



ECO-SOCIAL PAVEMENT

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Abstract — Due to the increasing population and its large use of vehicles the pollution and its effects on human being is increasing in the urban cities and hence this gave the idea of Eco-Social pavement to come into existence. With this pavement, an attempt is being made to reduce this pollution and also an effective disposal of storm-water.

In this project an experimental study is carried out for reducing vehicular pollution and storm water disposal. This study includes the step wise procedure for construction of Eco-Social pavement. The field survey consists the material selection for making of pavement and collecting samples for testing. The lab work consist testing of collected samples for proper selection of material for work as per the standard maintained in IS code. The constructed pervious concrete block of sizes 38cm×25cm×8cm by using aggregate of sizes 10mm, 6.3mm, and 4.75mm with TiO₂ coat on surface of pavement for making of Eco-Social pavement. Three pervious block of each aggregate is used for testing strength, infiltration rate and pollution control test. The test result for pollution control reveals that there is substantial reduction of air contaminants from vehicles, the test conclude that there is 84 % of CO removal and near about more than 50% nitrogen removal in the various form of gases.

To make this project 100% successful we are proposing the concept to construct the exhaust system of vehicles in such a way that, it will work automatically. For example, when vehicle enter in to highly trafficked areas the exhaust system of vehicles will automatically come down a very few cm above the Eco-Social pavement so as to take the dual advantages of vehicles and Eco-Social pavement.

I. INTRODUCTION

Today is the era of industrialization, globalization, and modernization. Due to this 3 “ization” the nature in 21 centuries is turning towards devastation. The green cover of earth is reducing hence the problems like global warming is arising. But it is not harmful yet. 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, increasing population, Traffic and industrial pollution, Storm water and drainage problems, Road accident, Health condition, Living standard. These are just the highlighted problems which are creating a negative impact on urban cities. The people from cities are now migrating towards the safe areas where pollution will be minimum as well as less disturbance. But their migration is also increasing new load on new areas where they are supposed to live. This cycle is going on increasing day by day. And it is sure that, “that day is no long when we will be the killer of ourselves”. These problems are arising due to vehicular pollution and ineffective storm water disposal. For that reason, the road system is partly responsible for pollution because the road surface does not contribute to control the pollution that’s why the exhaust system of vehicles directly emits the pollution in to the atmosphere. Most of the pavements are impermeable so there are no attempts made by vehicular industry to make their exhaust downward. Because there is no medium (pavement) underneath that can absorb and reduce the pollution. It is true that the new innovation of “Catalytic converter” in vehicular industry helps to minimize the pollution, but as vehicles becomes old the efficiency of catalytic converter decreases. Hence our attempt is to make “ECO-SOCIAL Pavement”. Likewise, many judicial steps are taken by Supreme Court of INDIA in their Order dated 9th May, 2002 in W.P. No. 13029 of 1985 directed that a scheme be prepared for improvement of air environment with special reference to vehicular pollution in cities other than Delhi, which are equally or more polluted. In this regard, Inter-ministerial discussions were held in New Delhi as also in the conference of State Environment Secretaries and Chairpersons of Pollution Control Boards/Committees, to draw a plan of action to reduce the air pollution due to vehicles. 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. The measures taken by various agencies viz. Ministry of Road Transport and Highways and Transport

epartment, Pune Municipal Corporation, Ministry of Petroleum and Natural Gas, Pune Municipal Transport (PMT), local offices of the Oil Companies, MPCB, Dist. Supply Office, Regional Transport Offices at Pune and Pimpri Chinchwad and PCMC have been incorporated in the revised Action Plan to control air emissions in Pune and Pimpri Chinchwad cities. The revised plan is prepared keeping in mind the directives of Environment Protection Control Authority (EPCA) to submit the Action Plan in the format prescribed by the authority, to maintain uniformity while making submissions before Honorable Supreme Court of India. This is just an overview of the metropolitan cities. Our government as well as judiciary had been taking steps to control the air pollution and storm water problem, but there is no 100% control over the same. These problems (Traffic pollution and storm water) in rainy season are disturbing the human life. Hence revised action plan to Pune city is one of the concepts to control this. But in the revised action plan many concepts were decided. The following is the overview about action plan for sake of understanding.

II. THE METHODOLOGY AND INVESTIGATIONS

A. Data Collection

Titanium dioxide: is a naturally occurring compound and is used in toothpaste, sunscreen, paint, plastics, cosmetics, and other products. Because it is white, harmless, and inexpensive, TiO_2 powders were used for white pigments in ancient times. It is used in sunscreen because it can absorb UV light without being consumed in the reaction.

Photocatalytic effect of TiO_2 :

In the sunlight, TiO_2 can have a photocatalytic effect, in which it turns into a “photo-bleach” and degrades fabrics and paint when sunlight is present. A photocatalyst is “a material that uses solar energy to accelerate chemical reactions without being consumed or depleted in the process”. Photocatalysis of TiO_2 powders started developing in industrial technology in the 1980s. Heterogeneous photocatalytic reactions have been studied for more than fifty years. Researchers in Europe and Japan had studied photocatalytic compounds and they reduced pollution for over four years. In the sunlight, TiO_2 is activated by ultraviolet (UV) radiation ($\lambda < 390 \text{ nm}$) to oxidize air pollutants, such as nitrogen oxides (NO_x) and volatile organic compound (VOCs), into other inorganic compounds. In a photocatalytic reaction with TiO_2 , no chemical reactants are used. The TiO_2 does not get consumed in the reaction; so it can theoretically be used indefinitely. TiO_2 photocatalysis can be performed even in weak UV light. TiO_2 (anatase) has a wide band gap, thus only ultraviolet light with a wavelength below 387 nm is absorbed. Photocatalysts activated by UV lights decomposes the organic materials like components of dirt (soot, grime, oil, and particulates), biological organisms (mold, algae, bacteria, and allergens), airborne pollutants (VOC, tobacco smoke, NO_x , and SO_x), and chemicals that cause odours. Most inorganic pollutants, like rust stains, are not catalyzed. The decomposition products are oxygen, carbon dioxide, water, sulphate, nitrate, and other inorganic molecules. There are many commercial products that use photocatalytic reactions to make them self-cleaning materials. Some successful examples are glasses, tiles, and concrete. Titanium dioxide is used in concrete for buildings and ceramics for tiles, but only the part at the surface can be activated. These products can self-clean and reduce NO_x in the atmosphere. These applications are largely developed in Japan by Toto Company and also in Europe with the product, TX Active, from Italcementi. The Italian company, Italcementi, developed a type of cement with titanium dioxide on the surface called TX Active (“New kind of cement absorbs pollution”). Tests on a road have shown it to reduce the nitrogen dioxide and carbon monoxide by up to 65 percent. The photocatalysis process of the titanium dioxide worked best in bright sunlight. TX Active cement has been used on buildings such as Paris’ Charles de Gaulle Airport, Rome’s Dives in Misericordia church, and Bordeaux’s Hotel de Police. Photocatalytic concrete is starting to be used more in architectural and civil engineering projects in Europe and Asia as a self-cleaning material. Some benefits of photocatalytic concrete are that it decomposes chemicals that contribute to soiling and air pollution, it keeps the concrete cleaner, and it reflects much of the sun’s heat and reduces heat gain because of its white color. Italcementi’s TX Active photocatalytic cements that self-clean and depollute air are now available in North America. The precast concrete Jubilee Church in Rome, built in 2003, has white concrete elements that are at 85 feet high. To keep it clean in the polluted neighborhood that it is located in, Italcementi’s TX Active photocatalytic cement was used. TiO_2 is recently found to be an excellent photocatalyst to be used in pavement engineering for reducing vehicle emission pollutants. Figure 3.1 illustrates the photocatalytic effect of TiO_2 on pavement in a transportation environment. Pollutants from vehicle exhaust adsorb to the pavement. The TiO_2 coating on the pavement surface activates with the ultraviolet sunlight to break down the pollutants. The final products are then desorbed from the pavement

