Evaluation of Strontium Aluminate in Traffic Paint Pavement Markings for Rural and Unilluminated Roads

Riches BACERO a, Dexter TO b, Jansen Paul ARISTA c, Marc Kevin DELA CRUZ d, John Paul VILLANEVA e Francis Aldrine UY f

School of Civil Environmental and Geological Engineering, Mapúa Institute of Technology, Muralla St. Intramuros Manila, Philippines

E-mail: sehcir802002@yahoo.com
E-mail: to_dexter@yahoo.com
E-mail: faauy@yahoo.com.ph

Abstract: The researchers introduced different quantities of strontium aluminate to traffic paint to achieve phosphorescence. Factors to consider for this study are charging time, lux received, luminance emitted, amount of SrAl2O4:Eu added and its effects through abrasion. It was found out that the luminance emitted vs time follows a power

\[ f(x) = ax^n \]

where x is in minutes. There are positive trends when relating lux emitted with charging time with percent strontium aluminate added with millimeters of paint removed.

Keywords: Transportation Engineering, Material Testing, Pavement Marking

1. INTRODUCTION

Strontium Aluminate, a chemical substance commonly doped with Europium, Dysprosium or any dopant (Ropp, 2013), is generally known as glow-in-the-dark powder and is frequently observed on escape path markers, glow-in-the-dark toys and other applications which often operate in the absence of light. As such, it is possible to incorporate this compound to other materials that would benefit from the partial illumination for the material to be noticed at night (Haranath, et al., 2003).

Visibility is one of the most important aspects of transportation and transportation safety (Garber and Hoel, 2009). Inadequate roadway visibility can often result to mishaps and could potentially cause fatalities (CIE, 2007). To reduce the incidence of these events; reflectorized markings, barriers and lightings and other traffic devices are installed on roadways in order to increase roadway visibility especially at night (Bindra, 1977) (Fajardo, 1993). Sometimes, the presences of these safety features are inadequate and unfortunately it is ignored in some places or worse, there is no presence of these safety features at all (DPWH, 2012).

Reflective/ reflectorized roadway markings on the other hand are only visible when light from an approaching source or vehicle is present and could only be noticed at a limited distance. This is often overlooked by the observer especially on empty roads and provincial highways or at high vehicle speed. Some roadways on the outskirts of Metro Manila, especially for those far from urbanization, have minimal safety features installed. (e.g. poor roadway lighting conditions, inadequate lane divisions between opposing traffic lanes and difficulty in the geometry of the roadway from the horizon due to alignment and terrain). Thus, causing decreased roadway visibility, this in turn impairs the road user’s ability to drive comfortably and conveniently.

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1.1 Statement of the Problem

This study aims to find an alternative and economically viable solution to mitigate traffic accidents by means of enhancing the driver’s characteristics through glow in the dark traffic markings as another choice for delineation of the roadway.

1.2 Objectives

To be able to evaluate the luminescent paint from adding Strontium Aluminate of different ratio to commercially available reflectorized traffic paint that conforms to local standards (if any) for road applications. It specifically aims:

1. To determine the relationships of ratio of strontium aluminate added to paint to luminance
2. To measure the luminance of constant ratio of paint to strontium aluminate with varying charging time
3. To test the performance of the created glow in the dark paint on a controlled environment simulating rainy season and wear
4. To study the viability of the created glow in the dark paint using cost analysis

1.3 Significance of Study

This study can provide insights about the utilization of luminescent pavement markings as an alternative in order to reduce traffic accidents caused by insufficient roadway delineation and roadway visibility. This study can also provide expanded tools to engineers and professionals alike wherein traditional approach to roadway safety is either costly due to lack of access to electricity, manpower and other necessities that would incur additional costs or due to impracticality.

