Experimental Investigation on the Reduction of Common Air Pollutants from Vehicle Emission Using Concrete Bricks with Titanium Dioxide

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***Abstract* — On a global scale, air pollution is considered to be one of the leading environmental problems. Energy consumption, fuel burnings, industrial processes, and emissions continue to worsen our current air condition. With the knowledge that titanium dioxide can decompose harmful gases through the process called photocatalysis, an investigation regarding its utilization on concrete bricks to reduce common air pollutants from vehicular emission is pursued by the researchers. Through experimentation, the study aims to know the percentage reduction on the following parameters: carbon monoxide (CO), nitrogen dioxide (NO_2), sulfur dioxide (SO_2) and lead (Pb). The tests used in accordance to the objective of the study were air test, which is conducted by First Analytical Services and Technical Cooperatives (F.A.S.T laboratories). After the analysis, the data were recorded and tabulated. Graphs were presented to show the differences in percentage reductions. Results of air test showed relative reduction on air pollutants, an average reduction of 77.38 percent on carbon monoxide, 40.48 percent on nitrogen dioxide and 81.43 percent on sulfur dioxide. The Researchers conclude that concrete bricks with titanium dioxide will be able to help reduce air pollution especially on urbanized areas experiencing high vehicular emissions.**

***Index Terms*—air, pollution, titanium dioxide, pollution control**

I. Background of the Study

A. Introduction

As we are now experiencing the modern times, different fields of study continue to develop much further. Transportation engineering which is a component of civil engineering undergoes constant advancement with respect to time, due to the fact that transportation plays a very vital role in our everyday life.

Back then, people carry or push the goods that they are going to transfer from one place to another until they learned to use domesticated animals for the purpose of transportation. About 3,500 B.C., wheel and axle have been invented that made transportation much easier. This development leads to the need for better roads, giving birth to early pavement technology which we can trace from the roads that Romans have built.

Nowadays, with the continuous development of cities and constant innovation of vehicles, roads and highways are being constructed to supply the increasing demand for road service. Once an arable land now turned into a road to provide alternative ways, bridges and railways are built conducive to faster mode of transportation and traffic systems are designed to improve the use of road and highways [1].

As we can see, the evolution of transportation has helped people to improve ways for living. But on an environmental point of view, roads and highways are being turned into a production site of pollutants. It is sad to say that the improvement of man's daily living is somehow directly proportional to the destruction of environment.

B. Background of the Study

Vehicular emissions can produce harmful pollutants such as carbon monoxide, nitrogen dioxide, and sulfur dioxide which pose a great threat to humans and the environment. By being exposed to polluted air, study shows that our health may be at risk to chronic obstructive pulmonary diseases (COPD), Heart Disease and even Cancer. *(ENHI, 2006)*

Carbon monoxide which is emitted by vehicles can turn into carbon dioxide which is considered as a greenhouse gas (heat-trapping gases) and can promote global warming. Global warming will further affect the environment and worsen environmental issues.

Since we are not able to stop the production and use of vehicle for transportation, various academic studies were conducted to air pollutants. One of which is the application of titanium dioxide (TiO_2) as photocatalytic material in construction. e.g. paints, cement, and concrete.

Back then, about 80 percent of the world's titanium dioxide outputs are used in paints and pigment industry. Titanium dioxide gained a widespread acclaim as a

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pigment ever since it became a viable alternative for the toxic white lead used in old paints. [2]

However, in year 1976, another important commercial application of titanium dioxide has been discovered: its role as a photocatalyst, which means it uses light energy in the promotion of chemical reaction. Its photocatalytic properties were discovered by chance by a graduate student named Akira Fujishima who is working under the guidance of Associate Professor Kenichi Honda. Fujishima noticed that the titanium dioxide absorbs the energy when being irradiated by light. Afterwards, it enables the decomposition of water into hydrogen and oxygen. [3] Despite those who have doubt this claim, Fujishima was able to publish his work in the journal Nature (1972), creating a way for a new phenomenon now known as the Honda-Fujishima effect, named after its discoverers. [4]

Aside from being used as a pigment, titanium dioxide can also be added to paints, cement, windows, tiles or other products for its ability to sterilize and deodorize and its anti-fouling properties. [5]

C. *Objectives of the Study*

The study aimed to determine the percentage reduction of nitrogen dioxide, sulfur dioxide, carbon monoxide, and lead from vehicle emission; using concrete bricks with titanium dioxide.