Photocatalytic effect of TiO_2 in water:

Not only can TiO_2 be used to remove pollutants in air, it can also be used to remove pollutants in water. Cho et al. (2006) used TiO_2 photocatalysis to treat groundwater contaminated with BTEX (benzene, toluene, ethylbenzene, xylene isomers) and TPHs (total petroleum hydrocarbons) and showed it to be an effective technique in the remediation of groundwater contaminated with petroleum. Though photocatalytic gradation of organic pollutants in water treatment works, it is difficult to separate and retrieve the small TiO_2 suspended particles. Because this can be a major problem,

Bolt et al. (2011) suggests a more suitable alternative is to incorporate TiO_2 into cementitious construction materials, which will immobilize the TiO_2 while still allowing photocatalytic degradation to take place.

Hydrophilic Effect of TiO_2 :

When photocatalytic oxidation decomposes staining compounds that are absorbed on a surface, the surface is cleaned and converted into a highly hydrophilic state (Hashimoto et al. 2005). Stains on the TiO_2 treated hydrophilic surface can be washed away easily, having a self-cleaning function, as the water flushes between the stain and the hydrophilic TiO_2 . Surfaces that typically fog due to steam, like mirrors and glasses, can be de-fogged by the hydrophilic TiO_2 application on the surface. Titanium dioxide films on glass can oxidize stains on the windows with sunlight

(photocatalysis) and can remove organic or inorganic pollutants when wetted with films of water (photo induced super hydrophilicity).

Chen and Liu (2010) found nano- TiO_2 to be capable of purifying vehicle emissions in a real traffic environment. It was reported that NO_x was removed from vehicle emissions when TiO_2 was applied to asphalt pavement. Purifying NO and NO_2 from vehicle-emitted NO_x showed good decontaminating effects, with a photocatalytic rate higher than 20%. When humidity gradually increased, decontamination of NO_x through TiO_2 increased. When the environment was dry (little moisture), water molecules had difficulty forming film on the TiO_2 surface. In the range of 0 to 1 mW/ cm^2 of UV intensity, the photocatalytic reaction rate increased linearly. In the range of 2 to 4 mW/ cm^2 of UV intensity, the photocatalytic reaction rate increased by square root of UV intensity. The contrast experiment (outdoor) yielded a NO_x decontaminating rate between 6% and 12%. Though TiO_2 treatment on pavements has been proven to remove pollutants from vehicle emissions (Chen & Liu, 2010), research is still being conducted on making the TiO_2 treatment resistant against vehicle traffic and natural weathering on pavements. A Louisiana study reported three different methods for applying TiO_2 to the surface of traditional concrete pavement (Hassan et al., 2010). They applied a cement-water coating with sand fines and TiO_2 nanomaterial (Cristal Millennium PC105), an ultra-thin water-based TiO_2 coating (PURETI), and sprinkled nano-sized TiO_2 particles to the fresh concrete surface prior to curing. The cement-water coating with 5% content of TiO_2 had the highest NO removal, producing 26.9% efficiency of NO removal before applied abrasion, and maintaining above 20% efficiency of NO removal after rotary abrasion and loaded-wheel tests. The NO removal was tested for 5 hours using an environmental setup with room temperature, 50% humidity, fluorescent lamps, a flow rate of 9 L/min, and an initial NO concentration of 410 ppb.

In Hong Kong, TiO_2 coated concrete paving blocks were exposed to environmental conditions for 4 months and 12 months at 5 different pedestrian roads (Chai-Mei Yu, 2003). The photocatalytic activity of the TiO_2 -coated paving blocks decreased in heavy pedestrian traffic areas, as contaminants accumulated on the surface (Chai-Mei Yu, 2003). The non-pedestrian areas did not significantly affect the NO_x removal activity of the paving blocks. Washing the blocks with water did not fully recover the photocatalytic activity. Reactive surface area was lost from the accumulation of dust, dirt, oil, grease, and even discarded chewing gum (Chai-Mei Yu, 2003). Ramirez et al. (2009) tested eight different cementitious material sample types coated with two different TiO_2 coating techniques: dip-coating and sol-gel. They tested the toluene removal efficiency and weathering resistance, characterized by different flows of water and air to simulate real rain and wind conditions. Four of the sample types were commercial materials, which included concrete and plaster materials mainly used for wall and floor covering. The other four sample types were substrate materials, which included one commercial autoclaved white concrete material and three other concrete tiles manufactured with different finishing techniques. As samples were coated with TiO_2 , the dip-coating method involved dipping the samples in a TiO_2 suspension in ethanol (0.05 g/ml). The sol-gel method involved immersing the samples into a mixture of titanium diisopropoxide bis (acetylacetonate) (24 ml), isopropanol (171 ml) and water (5 ml). The TiO_2 coated top-side of each sample had a surface area of 80 cm^2 , and all other sides of each sample were sealed with a water dispersed epoxy coating. After testing the toluene pollutant removal in a flow-through chamber with an 18W UV lamp and toluene inlet concentration of 12.3, 1.2 ppmv, the highest toluene removal efficiency was 86.2, 0.4 % from the autoclaved aerated white concrete dip-coated sample.

Factors Affecting Photocatalytic Effect:

Photocatalysis can be affected by environmental factors, such as light wavelength and intensity, relative humidity, temperature, and wind. The best results for the photocatalytic effect are with higher temperatures and light intensities greater than 300 nm (Katzman, 2006). An optimal condition to remove air pollutants would be a hot summer day with low relative humidity and no wind. Factors that can affect the photocatalytic effect of TiO_2 when applied to concrete may include porosity, humidity, aggregate type, aggregate size, application method, and applied wear. Ramirez et al. (2009) observed better retention of TiO_2 particles on the sample surface and a higher toluene removal efficiency when samples had higher porosity. Higher humidity was reported to have lower efficiency in nitric oxide removal (Dylla et al., 2010). Coatings without fines were reported to have higher nitric oxide removal efficiency than coatings with fines (Dylla et al., 2010). As reported in the concrete application study by Hassan et al. (2010), because the weathering simulation exposed some of the TiO_2 particles embedded in the surface, applying the loaded-wheel test seemed to improve the nitric oxide removal efficiency. Applying rotary abrasion seemed to decrease the nitric oxide removal efficiency.