1.4 Scope and Delimitation

This study covers from the feasibility of developing an alternative method of illuminating the roadway through phosphorescent pavement markings up to the conclusion of equations of strontium aluminate to the traffic paint with respect to cost and luminance and its possible integration with roadway lighting using cost benefit analysis during rainy season only. All experiments were conducted in a controlled environment

This study only covered the phosphorescent property specifically luminance and didn’t cover the other physical (eg. Mechanoluminesce, emission spectrum, spectroscopic composition, etc), chemical property and other characteristics of Strontium Aluminate and when mixed with paint.

Retroreflection (mcd/m²/lux) and the range of the visibility range of the Strontium Aluminate mixed paint was not measured in this study. Also, risk assessment, safety audit and other tools that evaluated the hazard or safety of the road was not covered in this study. Lastly, traffic psychology and behavior of road user in response to the glow in the dark markings were not part of the study. The effects of the phosphorescent paint to other creatures were also not studied in this study.

Other factors affecting the luminance emitted were not measured due to its difficulty in quantifying the data and lack of resources. Some of which are the brightness of the illuminant,
wavelength or the emission spectra of the source (since D65 illuminant is the closest illuminant simulating sunlight and the researchers were not able to find the definition of the illuminant from organizations like Commission Internationale L’eclirge (CIE), lastly other external effects affecting the sample in a controlled environment like minute amount of light coming from the digital camera, laptop and other equipment were not measure which directly affects the relative luminance of the sample.

Lastly this study focuses the application of the said chemical to cold applied traffic paint only specifically for roadway use only. Its other potential uses were not further discussed and evaluated.

2. METHODOLOGY

![Analytical Framework Diagram]

Figure 2.1 Analytical Framework

2.1 Quantitative Analysis

All tests under this section shall be measured by illuminance in addition to other desired test required in this section. Illuminance is measured with respect to time to observe the decay of the observed element or to measure the intensity of light with respect to the surface of the material.

Sunlight is measured from the lux meter throughout the month of September to October during the monsoon season. Light source emitted an hour before dark is assumed crucial since it charges the strontium aluminate mixed paint. In this test, the researchers obtained the average illuminance from 5pm-6pm from previous testing and replicate the conditions in a controlled environment and compare the illuminance emitted. Depending on the amount of lighting present during the day, the amount absorbed by the glow in the dark traffic paint depended on the illuminance present throughout the entire day. This part of the testing
gathered average illuminance on an overcast condition.

The light source is one of the factors that affect the glow of the chemical. The higher the illuminance of the light source, the higher the light it emits. In this case, the researchers used fluorescent light as their main light source for other tests. The researchers gathered the illuminance emitted by the fluorescent light bulb on to the panel which is divided into thirty samples per panel per testing and record it for other correlation.

All items in this section shall evaluate the performance of mixed strontium aluminate to paint with respect to (a.) luminance emitted vs time and (b.) its durability compared to the controlled sample.

To measure luminance, the researchers used a Digital Single Lens Refraction (DSLR) camera, an adopted method by Hiscocks (2011) instead of a luminance meter since the availability of resources is limited.

\[ N_d = K_c \left( \frac{t \cdot S}{f_s^2} \right) L_s \]  

where the quantities are:

- \( N_d \): Digital number (value) of the pixel in the image (through the aid of an image sensing software)
- \( K_c \): Calibration constant for the camera
- \( t \): Exposure time, seconds
- \( f_s \): Aperture number (f-stop)
- \( S \): ISO Sensitivity of the film
- \( L_s \): Luminance of the scene, candela/meter²

The luminance of created sample varies to the amount of strontium aluminate with certain proportionality. In this test, the researchers determine the amount of strontium aluminate needed to conform to the user’s preference by adding a respective percent weight of 15%, 30%, 45%, 60% and 75% per liter of paint.

The amount of light emitted by the mixed chemical and paint depends on the time exposed on the light source. Upon doing this test, the researchers may establish the relationship of luminance emitted with respect to charging time. Standard illuminant D65 was used as specified by CIE or fluorescent light bulbs.