Specifically, it aimed:

- To develop alternative construction materials that would help reduce nitrogen dioxide, sulfur dioxide, carbon monoxide, and lead from vehicle emission.
- To determine if titanium dioxide will have equal effectiveness in reducing the four common air pollutants:

  Nitrogen dioxide
  Sulfur dioxide
  Carbon monoxide
  Lead; and
- To test the effectiveness of bricks with titanium dioxide after a time duration (exposed to different weather conditions)

D. *Scope and Limitations*

The experimental investigation on the reduction of common pollutants from vehicle emission in air focuses on the following points:

- Percentage reduction on carbon monoxide (CO), lead (Pb), nitrogen dioxide (NO_2), and sulfur dioxide (SO_2) by the use of concrete bricks with titanium dioxide.
- Air pollutant reduction will be analysed by conducting initial and final tests, wherein the final test consist of three trials through a simulation of air polluted environment.
- The parameters of the air test to be conducted are the following: carbon monoxide (CO), lead (Pb) nitrogen dioxide (NO_2), and sulfur dioxide (SO_2).
- The experimental investigation will occur with the use of controlled area instead of ambient air condition
- The study focuses on the ability of the subject material (bricks with titanium dioxide) to reduce common air pollutant that are present in the atmosphere rather than the ability of the subject material to withstand loads.
- The study does not focus on producing a customised bricks that will have greater compressive strength with normal bricks.
- The concrete bricks with titanium will be used for pavements limited to pedestrian and light weight loads.
- Titanium dioxide anatase grade will be the subject of the experimentation.
- There will only be one sampling point to have an overview with reaction of normal bricks in a controlled environment.
- To have an overview about the durability and effectiveness of titanium dioxide after a month (exposed to different weather conditions) there will only be one sampling point.

II. METHODS

This study involves evaluating the environmental aid of TiO_2 mixture on concrete bricks. The goal is to find a TiO_2 application that works effectively in an Air polluted environment.

A. *Research Design*

The emission of common air pollutants (carbon monoxide (CO), lead (Pb), nitrogen dioxide (NO_2), sulfur dioxide (SO_2), by transportation, industrial, and agricultural industries is a major contributor to air pollution. The development of an alternative construction material that will reduce air pollutants was the focus of the study.

The effectiveness of titanium dioxide has emerged because of its photo catalytic property that is used for environmental purification. It has been a main ingredient to produce a paint product that can break down noxious air pollutants and convert them into harmless substances. Existing studies subjecting the natural occurring mineral applied into concrete was also discovered to have a self-cleaning capability.

The optimization of the use of TiO_2 was carried out in the research. To determine the performance of bricks with TiO_2 in a controlled area, air quality test was then conducted for the data analysis.

B. *Data Gathering Procedure*

Primary data were collected from the vehicle used as source of pollutant. The vehicle was subjected in an emission test to assess whether it positively emitted the pollution required for the experiment.

Data were also accumulated from the air testing company (*F.A.S.T. Laboratories*) where initial and final testing was conducted for the baseline and result data respectively.

Four gases were subjected to the tests: carbon monoxide (CO), nitrogen dioxide (NO_2), sulfur dioxide (SO_2), and lead (Pb). The ambient air test for each gas had different corresponding methods to which the amount of gases were measured in ppm (parts per million) and µg/Ncm (micrograms per normal cubic meter). The following tests are listed:

- Tedlar bag collection

  This method uses a bag to collect an air sample that normally involves active sampling. In this experiment, sampling with a pump was conducted where small pump with low flow rates (50-200 mL/min) and tubing were used to fill the bag. Carbon monoxide (CO) was measured in ppm using this test.
- Gas bubbler/Liquid Absorption

  In this method, the air touches the solution then the gas sample is subjected to resolution and reaction. To bring out high degree (pollutant) gas-liquid contact, impingers& midget type's devices are used. These devices can handle sample flow rates about 30 to 3 litres per minutes respectively. Particular absorbent-liquid is filled inside impinger. Flow is controlled with help of flow control devices. Nitrogen dioxide (NO_2) and sulfur dioxide (SO_2) were measured in µg/Ncm using this test.
- AAS (Atomic Absorption Spectroscopy)

  This technique makes use of the wavelengths of light specifically absorbed by an element. They correspond to the energies needed to promote electrons from one energy level to another, higher, energy level. Lead (Pb) was measured in ppm using this test.