Other TiO_2 Applications:

Various construction materials for NO_x removal exist for both indoor and outdoor environments. As cited by Chen et al. (2007), a commercial mineral paint with 3% TiO₂ achieved a nitrogen oxide removal rate of 0.21 µg/m²s. A translucent paint with 5% TiO₂ achieved a nitrogen oxide removal rate of 0.06 µg/m²s. Floors painted with a layer of NO removing paint were reported to be effective in NO removal. For outdoor applications, photocatalytic paving was said to be more effective than planting trees, decomposing 15% of nitrous oxide from cars along the roadway. Air purification panels were said to be suitable for placing near roads to remove NO_x from cars. Sound-proof walls along roadways have been reported as a surface for photocatalytic material application. In California, Toto Frontier USA uses TiO₂ to make self-cleaning ceramic tiles for use in places like hospitals and public restrooms, where it is vitally important to keep clean (Frazer, 2001). TiO₂ can also be used to treat the air and prevent fruits, vegetables, and cut flowers from spoiling and increase shelf life in storage areas (Frazer, 2001). Mitsubishi Materials Corporation in Japan developed paving stones called "Noxer" blocks that use TiO₂ to remove NO_x from the air (Frazer, 2001). Other uses for TiO₂ include detoxification of wastewater used for rice hull disinfection, water treatment of hydroponic culture systems, treatment of VOC-polluted soils, and efficient water evaporation from hydrophilic surfaces (Hashimoto et al., 2005).

TiO₂ Cost:

In the United States, there is little commercial availability of photocatalytic building materials (Katzman, 2006). As of 2006, Titanium Dioxide air pollution-reducing products were best found from Essroc (a North American subsidiary of Italcementi) and Green Millenium (based in California). A U.S. based company formed in 2004, PURETI, uses an electrostatic sprayer to adhere a water-based TiO₂ to a variety of surface types. PURETI products are applied to keep surfaces clean, such as buildings, aircraft, ships, curtains, carpets, and windows. Using titanium dioxide coating can be quite expensive, however, with time and increase in demand, it is expected that the cost will decrease, as there will be more producers with this technology. As of year 2010, the average market price of ultrafine/nano titanium dioxide was \$9.07/lb (Dylla et al., 2010).

TiO₂ Maintenance:

The performance of NO_x removal can be self-maintained. Calcium nitrate that accumulates on the surface can be washed away by rainfall (Chen et al., 2007). In a photocatalytic reaction with titanium dioxide, the TiO₂ does not get consumed in the reaction; so it can theoretically be used indefinitely. Studies are still being conducted on the best application method for titanium dioxide on pavements to resist against traffic loading and natural weathering. The first air purifying concrete and asphalt pavement to be laid in the United States was laid at Louisiana State University in December 2010 (Berthelot, 2010). There were 0.25 miles of the photocatalytic asphalt pavement laid on Aster Street and 0.25 miles of the concrete pavement on the campus. An ultra-thin water-based TiO₂ coating (PURETI) was used on both of the pavements. Before field implementation, laboratory evaluation conducted at Louisiana State University showed 25.0% efficiency of NO removal with the PURETI coating on concrete specimens (Hassan et al., 2010) and 39 to 52% efficiency of NO_x removal using the PURETI coating on warm-mix asphalt specimens (Hassan et al., 2011).

Pervious 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.

Pervious Concrete Applications:

Pervious concrete can be applied to footpaths, parking lots, paths in parks, shoulders, tennis courts, patios, slope stabilization, swimming pool decks, green house floors, zoo areas, drains, noise barriers, driveways, friction course for highway pavements, and low volume roads (Obla, 2007). It can also be used to allow green growth, such as placing it onto the ocean floor to form man-made seaweed and fish reefs and revive the disappearing marine environment due to pollution and exploitation (Li, 2011). The porous base is favourable to the seaweed's clinging, which in turn provides the feeding grounds that the fish and shellfish need.

Advantages of Pervious Concrete:

Pervious concrete pavement has many advantages that help improve the quality of the environment in cities. With pervious pavement installed, rainwater can filter into the ground, which replenishes groundwater resources (Yang & Jiang, 2002). Because pervious concrete is air permeable and water permeable, the soil beneath is kept wet. Trees planted in pervious concrete parking lots will get more air and water to the roots. A large silver maple tree died in a Salt Lake City parking lot because it could not get water to its roots from the impervious concrete that surrounded it (Rocke & Bowers, 2009). Driver comfort and safety is addressed, as permeable concrete will absorb noise from tire-to-pavement interaction and also reduce the hydroplaning effect during high rains. In the winter, snow can drain through the pervious

concrete as it starts to melt, reducing the amount of snow left on the surface when compared to traditional non-pervious pavements. Pervious concrete does not have a significant contribution to the urban heat island effect like traditional non-pervious pavements do. Due to its unique void structure, pervious concrete has an insulating capability during the daytime heating cycle, as base temperatures remain similar to cooler surfaces like soil and lighter concrete (Haselbach, 2009). Not only can pervious concrete be environmentally friendly, but it can also be aesthetically pleasing. For the 2008 Olympics in Beijing, China, about 2.7 million square feet of multi-colored pervious concrete was installed in dock frontage for the rowing and sailing venue (Rocke & Bowers, 2009). The bottom “lift” layer used larger aggregates, and the top layer used smaller aggregates that were colored.

Pervious Concrete Cost & Maintenance:

Pervious concrete is made of the same materials as regular concrete, which includes cement, aggregate, and water, so the materials cost is about the same for both concrete types. It would be a different in the proportions, as pervious concrete uses less cement, no fines, and more aggregate than regular concrete. Even though the first use of pervious concrete was in 1852 (Ghafoori & Dutta 1995; Obla, 2007), it is still a relatively new concept in some areas of the country. Because it may be unfamiliar to some manufacturers, it may cause it to be more costly for preparation work and installation. However, in the long term, the benefits will pay off. Installing pervious concrete may reduce costs in installing drainage and storm water systems. Costs can range from \$2 to \$6.50 per square foot of installed pavement. Pervious concrete may require annual cleaning to unclog the pores. Cleaning options may include vacuuming or pressure washing to clear out debris from the voids.