Pavement markings are prone to destruction from daily wear. In this test, the created sample is tested into a reciprocating machine or any available test that creates abrasion. The results of this test determined the theoretical average life span of the sample in comparison to the ordinary traffic paint.

The sample is exposed into a modified drill bit with sand paper attached to the drill. Samples are classified into percent strontium aluminate namely 0% (control), 15%, 30%, 45%, 60% and 75% mix. The purpose of this test is to determine whether the mixture of strontium aluminate with paint significantly impair the performance of the mixed paint on the road. The lifespan also depends on the weather condition. Five samples are created for each of the two following weather condition. One for dry and the other is for simulation for moist or wet conditions.

2.2 Qualitative Research

The researchers interviewed a professional from (Department of Public Works and Highways) DPWH particularly in Bureau of Construction, Planning or Quality and Safety with knowledge regarding about pavement markings, highway lighting, estimation and construction. This was also be the basis for cost estimation to be computed for costs analysis.
of the pavement markings.

Using the data gathered through interview and other tests, the researchers can apply the cost obtained in the preliminary and long term cost of each percentage of ratios of the two materials versus the initial and long term costs of highway lightings and its maintenance using cost analysis.

After evaluating the cost analysis of the product, the researchers then focus in integration of this technology to highway lighting and observe the optimum amount needed for each and evaluate the long term effects.

2.3 Data Collection

The researchers determined the relationship of strontium aluminate with respect to time charged, the amount of strontium aluminate to be added with respect to the amount of paint and the illuminance received by the sample. The created standard sample shall be tested in accordance to ASTM and/or AASHTO specifications if applicable. Tested material for a variable without standard procedure shall be based on equipment and practicality. If not, then researchers adapted a specific type of tests that would measure the desired variable. A control sample of the same material shall also be tested to see if any significant changes in the quality of the material are noticed.

The researchers then compare the additional costs incurred when adding the chemical and weight if the cost incurred is small compared to the original material used for delineation. The samples was tested by first measuring luminance by using a Digital Single Lens Refraction (DSLR) camera, an adopted method by Hiscocks (2011) instead of a luminance meter since the availability of resources used is limited. The sample is measured for a 1.5-2 hour duration, as much as possible without any external light source present, after exposing the sample to a standard light source that emits the same illuminance as the broad daylight, in this case, the standard light source is D65 based from CIE (since there is a vague description of a D65 illuminant, the researchers used a fluorescent light bulb instead since it is readily available). The sample was exposed for 15 minutes, 30 minutes, and 1 hour. The sample was also tested for different ratio of Strontium Aluminate with amount of paint. Lastly for luminescence, lighting source was also different by measuring and plotting the illuminance from 6am to 6pm or until daylight is observed and these lighting sources was also used to test whether the amount of absorbed light is significant to the amount emitted by the mixed paint of different ratio.

For performance, the mixed paint was subjected to different impairment like abrasion to determine changes present whether the wear is accelerated or decelerated. Aside from these tests, samples shall be exposed in simulated weather conditions eg. Dry and wet/moist conditions though controlled environment while abrasion testing.

Variables to be measured:

1. Illuminance vs time
   1.1. vs percent of strontium aluminate added
   1.2. vs charging time
   1.3. vs intensity of light source

2. Paint thickness before and after wear testing
   2.1 On dry conditions
   2.2 On humid/wet conditions
2.4 Creation of Samples

This section discusses the procedures in creating the samples needed for luminance measurement and which was used on abrasion testing.

For batching of strontium aluminate to paint, a 500ml container was used for the container of traffic paint and 0, 75, 150, 225, 300 and 375 grams of strontium aluminate were used in each of the six respective containers which correspond to 0%, 15%, 30%, 45%, 60% and 75%. Six identical illustration boards were used for the application of traffic paint with strontium aluminate and paint. The respective mixture is then applied to the each of the individual 1/8 illustration boards and were left to dry. The illustration boards were then divided (marked) into five identical columns along the length and six identical rows with spacing from that of the columns to create a grid with unmarked leftovers at the bottom.