The researchers set a controlled area as shown in Fig. 1 that was polluted by the vehicle. Values of various pollutants presented in the experimental setup were measured at a specified time. Initial air testing procedure was conducted and the air testing company acquires the data of the air sample obtained from the controlled area without the customized bricks. Every test had duration of 30 minutes. After the initial test, the researchers installed the customized bricks inside the controlled area as shown in Fig. 2 to conduct the final test consisting of three trials. Results from the initial and final tests were gathered after ten working days.

Customized bricks were laid and let exposed to sun, rain, and dust for one month. Test consisting of two parts; with installed customized bricks and with installed common concrete bricks, was conducted. Every part had duration of 30 minutes. This test was conducted to test the durability and effectiveness of customized bricks after a time lag and to consider whether the common concrete bricks can also accumulate significant effect on the reduction of pollution in the controlled area, differentiating the customized bricks from the latter.

C. Project Testing and Evaluation

The air test equipment was installed inside the simulated environment as shown in Fig. 1. The air inside the controlled area was monitored and tested providing a baseline data for its initial air quality condition.

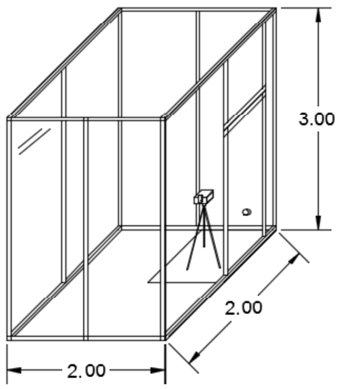

Figure 1. Controlled Area without Bricks

The succeeding tests were conducted with the bricks with titanium dioxide as shown in Fig. 2. The air test equipment was placed at the same position as it is in the initial test. The area was polluted by common air pollutants, data were then recorded.

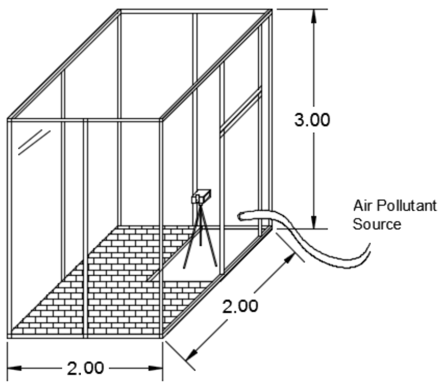

Figure 2. Controlled area with bricks with TiO_2 and normal bricks

After a month lag, tests were conducted; (1) controlled area installed with customized bricks, (2) controlled area installed with common concrete bricks. The air test equipment is placed at the same position as it is in the previous tests. In each test, the area is polluted by high common air pollutants. Data were then recorded.

D. Mix Design and Sample Preparation

One hundred fifty pieces of concrete brick samples were prepared in this study to be installed in the four square meter of the simulated air polluted area. Each sample is approximately eight inches long, four inches wide, and two inches thick (203.2 mm x 101.6 mm x 25.4 mm). The trial samples were made using commercially prepared dry mix of concrete materials, titanium dioxide and water-cement ratio of 0.45. Specimens were composed of two layers. The bottom layer having 100 percent premixed concrete, top layer 30 percent concrete, and 70 percent titanium dioxide mix. The samples were stacked in a cool area being covered by a mover's blanket shielded with plastic sheeting and are left to cure for two weeks.

III. RESULTS AND DISCUSSION

Air test results were present. The results were presented in graph and table form. The results displayed the percent reduction of air pollutants CO, NO_2, SO_2, and Pb according to the setup of bricks and controlled area. The concentrations of pollutants were measured based on 30 minutes time testing duration. Time elapsed starts after the every successful engine fire. Compressive strengths of bricks were presented in MPa and Psi values. Plot showing the result for emission test were shown in the appendix. They were not included in this section and only serves as a proof of the qualification of the vehicle subjected in the experiment as a pollutant source.