Pervious concrete with TiO₂:

Most existing studies have focused on applying TiO₂ on non-pervious pavements. This places some challenges in improving the photocatalytic effect due to several reasons. Since direct interaction of TiO₂ with UV light is very critical, mixing TiO₂ into traditional concrete can only have limited NO_x reduction effectiveness at the air/solid interface. The process was observed to improve after the concrete material was abraded (some cement paste was peeled off and more TiO₂ was exposed at the surface) (Hassan et al., 2010). The durability of the photocatalytic effect becomes another challenge if TiO₂ is applied to highly trafficked highways through surface material adhesion. The dynamic tire-pavement interaction under shear and abrasion impact can dislodge coated TiO₂ particles at the surface, leaving untreated pavements. Therefore, to maximize the effect of air purification in pavements through the TiO₂ photocatalytic reaction, coating TiO₂ on the substrate of pervious concrete could have a number of benefits. As compared to traditional concrete pavements which have low porosities and relatively smooth surface textures, pervious concrete pavements have much higher porosities and rougher surface features. TiO₂ particles can stay protected within the pores of the pervious concrete during traffic loading. The higher void ratio and the increased concave surface texture (due to surface voids) with more surface area could enhance the bonding and durability of the applied TiO₂ at the surface, reduce impacts due to traffic abrasion and climate (snow, ice, water, heat, etc.), and increase the direct contact between TiO₂ and natural light. At the same time, pervious concrete pavement allows water to infiltrate completely through it so that rainwater can filter into the ground and replenish groundwater resources (Yang & Jiang, 2003). Installing 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, TiO₂ 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.

The following test procedure is followed for construction of pervious pavement:

Pervious concrete was mixed in a drum concrete mixer or hand mixing with the calculated material proportions, distributed into each sample mould with the calculated minimum/maximum mass range, and compacted to the determined volume with the concrete compactor machine.

The following procedure is followed; Take the calculated amount of ingredients of pervious concrete in mixture or on the solid impervious plat form. The Figure 3.7 shows ingredients of the pervious concrete mix. Dry mix the ingredients of concrete by hand on solid platform. Figure 3.8 shows dry mix of concrete. Add sufficient quantity of water and mix it thoroughly to make mixture homogeneous. Figure 3.9 shows wet mixing of concrete. Do the “Ball test” (see below on how to do this test) for checking the workability of concrete. If it mix could not form a ball, we should add more water in small increment then again mix and then again do the “Ball test until the test is OK Fill the sample in the mould and compact it with mallet. Figure 3.11 shows the filling of the mould. Keep the block for curing for 7 days. Figure 3.12 shows filling of the mould. Prepare the cubes of respective pervious concrete of checking compressive strength. Test the compressive strength of the block and proceed for design.

Pollution under control (PUC):

PUC is the machine used for testing the pollutants from the vehicles. The Non Polluting Vehicle mark is a mandatory [certification mark](#) required on all new [motor vehicles](#) sold in India. The mark certifies that the motor vehicle conforms to the relevant version of the standards. This certification for a brand new vehicle has a limited validity of one year from the date of sale of the vehicle. After this, the vehicle has to be tested afresh.

The PUC test was conducted in Geetanjali PUC center, Girijanagar, Pimpri-MIDC, Baramati. Dist- Pune. The licence number is MH-42/02/2007, Mb.No.-986063564. The following Figure 3.14 shows PUC machine which is used for testing of Eco-Social pavement, The test procedure for PUC measurement is as below; Check that the power supply is as

per specifications of the manufacturer and electrical earthing is proper. Check that all the accessories as per manufacturer are available and are functioning properly. Check the span and zero calibration using sample gas of suitable value for CO as well as HC. Check the electrical calibration. Check the sampling system is leak proof. The printer is working correctly and the print out details is correct. Checking of no. of vehicle for idling emission measurement using this analyzer.

The exhaust system of vehicles:

The exhaust system of all the vehicles is horizontal in design, hence the exhaust emits air pollutants directly in to the atmosphere. Due to this the pedestrians and the people living in the locality have to suffer from this air pollution. They suffer from different diseases and disorders like Asthama, Blood cancer, throat cancer, visibility loss, cardiovascular diseases, headache, and death are the severe symptoms of this air pollution. The main problem of vehicular air pollution is the design of the exhaust system. As there is no platform on the road pavement to absorb the vehicular pollution hence the exhaust emits pollutants directly in to the atmosphere. This horizontal design of exhaust of vehicles is responsible for taking death of people.

To reduce this the exhaust system of vehicle should be designed in such a way that the tail end of exhaust pipe should be flexible in nature which works automatically based on sensor provided at the tail end of the exhaust pipe. The tail end of pipe should come down when vehicle come in the highly trafficked areas. Otherwise high pollution zones are created where the vehicles have mandatory to take their tail end of exhaust downward (a very few cm above the road pavement). Hence for this new approach of exhaust system of vehicles the vehicular industry should take positive approach and should analyse a vehicle according to this design. An experiment was conducted during the project on two wheeler vehicle which transmits its air pollutants 2 inch above the porous pavement coated with TiO_2 having the 50% CO removal, 65% NO_2 removal. Let's understand the typical design of exhaust of car before visualising the new approach of exhaust system.

The exhaust system, shown in Figure 3.15, is the waste disposal system of your vehicle. When the fuel system brings the fuel and air together in the cylinders to drive the vehicle, waste products are formed, and some of them are toxic.

Now that people all over the world are finally aware of how toxic exhaust gases can be for people and how drastically they affect global warming, it's really important to understand the system that works to detoxify these pollutants and disburse them as safely as possible.

As the exhaust gases pass from the cylinders in the engine through the muffler to the tailpipe at the rear of the vehicle and into the air, emissions control devices including the PCV valve, various sensors, a catalytic converter, and other components work to reduce or remove the harmful substances and recycle unburned fuel vapours.

Tip: There's little you can do to maintain or repair most of the parts in the exhaust system except to check and clean your PCV valve and replace it, if necessary; and troubleshoot to see whether your catalytic converter needs to be replaced. If the converter, the tailpipe, or the muffler needs to be replaced, have the job done by a professional.

The Muffler:

Exhaust pipes carry what's left of the exhaust gases through a muffler, which controls the noise of the escaping gases to the tailpipe and out of the vehicle (see Figure 3.16). If it fails, a ticket is given probably for disturbing the peace! Besides keeping the noise down, the muffler also has an effect on the pressure required to pass the exhaust gases through it, which creates the "back pressure" that the engine requires to run efficiently and affects the temperature and therefore the efficiency of the catalytic converter.

The PCV valve:

The PCV valve (shown in figure 3.17) is part of the positive crankcase ventilation system, which reroutes unburned gases, or blow-by, from the crankcase to the intake manifold and back to the engine, where they can be reburned in the cylinders. This process cuts the amount of pollution released into the environment. It also increases fuel economy because unburned fuel in the blow-by is consumed the second time around. The PCV valve also extends the life of the engine by reducing the water vapour and acid deposits that contaminate oil and form engine sludge. Figure 3.8 shows you how the PCV valve works.