3. ANALYSIS AND FINDINGS

3.1 Quantitative Research

The tables shown below are the collected data for illuminance at various locations using a lux meter. The data collected shows the illuminance for the month of September to the early October. Data was unavailable on other dates either because of the researchers’ schedule or because of the inclement weather.

<table>
<thead>
<tr>
<th>Date</th>
<th>Time</th>
<th>5:00</th>
<th>5:10</th>
<th>5:20</th>
<th>5:30</th>
<th>5:40</th>
<th>5:50</th>
<th>6:00</th>
<th>Weather</th>
</tr>
</thead>
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<td>562</td>
<td>327</td>
<td>217</td>
<td>107</td>
<td>59</td>
<td></td>
<td></td>
<td>Overcast</td>
</tr>
<tr>
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<td>5040</td>
<td>3730</td>
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<td>2259</td>
<td>1234</td>
<td>625</td>
<td>235</td>
<td>Sunny</td>
</tr>
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<td>3300</td>
<td>2670</td>
<td>2070</td>
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<td>498</td>
<td>95</td>
<td>Overcast</td>
</tr>
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<td>22100</td>
<td>4760</td>
<td>4830</td>
<td>2450</td>
<td>870</td>
<td>350</td>
<td>Sunny</td>
</tr>
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<td>5:00</td>
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<td>702</td>
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<td>1125</td>
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<td>19000</td>
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<td>1145</td>
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</tr>
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<td>2750</td>
<td>2310</td>
<td>574</td>
<td>265</td>
<td>41</td>
<td>14</td>
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</tr>
<tr>
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<td>11</td>
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<td>1401</td>
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<td>738</td>
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</tr>
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<td>1802</td>
<td>309</td>
<td>192</td>
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<td>5:00</td>
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<td>632</td>
<td>531</td>
<td>280</td>
<td>113</td>
<td>9</td>
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<td>2150</td>
<td>980</td>
<td>320</td>
<td>130</td>
<td>30</td>
<td>6</td>
<td>Sunny</td>
</tr>
<tr>
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<td>565</td>
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<td>252</td>
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<td>22</td>
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<td>3</td>
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<td>11</td>
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<td>192</td>
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<td>22</td>
<td>2</td>
<td>Overcast</td>
</tr>
</tbody>
</table>
As predicted, the decay of sunlight from 5:00-6:00pm was logarithmic. Maximum illuminance obtained at the start of the experiment was 32,800 lux which was during sunny weather. From the data, whether sunny or overcasts, the illuminance received by the paint significantly decrease as time progresses. From what the researchers experienced, the strontium aluminate mixed paint’s emitted light is noticeably visible if the environment is darker compared to the paint itself. For most of the data obtained, the illuminance emitted by the sun dropped below 1000 before 5:20 which in turns starts to make the glow in the dark traffic paint glow.
The data were obtained during the exposure of the samples before turning off the lights. Illuminance measurement was divided into thirty panels with a corresponding measurement. The researchers did two different ranges for each of the 15, 30 and 60 minutes charging time (a) which ranges from 700-1000 lux and (b) which ranges from 1500-4000 lux. These data would be used for correlation of illuminance received per panel and per sample versus the total luminance emitted.

Shown in the proceeding tables in appendix B are the data collected from luminance testing with the different variables measured and processed. These testing are namely: 15 mins charging time (a and b), 30 mins charging time (a and b) and 60 mins charging time (a and b). The table following each and every testing would be the computed luminance and lastly the graph of its luminance (cd/m^2) produced vs time (mins). The table after the graph of luminance vs time is a summary of individual curve fitted data, its corresponding area when integrated throughout the entire 720 hours of decay and its average luminance emitted. The graph after that table is the average luminance produced versus time to check the trends produced by the experiment. The graphs are curve fitted and was used to graph the equation of the scatterplots obtained throughout the experiment. The nature of the equations obtained would be explained in the succeeding page.