A. Result Testing and Evaluation

TABLE I. SUMMARY OF AIR TEST RESULTS

SUMMARY OF AIR TEST RESULT					
LOCATION	Stn. No.	CO, (PPM)	NO2, (PPM)	SO2, (ug/Ncm)	LEAD (ug/Ncm)
Initial Run (Without Blocks)	1	273	0.28	339	less than 0.05
Final Run 1 (With Blocks)	2	53.8	0.16	72	less than 0.05
Final Run 2 (With Blocks)	3	77.7	0.17	56	less than 0.05
Final Run 3 (With Blocks)	4	50.1	0.17	61	less than 0.05

The results shown in Table I are the data gathered during the primary air testing. Four sampling points were used to test the efficiency of the concrete bricks with titanium dioxide in the reduction of common pollutants from vehicular emission such as carbon monoxide (CO), nitrogen dioxide (NO_2), sulfur dioxide (SO_2) and lead (Pb). The sampling method used for carbon monoxide (CO) is referred to as Tedlar Bag Collection. Gas Bubbler/Liquid Absorption was used for both nitrogen dioxide (NO_2) and sulfur dioxide (SO_2) while for lead (Pb), Atomic Absorption Spectrometry (AAS) was used.

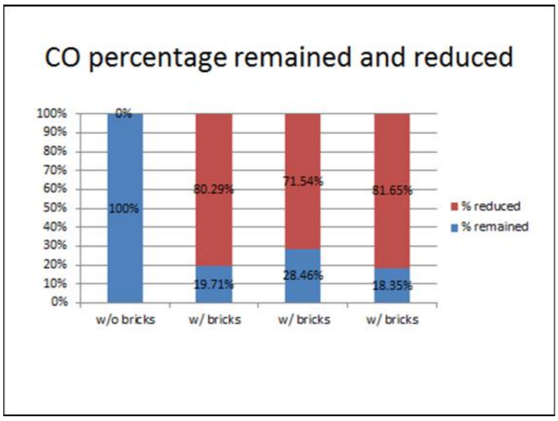

Figure 3. Percentage Reduction on CO

Fig. 3 shows the percent reduction of CO from initial test to the final test consisting of three trials. The bar shows the reaction of CO in bricks with TiO_2 has an average of 40.48 percent reduction on the initial amount of air pollution.

The CO graph results for final test consisting three trials are relatively close. The graph shows an initial CO concentration of 273 ppm. The CO level decreases at 53.8 ppm by the first run of final test. Second and third runs of final test were then conducted and accumulated a relative CO level of 77.7 and 50.1 respectively. The difference in the level of CO in the initial test and first run in the final test is 80.29 percent. The second and third run of final test showed a difference of 195.3 ppm (71.54%) and 222.9 ppm (81.65%) respectively.

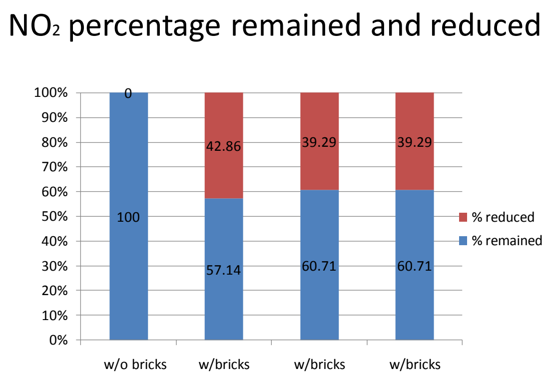

Figure 4. Percent Reduction on NO_2

Fig. 4 summarizes the percent reduction of NO_2 from initial test to the final test consisting of three trials. The bar shows that the reaction of NO_2 in bricks with TiO_2 has an average of 40.48 percent reduction on the initial amount of air pollution.

The NO_2 graph results for final test consisting three trials are relatively close. The graph shows an initial NO_2 concentration of 0.28 ppm. The NO_2 level decreases around 0.16 by the first run of final test. Second and third runs of final test were then conducted and accumulated a relative NO_2 level decrease of 0.17 ppm. The difference in the level of NO_2 in the initial test and first run in the final test is 0.12 ppm or 42.86 percent. Second and third run of final test gave a difference of 0.13 ppm or 39.29 percent.