The catalytic converter:

The catalytic converter (shown in figure 3.9) is usually attached to the exhaust pipe just after the exhaust manifold pipes. It was developed to deal with smog by further reducing the toxic substances in the exhaust gases before they can pollute the air. The catalytic converter is basically a cylinder filled with either little ceramic beads or a honeycomb structure coated with minute amounts of expensive metal catalysts that interact with the pollutants:

Reduction catalysts (rhodium and palladium) turn the NO_x (nitrogen oxide) emissions to oxygen and nitrogen, which exist in the air that we breathe.

Oxidation catalysts (palladium and platinum) turn carbon monoxide and hydrocarbon into harmless carbon dioxide and water.

The use of catalytic converters brought about another development that has been of great benefit to the environment. Originally, the lead in gasoline fouled catalytic converters, rendering them less effective and eventually destroying them, so legislation was passed to remove lead from fuel. Because lead is toxic to humans and other animals, Removal of lead from automotive fuel and its emission benefited greatly..

Other Emissions Control Devices:

Other emissions control devices include an exhaust gas recirculation system (EGR). An EGR valve on the intake manifold allows a small percentage of the exhaust gases back into the intake manifold, which lowers the peak combustion temperature in the combustion chambers and results in lower NO_x emissions.

Also oxygen sensors tell the ECU about excess oxygen in the exhaust gases so that the ECU can correctly control the fuel/air mixture. Air injection systems and various other gizmos also help clean up the exhaust before it enters the air. Engineers are developing new ways to clean up and reduce automotive emissions every day. But the healthiest thing you can do is drive the most-efficient vehicle possible, as little as possible!

This was the attempts made by the vehicular industry to minimise the toxicity of air pollution, but after vehicle becomes older the efficiency of catalytic converter being loosing hence there is need for continuous maintenance of vehicle. But by chance if catalytic converter fails to work efficiently then it may create problem to living being (Pedestrians) or road user. Hence emitting the pollution directly on the pavement then the problem which arises becomes less, because pavement absorbs pollution and particulate matter from vehicle will accumulate on the road surface.

B. Field work:

For construction of eco-social pavement one should know the environmental condition of place where work is going on along with the quality and quantity of material which are locally available. The design of pervious concrete in cold climate may create problem of choking of voids with snow and in hot climate there may be temperature cracks, expansion and contraction cracks. Hence before taking the construction work the field analysis is very important to;

Collection of vehicular pollution data:

This data is collected from PCMC (Pimpri Chinchawad Municipal Corporation) and PMC (Pune Municipal Corporation). The data is based on the survey done by Central Institute of Road Transport [CIRT], Pune, in 2002, is shown in Table 3.1 vehicular inventory of pollution load in PMC

Table1: Vehicular inventory of pollution load in PMC

Vehicle Type	No.of vehicles	CO	NO _x	SO ₂	HC	TSP	PM ₁₀	Total
Cars	71,771	20.20	2.32	0.034	3.80	0.30	0.20	26.854
2 Wheelers	560,359	36.10	0.30	0.058	19.20	0.90	0.70	57.258
Rickshaws	30,785	28.00	0.75	0.036	18.40	0.90	0.70	48.786
Taxis	1,633	2.70	0.25	0.002	0.50	0.03	0.02	3.502
Buses	6,602	9.20	9.72	0.903	1.80	1.42	1.11	24.153
Trucks	10,367	7.50	9.51	0.724	1.20	1.38	1.09	21.404
Total	681,517	103.7	22.8	1.757	44.90	4.93	3.82	181.957

All figures of pollutants are in Tonnes per day

From Table 3.1 and Table 3.2 we come to know that the huge amount of particulate matter develop in the PMC and PCMC. This pollutants may deteriorates or responsible for Global warming. Due to these pollutants the temperature of Pune city is risen. The heat island effect on the road causes accidents of road user.

Table .2: Vehicular inventory of pollution load in PCMC

Vehicle Type	No.of vehicles	CO	NO _x	SO ₂	HC	TSP	PM ₁₀	Total
Cars	27,224	7.66	0.90	0.012	1.44	0.11	0.07	10.192
2 Wheelers	211,837	13.64	0.11	0.021	7.20	0.34	0.26	21.57
Rickshaws	10,203	9.27	0.24	0.011	6.10	0.30	0.23	16.15
Taxis	587	0.94	0.09	0.0007	0.17	0.01	0.007	1.21
Buses	214	0.30	0.31	0.03	0.06	0.04	0.35	1.09
Trucks	18,492	13.37	16.9	1.30	2.14	2.46	1.94	38.17
Total	268,557	45.18	18.6	1.37	17.11	3.26	2.85	88.38

All figures of pollutants are in Tonnes per day

The material required for project is collected from different stone crusher surrounding to Baramati and Daund. The samples were collected from five stone crusher and the tests on aggregate were conducted in the lab. After the test result it concluded that the aggregate from Sai Stone Crusher, Daund is the best for construction purposes hence brought the aggregate from the same stone crusher. The test results are included in upcoming paragraph.

The cement confirming to IS code is preferred for project. The ACC cement OPC 53 grade was used by taking the field test on cement.

The TiO₂ had brought from Gandhi Chemicals, Budhawar peth, Pune.

B. Lab work:

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; Cement, Aggregate, TiO₂, Water

The project had focussed on selection of quality materials hence various lab tests on materials are conducted prior to use.

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.

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:

Apparatus:

Sieve sizes of 20mm, 16mm, 12.5mm, 10mm, 6.3mm, 4.75mm, weighing machine etc.

Procedure-The sieve sizes are properly arranged in the descending order from top to bottom. The aggregate are poured on the top sieve of size 20 mm. The complete assembly of sieve pans are shaken by hand or by using vibrator. The aggregate retained on each sieve is then measured. Then gradation curve is prepared

Table.3: 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

Conclusion: For making of pervious concrete the above gradation needed to be followed. The aggregate required for pervious concrete must be uniformly graded instead of well graded.

Water absorption test and specific gravity test:

Procedure: About 2 kg of the aggregate sample is washed thoroughly to remove fines, drained and then placed in the wire basket and immersed in distilled water at a temperature between 22° to 32°C with a cover of at least 50mm of water above the top of the basket. Immediately after immersion the entrapped air is removed from the sample by lifting the basket containing it 25mm above the base of the tank and allowing it to drop 25 times at the rate of about one drop per second. The basket and the aggregate should remain completely immersed in water for a period of 24 +/- 0.5 hours afterwards. The basket and the sample are then weighed while suspended in water at a temperature of 22° to 32°C. In case it is necessary to transfer the basket and the sample to a different tank for weighing, they should be jolted 25 times as described above in the new tank to remove air before weighing. This weight is noted while suspended in water W₁ g. The basket and the aggregate are then removed from water and allowed to drain for a few minutes, after which the aggregates are transferred to one of the dry absorbent clothes. The empty basket is then returned to the tank of water, jolted 25 times and weight in water W₂ g. The aggregates placed on the absorbent clothes are surface dried till no further moisture could be removed by this cloth. Then the aggregates are transferred to the second dry cloth spread in a single layer, covered and allowed to dry for at least 10 minutes until the aggregates are completely surface dry. 10 to 50 minutes drying may be needed. The aggregates should not be exposed to the atmosphere, direct sunlight or any other source of heat while surface drying. A gentle current of unheated air may be used during the first ten minutes to accelerate the drying of aggregate surface. The surface dried aggregate is then weighed W₃ g. The aggregate is placed in a shallow tray and kept in an oven maintained at a temperature of 110°C for 24 hours. It is then removed from the oven, cooled in an airtight container and weighed W₄ g. At least two tests should be carried out, but not concurrently.

