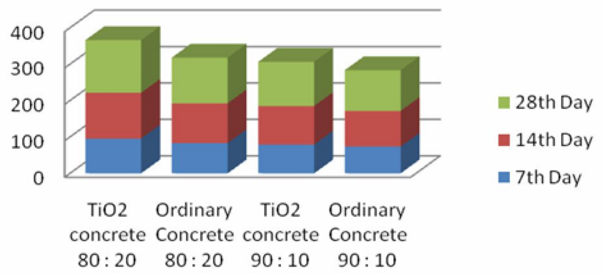
Split Tensile Strength:

The split tensile strength for all the samples of four mixes are tabulated in table 2 and graphically represented in fig 2.

Table 2: Split Tensile Strength Result

Aggregate Ratio	Samples of Specimens	Split tensile strength of concrete in N/mm^2		
		7^{th} Day	14^{th} Day	28^{th} Day
80:20	TiO_2 concrete	2.4	3.11	3.68
		2.26	2.90	3.40
		2.55	3.32	3.82
	Ordinary concrete	1.84	2.40	2.76
		1.98	2.55	2.9
		1.77	2.33	2.68
90:10	TiO_2 concrete	2.12	2.68	3.12
		1.98	2.54	2.91
		1.91	2.40	2.90
	Ordinary Concrete	1.68	1.98	2.33
		1.84	2.23	2.76
		1.70	2.28	2.51

Fig 2 : Split Tensile Strength Comparison Bar Chart



Permeability of concrete:

The infiltration rates of water in pervious concrete of different samples were represented as permeability value in mm/hr in table 3.

Table 4.3 : Permeability Test Result

Aggregate type	Mean value absorption	Aggregate retained between pair of sieve[6]	w/ c ratio[6]	Voids %	Age	Sample of specimen	Permeability value mm/hr	
							Aggregate Ratio 80:20	Aggregate Ratio 90:10
A(Angular)	0.62	12.5mm to 10mm	0.30	39.96	28	TiO_2 concrete	1236	1760
						Ordinary concrete	1124	1538

The characteristic compressive strength of TiO_2 blended pervious concrete of aggregate ratios 80:20 and 90:10 is increased by 15% and 8% than that of ordinary pervious concrete of same aggregate ratios.

The characteristic compressive strength of TiO_2 blended pervious concrete of aggregate is increased by around 21% by decreasing the aggregate ratio from 90:10 to 80:20.

The split tensile strength of TiO_2 blended pervious concrete of aggregate ratios 80:20 and 90:10 is increased by around 30% and 13% respectively than that of ordinary pervious concrete of same aggregate ratios.

The permeability value of pervious concrete of aggregate ratios 80:20 and 90:10 is increased by 10% and 15% respectively when 2% of cement content is replaced with TiO_2 particles.

Discussion:

It can be concluded that the performance of M35 grade pervious concrete has been enhanced in terms of compressive strength, Split tensile strength and permeability when the cement content is partially replaced with 2% titanium Oxide (TiO_2) particles.

The investigation of this project is to gain better understanding properties of the pervious concrete with TiO_2 concrete.

Experimental analysis has been done on fabricated pervious concrete of cubes and cylinders using Universal Testing Machine to find the compressive strength and tensile strength. Permeability of the concrete has been tested using constant head method. From this investigation it is found that addition of TiO2 cause aeration reaction considerably improves the permeability. The result of this project indicates that the Titanium oxide (TiO_2) pervious concrete is much better than conventional pervious concrete. The permeability values in mm/hr is found to decreasing by 9% in TiO_2 pervious having aggregate concrete compared to ordinary pervious concrete having aggregate ratio 80:20 and it is also found to be increases by 42% in TiO_2 pervious concrete when aggregate ratio is increases from 80:20 to 90:10. Further studies can be carried out on pervious concrete by varying the percentage of TiO_2 and aggregate ratio.

From the mechanical properties studied, it clearly shows that the pervious concrete can be blended with TiO_2 can be used in practical application in future.. It is inferred from the study that the usage of TiO_2 in pervious concrete can be recommended for drainage facility and control of air pollution during rains.

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