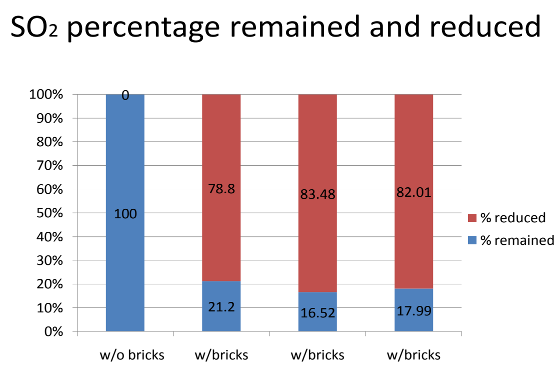

Figure 5. Percent Reduction on SO_2

Fig. 5 shows the percent reduction of SO_2 from initial test to the final test consisting of three trials. The bar shows that the reaction of SO_2 in bricks with TiO_2 has an average of 40.48 percent reduction on the initial amount of air pollution.

The SO_2 graph results for the final test consisting three trials are relatively close. The graph shows an initial SO_2 concentration of 339 ug/Ncm. The SO_2 level decreases around 72 ug/Ncm by the first run of the final test. The second and third runs of final test were then conducted and accumulated a relative SO_2 level decrease of 56 ug/Ncm and 61 ug/Ncm or 82.01 percent, respectively. The difference in the level of SO_2 in the initial test and first run in the final test is 267 ug/Ncm or 78.8 percent. The second and third run of the final test gave a difference of 286 ug/Ncm or 83.48 percent and 278 ug/Ncm or 82.01 percent, respectively.

IV. Summary

The overriding purpose of this study was to determine the percentage reduction of nitrogen dioxide, sulfur dioxide, carbon monoxide, and lead from vehicle emission using concrete bricks with titanium dioxide. To accomplish that goal, we conducted an experiment wherein a controlled area was set to be the subject field of observation. This controlled area serves as a simulated environment where the test equipment was installed in order to collect the amount of pollutants existing on the area that source from vehicular emission. The test was divided into two cases to represent initial and final testing; initial test, where the polluted controlled area underwent an air test to obtain the baseline data; and final test, which comprises three trials, where the polluted controlled area including bricks with TiO_2 underwent an air test to obtain the resulting data.

Results indicated significant reductions in NO_2, SO_2, and CO pollutant levels but show no difference in Pb implying that TiO_2 has acquired no successive effect on it. The efficacy of TiO_2 on the first two gases has no equal effectiveness in terms of accrued values in each of them.

Just to have an overview about the effectiveness and durability of bricks with TiO_2 and to have an overview with reaction of normal bricks in a controlled environment a secondary test was then conducted.

The researchers have attained the goal of developing an alternative construction material that would help reduce common pollutants from vehicle emission through the application of TiO_2 on bricks.

V. Conclusion

The researchers have investigated the effectiveness of concrete bricks with titanium dioxide in reducing the given parameters: carbon monoxide (CO), lead (Pb), nitrogen dioxide (NO_2), and sulfur dioxide (SO_2). Through experimentation and interpretation of data gathered from the laboratory, the researchers concluded that the average reduction on carbon dioxide is 77.83 percent and on nitrogen dioxide is 40.48 percent. An average of 81.43 percent is known to be the reduction on sulfur dioxide (SO_2). Since the customized bricks created by the researchers were able to cause a relatively great reduction on NOx, SOx and CO, it may be of great help towards the environment and community.

Since the researchers were the first to conduct a study on the effect of titanium dioxide on lead, it is found that there is no recorded reduction based on the laboratory report.

VI. Recommendation

The following recommendations are offered as possible ways to improve this study.

- Since the parameters that have been set by the researchers are common air pollutants emitted by vehicles, future researchers may set different parameters which they can also investigate through experimentation regarding the effectiveness of Titanium Dioxide on decomposing harmful gases.
- The researchers have used a controlled area wherein the specifications are stated in Chapter 3 of this study. Future researches can innovate ways that can show a more precise test with regards to the effectiveness of TiO_2 in ambient air condition.
- Future researchers may use other ratios regarding TiO2 and cement to determine if the percent reduction in the pollutants and compressive strength of bricks will be different than that of 70-30 ratio basis.
- Since the current researchers mainly focuses on the reduction of common air pollutants from vehicle emission using concrete bricks with titanium dioxide, Future researchers may conduct additional sampling points with regards to testing the efficiency of normal concrete bricks in reducing air pollutants.

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