Calculations:

Weight of saturated aggregate suspended in water with the basket (w₁) = 4344 gm

Weight of basket suspended in water (w₂) = 694 gm

Weight of saturated aggregate in water = (w₁-w₂) = 3414 gm

Weight of saturated surface dry aggregate in air (w₄) = 5258 gm

Weight of water equal to the volume of the aggregate = (w₃-w₅) gm

Specific gravity = $\frac{\text{Dry weight of aggregate}}{\text{Weight of equal volume of water}}$

$$\frac{W_4}{W_3 - W_4} = \frac{W_4}{W_3 - W_4} \dots\dots\dots \text{Equation 3.1}$$

Water absorption = $\frac{\text{Percent by weight of water absorbed in terms oven dried}}{\text{weight of aggregates.}}$

$$= \frac{(W_3 - W_4)}{W_4} \times 100 \dots\dots\dots \text{Equation 3.2}$$

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

Impact test:

Theory and scope:

Toughness is the property of a material to easiest impact. Due to moving loads the aggregates are subjected to pounding action or impact and there is possibility of stones breaking into smaller pieces. Therefore a test designed to evaluate the toughness of stones i.e., the resistance of the stones to fracture under repeated impacts may be called Impact test on aggregates. The test can also be carried on cylindrical stone specimen known as Page Impact test. The aggregate Impact test has been standardized by Indian Standard Institution. The aggregate impact test is conducted as per IS-2386 Part IV. The aggregate Impact value indicates a relative measure of the resistance of aggregate to a sudden shock or an Impact, which in some aggregates differs from its resistance to a slope compressive load in crushing test. A modified Impact test is also often carried out in the case of soft aggregates to find the wet Impact value after soaking the test sample. Various agencies have specified the maximum permissible aggregate Impact values for the different types of pavements. IRC has specified the following values. The maximum allowable aggregate Impact value for water bound Macadam; Sub-Base coarse 50% where as cement concrete used in base course is 45%. WBM base course with Bitumen surface in should be 40%. Bituminous Macadam base course should have A.I.V of 35%. All the surface courses should possess an A.I.V below 30%.

Procedure: The test sample consists of aggregates passing 12.5mm sieve and retained on 10mm sieve and dried in an oven for 4 hours at a temperature of 100 C to 110 C. The aggregates are filled up to about 1/3 full in the cylindrical measure and tamped 25 times with rounded end of the tamping rod. The rest of the cylindrical measure is filled by two layers and each layer being tamped 25 times. The overflow of aggregates in cylindrical measure is cut off by tamping rod using it has a straight edge. Then the entire aggregate sample in a measuring cylinder is weighted nearing to 0.01gm. The aggregates from the cylindrical measure are carefully transferred into the cup which is firmly fixed in position on the base plate of machine. Then it is tamped 25 times. The hammer is raised until its lower face is 38cm above the upper surface of aggregates in the cup and allowed to fall freely on the aggregates. The test sample is subjected to a total of 15 such blows each being delivered at an interval of not less than one second. The crushed aggregate is than removed from the cup and the whole of it is sieved on 2.36mm sieve until no significant amount passes. The fraction passing the sieve is weighed accurate to 0.1gm. Repeat the above steps with other fresh sample. Let the original weight of the oven dry sample be w_1 gm and the weight of fraction passing 2.36mm I.S sieve be w_2 gm. Then aggregate Impact value is expressed as the % of fines formed in terms of the total weight of the sample. Aggregate Impact Value = $\frac{w_2}{w_1} \times 100$ %

.....Equation 3.4

Observation and Calculation:

Table 4: Observation 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
5	Aggregate Impact Value = $(W_2/W_1) \times 100$ Percent.	13.6	13.7	13.65

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

Aggregate crushing strength test:

This is one of the major Mechanical properties required in a road stone. The test evaluates the ability of the Aggregates used in road construction to withstand the stresses induced by moving vehicles in the form of crushing. With this the aggregates should also provide sufficient resistance to crushing under the roller during construction and under rigid tyre rims of heavily loaded animal drawn vehicles. The crushing strength or aggregate crushing value of a given road aggregate is found out as per IS-2386 Part- 4. The aggregate crushing value provides a relative measure of resistance to crushing under a gradually applied compressive load. To achieve a high quality of pavement aggregate possessing low aggregate crushing value should be preferred. The aggregate crushing value of the coarse aggregates used for cement

concrete pavement at surface should not exceed 30% and aggregates used for concrete other than for wearing surfaces, shall not exceed 45% as specified by Indian Standard (IS) and Indian Road Congress (IRC).

Procedure: The aggregate in surface-dry condition before testing and passing 12.5 mm sieve and retained on 10 mm sieve is selected. The cylindrical measure is filled by the test sample of the aggregate in three layers of approximately equal depth, each layer being tamped 25 times by the rounded end of the tamping rod. After the third layer is tamped, the aggregates at the top of the cylindrical measure are leveled off by using the tamping rod as a straight edge. Then the test sample is weighed. Let that be w_1 gm. Then the cylinder of test apparatus is kept on the base plate and one third of the sample from cylindrical measure is transferred into cylinder and tamped 25 times by rounded end of the tamping rod. Similarly aggregate in three layers of approximately equal depth, each layer being tamped 25 times by rounded end of the tamping rod. Then the cylinder with test sample and plunger in position is placed on compression testing machine. Load is then applied through the plunger at a uniform rate of 4 tonnes per minute until the total load is 40 tonnes and the load is released. Aggregates including the crushed position are removed from the cylinder and sieved on a 2.36mm IS sieve and material which passes this sieve is collected and weighed. Let this be w_2 gm. The above step is repeated with second sample of the same aggregate. The two tests are made for the same specimen for taking an average value. Total weight of dry sample taken is w_1 gm weight of the portion of crushed material passing 2.36mm IS sieve be w_2 gm. Then the aggregate crushing value is defined as the ratio of weight of fines passing the specified IS sieve to the total weight of the sample (w_1).

$$\text{Aggregate crushing value} = \frac{w_2}{w_1} \times 100 \% \quad \text{.....Equation 3.5}$$

Observation and Calculation:

Table 5: 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 %

Abrasion test:

Theory and Scope:

Abrasion is a measure of resistance to wear or hardness. It is an essentially property for road aggregates especially when used in wearing coarse. Due to the movements of traffic, the road stones used in the surfacing course are subjected to wearing actions at the top. When traffic moves on the road the soil particle (sand) which comes between the wheel and road surface causes abrasion on the road stone. The abrasion test on aggregate is found as per I.S.-2386 part-IV. Abrasion tests on aggregates are generally carried out by any one of the following methods- Los Angeles abrasion test. Deval abrasion test. Dorry abrasion test. We have conducted Abrasion test by using Los Angeles abrasion test.

Los Angeles Abrasion Test: The principle of Los Angeles abrasion test is to find the percentage wear due to the relative rubbing action between the aggregates and steel balls used as abrasive charge pounding action of these balls also exist while conducting the test. Maximum Allowable Los Angeles Abrasion Values of Aggregates in Different types of pavement layers as per Indian Road Congress (IRC) are:-For sub-base course a value of 60%. For base course such as WBM, Bituminous Macadam (B.M.), Built – Up spray grout base course and etc. value of 50%.

For surface course such as WBM, BM, Bituminous Penetration Macadam, Built-Up spray grout binder course and etc. a value of 40%. If aggregates are used in surface course as Bituminous carpet, Bituminous surface dressing, single or two coats, cement concrete surface coarse and etc. a value of 35%. If aggregates are used for bituminous concrete, Cement concrete pavement as surface coarse than aggregate abrasion value of 30% maximum.

Procedure: Clean and dry aggregate sample confirming to one of the grading A to G is used for the test. Aggregates weighing 5Kg for grading A, B, C or D and 10Kg for gradings E, F or G may be taken as test specimen and placed in the cylinder. The abrasive charge is also chosen in accordance with table no.1 and placed in the cylinder of the machine, and cover is fixed to make dust tight. The machine is rotated at a speed of 30 to 33 revolutions per minute. The machine is rotated for 500 revolutions for gradings A, B, C and D, for gradings E, F and G, it shall be rotated for 1000 revolutions. After the desired number of revolutions, the machine is stopped and the material is discharged from the machine taking care to take out entire stone dust. Using a sieve of size larger than 1.70mm I.S sieve, the material is first separated into two parts and the finer position is taken out and sieved further on a 1.7mm I.S sieve. Let the original weight of aggregate be w_1 gm, weight of aggregate retained on 1.70mm I.S sieve after the test be w_2 gm.

$$\text{Los Angeles abrasion value (\%)} = \frac{w_1 - w_2}{w_1} \times 100 \quad \text{.....Equation 3.6}$$

Observation and Calculation:

Table 6: Observation table for abrasion test

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%	

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. Target mean streangth

$$F_m = f_{ck} + k.s$$

$$S = 4 \dots \text{Assumed considering quality control}$$

$$F_m = 40 + 1.65 \times 4$$

$$F_m = 46.6 \text{ Mpa}$$

Water cement ratio

$$W/C = 0.27 \dots \text{For air entrained concrete pg-246, table 10.23 of M.L.Gambhir}$$

Water content

(As per table 10.20, pg-244, M.L.Gambhir)

For air entrained concrete

$$\text{Water} = 181 \text{ kg/m}^3 \dots \text{Stiff plastic.}$$

$$= 202 \text{ kg/m}^3 \dots \text{Plastic slump 75-100mm}$$

Cement content

$$W/C = 0.27$$

$$202/C = 0.27$$

$$\text{Cement} = 748.148 \text{ kg/m}^3$$

: From table 11.4 of M.L.Gambhir

$$\text{Fineness modulus} = 2.80$$

$$\text{Dry roded bulk volume} = 0.46 \% \text{ of volume of concrete}$$

$$\text{Density of 10mm aggregate} = 2190 \text{ kg/m}^3$$

$$\text{Weight of course aggregate} = 0.46 \times 2190$$

$$= 1007.4 \text{ kg/m}^3$$

Weight of ingredients

$$\text{Cement} = 748.148 \text{ kg/m}^3$$

$$\text{Aggregate} = 1190 \text{ kg/m}^3$$

$$\text{Water} = 202 \text{ kg/m}^3$$

$$\text{Proportions} = 1:1.58:0.27 \text{ is used}$$

Two sets of pervious concrete samples were prepared in this study. The first set of samples were trial samples to screen out potential TiO₂ application methods from a number of candidate application methods, like Commercial water based TiO₂, Addition of TiO₂ at the time of Mix design, The cement-TiO₂ paste coating. These trial samples were made on three each samples of 38 cm long, 25cm wide and 6 cm thick. The trial samples were made using single-sized aggregate of size 4.75mm, 6.3 mm, 10mm. Type I Portland cement, and a water-cement ratio of 0.30. The water-cement ratio was chosen based on previous work, which gave a porosity of 22%. Specimens were lightly compacted as typical in pervious concrete placements, and designed for a target porosity of 22%. The samples were covered and left to cure for 7 days. The mix design for the final-evaluation samples was based on the same previous work used to determine the mix design for the trial samples. As a result, the porosity turned out to be slightly higher for the final-evaluation samples, possibly due to the use of smaller-sized aggregates. The work had used aggregates similar in size for trial samples. The samples were covered and left to cure for 7 days. In addition, one traditional (non-pervious) concrete sample, which was the same size as the final-evaluation samples, was prepared as a control sample with a water-cement ratio of 0.48. A summary list of all of the concrete samples that were made is shown in the Table 3.7.

Table7: Summary table of concrete samples made

Sample	Sample type	Sample size	Aggregate size	Water-cement ratio
--------	-------------	-------------	----------------	--------------------

Commercial water based TiO ₂	Pervious	38cmx25cmx 6cm	4.75mm	0.28
Addition of TiO ₂ 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	38cmx25cmx 6cm	10mm	0.40

Blocks made out of concrete were made for both sample sets, the trial samples and the final-evaluation samples, to use as forms for top compaction. These compactor forms were used to compact the pervious concrete samples by placing the form on top of each sample that was freshly poured into its mould and then tapping the top of the compactor form with a rubber mallet hammer. Prior to making the pervious concrete samples, the amount of pervious concrete material to place into each sample mould prior to compaction and the amount of each material needed (cement, water, and aggregates) to make the pervious concrete had to be calculated.

Sample Preparation Method:

The preparation of pervious concrete consists of 3 steps:

Step 1: Estimate sample volume:

The average volume for the trial samples and the final-evaluation samples were calculated to be 3358 cm³ and 2401 cm³ respectively.

Step 2: Estimate mass per sample mould:

Once the volume was calculated, the next step was to calculate how much material to put into each mould when making the samples. The volume that was previously calculated was the same volume that the samples were to be compacted to. With that, the amount of fresh mass to compact within each mould was calculated. Calculations were based on previous work, which the previous samples had 22% porosity. 22% porosity was chosen for this research because it was a value representative to what is practiced in the field. Typically in the field, 15-25% voids are achieved in hardened pervious concrete. Variation is expected in the sample-making process, but the samples should not have a porosity that is too low, so 18% was chosen as the minimum porosity allowed. The minimum mass allowed to get 22% porosity and the maximum mass allowed to get 18% porosity were determined.

Step 3: 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 are shown in Table

Table8: Materials Proportions in Pervious Concrete

Materials	Mass ratio to cement	Mass for 3 mold	Porosity and Permeability of pervious concrete samples: Porosity Test The porosity test
Cement	1	748 Kg/m ³	
Aggregate	1.58	1190 Kg/m ³	
Water	0.30	202 Kg/m ³	

was performed on the prepared samples using the method proposed by Montes et al. (2005). Two different weights were determined for each sample: dry weight in the air (W_d) and submerged weight in the water with at least half an hour submerging time (W_s). Figure 3.1 shows the laboratory setup for determining the submerged weight of samples. The porosities (P) of the samples were calculated from the measured dry mass (W_d) and submerged mass (W_s) for each sample based on Equation 3.1, where ρ_w and V_t are the density of water and total volume of sample respectively.

$$P(\%) = \left(1 - \frac{W_d - W_s}{\rho_w V_t} \right) \times 100 \dots\dots\dots \text{Equation 3.7}$$

All samples within each batch were fairly consistent with porosity. Typically, an acceptable porosity for pervious concrete is between 15% and 25% voids. Of the trial samples, the porosities of the 10mm samples ranged from 24.65% to 26.75%, with an average of 25.40%. The porosities of the 6.3 mm samples ranged from 24.23% to 26.10%, with an average of 25.13%. Of the final-evaluation samples, the porosities of the 4.75 mm samples ranged from 18.23% to 22.23%, with an average of 20.23%. The porosities of non pervious sample is zero.

Infiltration Test: Pervious concrete allows water to infiltrate completely through it, as shown in Figure 3.25. 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 (Figure 3.26). 2000 mL of water was poured through the pipe (Figure 3.25) 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.

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

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. The following Figure 3.27 shows infiltration rate vs porosity for sample of 10mm and 4.75mm aggregate.

III. RESULTS AND DISCUSSION

In this chapter the discussion is made on the various results obtained in this project. The test results are compared with the standard result.

A. Tests on Aggregate:

Water absorption and specific gravity test: The water absorption value of aggregate is 1.55% and specific gravity is 3.27. The test result of water absorption and specific gravity of used aggregate are within permissible limit hence it is ok.

Impact test:

Test result: Impact value is 13.65%

Discussion: The impact value is 13.65% which is less than 45%, hence it can be suitable for pervious pavement.

Crushing strength test:

Test result: The aggregate crushing value is 14.7%.

Discussion: The crushing value of given aggregate is 14.7% which is less than 30%. So it can be suitable for road work.

Abrasion test:

Test result: Loss Angeles abrasion value is 17.5 %

Discussion: The aggregate abrasion value of aggregate is 17.5% which is less than 30% so it can be used for pavement work.

Infiltration rate and porosity:
 Table 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, TiO₂ 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.

PUC test on pavement for scooter:

Table 4.2: PUC test result.

Type of pollutants	PUC before test	PUC after test
CO % vol.	1.68	0.84
HC ppm	79	304
CO ₂ % vol.	3.60	5.80
O ₂ % vol.	14.42	10.51
P.E.F	0.538	0.537

LAMBDA	0.0 R	0.0 R
AFR	0.0 R	0.0 R
RPM	0.0	0.0

Discussion:

Test was carried on scooter for checking the efficiency of pavement for pollution absorption. The test conclude that there is 84 % of CO removal and near about more than 50% nitrogen removal in the various form. The particulate matter and carbon ash settles on the surface of the pavement. This test is conducted by using the PUC machine because it gives the practical results. These results may be varying in nature according to type of vehicle, type of surface pavement, speed of vehicle, fuel used etc.

Cost economics:

Table Cost analysis.

Sr.no.	Particulars of item	Quantity	Rate	Per	Amount
1.	Titanium dioxide (TiO ₂)	1 kg	450	Kg	450
2.	Cement	1 bag	350	Bag	350
3.	Aggregate	1 m ³	650	m ³	650
4.	Water	-	-	-	-
5.	PUC machine	L.S	500	L.S	500
Total					1950/m ³

For construction of pervious concrete of 1m³ is 1950 rupees (excluding transportation charges, overhead charges, and manpower wages).

The cost of pervious concrete and impervious concrete will be same if it considers the working efficiency of pervious pavement in absorbing pollution and storm water management instead of impervious pavement

IV. CONCLUSION

Because pavement has large surface area that is in contact with polluted air, treating pavements with TiO₂ reduces harmful emissions at street level and benefit a cleaner living environment for the public. Unlike traditional non-pervious pavements, the high porosity and surface roughness of pervious concrete pavement allow more TiO₂ particles to have direct contact with UV lights and thus improve removal efficiency. The open pore structure of pervious concrete also protects TiO₂ particles from traffic loading and environmental weathering. In addition to being a sustainable transportation facility for storm water runoff management, pervious concrete pavement, when coated with TiO₂ and widely implemented in urban roads and highway shoulders, results in improved air quality and thus a multi-phase cleaner transportation environment for future generations.

The test conclude that there is 84 % of CO removal and near about more than 50% nitrogen removal in the various form. The particulate matter and carbon ash settles on the surface of the pavement.

This project provides base for future eco friendly environment in urban areas. There is need of constructing the flexible exhaust system of vehicles so as to take dual advantages of pavement and vehicle. There are certain advantages and disadvantages with the construction of Eco-Social pavement.

Advantages of project: Road accidents are minimized. Health condition of people in urban cities is improved. Living standard of people is improved. Vehicular pollution in cities is reduced. It helps for effective storm water disposal. Global warming is minimized by implementing this project in highly polluted areas. It is aesthetically pleasing. The heat island effect on roads is minimized.

Disadvantages of project: As there is need of substantial changes in the exhaust system of vehicles hence this is costly and sophisticated technology. The Eco-Social pavement is made from pervious concrete hence at heavy traffic this is not feasible. There is need of more research for improving the strength of pervious pavement at heavy traffic. Need of under drainage system is required. Chances of blockage of voids of pavement resulting in decreasing of efficiency.

Application of project:

This project is best suitable for urban areas where there is high vehicular pollution. This project is based on the future condition of urban cities caused due to vehicular pollution. Today this project might not feel to be important but when the problem start arising then the project would be important. Hence problems in future should be understood and mankind must be ready to fight to these problems by implementing such innovative ideas. The following are certain area of application of this project In urban areas for reducing vehicular pollution and storm water disposal. In footpath, shoulders of road, in garden for draining out rain water. This is effectively used for rain water harvesting. This is used of lining of

wells, ditches etc. This pavement is applicable for treating waste water. This is used to the places where there is heavy runoff causing erosion. This technology is used in construction of buildings for treating pollution. These are some key application areas where we can work together. This project was just a positive approach to reduce the vehicular pollution in urban cities as well as storm water disposal. But there is more need of research in this field for implementing this project.

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