Figure 3.4 (shown below) is a sample output out of the thirty other same formats. Each curve represents the individual square analyzed from the thirty divisions of one illustration board with fixed percent strontium aluminate of constant exposure time and light intensity. This was obtained through curve fitting using power function which would be further explained in the later on how the researchers arrived at that tool used.

The table below (joined to create figure 3.4) is the corresponding equation obtained from the individual trend. This equation would be integrated (through the use of approximation) limits from 0.01 up to 720 minutes to determine the total output and was averaged by dividing the total output with the time elapsed (dx or dt).

![Figure 3.4 Sample output of the luminance measurement](image)

When the samples were analyzed and plotted per testing, the average luminance produced versus the illuminance exposed exhibit some inconsistent results. Nineteen out of thirty tests of luminance exhibit a positive trend which is the hypothesis while eleven out of the thirty exhibits a downward trend when relating luminance produced versus the illuminance used. These observations suggest that the luminance emitted is not solemnly based on the illuminance of the
environment. There are also other factors that were not measured during the test like brightness of the illuminant, the wavelength or the emission spectra of the source and other external effects.

Due to the methodology implemented by the researchers, the conditions (e.g. same camera settings, exposure time, environment and weather conditions) the tests were grouped per <n-minutes of charging time (trial)>. The researchers also collated and plotted the same data in a single graph per test (from 15% to 75% strontium aluminate).

Figure 3.5 Average luminance vs lux used (15 minutes charging time (a))

Figure 3.6 Average luminance vs lux used (15 minutes charging time (b))

Figure 3.7 Average luminance vs lux used (30 minutes charging time (a))
Conversely, when the data were group together per charging time, all exhibit a downward trend. These data are invalid since the analysis of the average luminance produced vs lux is meant to be analyzed per illustration board (per percent strontium aluminate) because when all of the data were grouped together per charging time in a single graph, there is little or no difference in the ordinates observed.

Another thing that is inappropriate for data use is when grouping all the data obtained from the tests for average luminance vs lux received since all have different camera settings which cause different varieties of average luminance produced. The graph below shows just that. (Red- 15 minutes, green- 30 minutes and blue- 60 minutes)
Figure 3.11 Average luminance vs lux used (15, 30 and 60 minutes charging time (a & b))

However, taking the average of the luminance produced throughout its entire 12 hour period and graphing it versus the average lux received per panel, the results were positive trend but there is weak correlation between the two. All data below are now averaged per panel whether lux received or total luminance emitted.

Table 3.2 Average lux received, total luminance emitted per panel, percent strontium aluminate added and charging time

<table>
<thead>
<tr>
<th>% SrAl2O4</th>
<th>lux received</th>
<th>total luminance</th>
<th>lux received</th>
<th>total luminance</th>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>1139.133</td>
<td>4.938023054</td>
<td>1512.433</td>
<td>365.9473214</td>
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<tr>
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<td>30 mins</td>
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<td></td>
<td></td>
</tr>
<tr>
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</tr>
</tbody>
</table>
Figure 3.12 Averaged total luminance emitted vs averaged total illuminance received

Figure 3.13 Averaged total luminance emitted vs percent strontium aluminate added (showing the trend of the observed data)

Figure 3.14 Averaged total luminance emitted vs percent strontium aluminate added (showing the trend of the individual data and its correlation)
Both graphs show a positive trend when comparing the average illuminance received versus the corresponding average total luminance produced. From that, the researchers can say that for every lux added to charge the mixed traffic paint, the total output/luminance emitted by the paint doubled.

The same case goes with the average total luminance produced versus the percent strontium aluminate added. As expected, for every percent of strontium aluminate added to the mixed traffic paint, the total output/luminance emitted by the paint increased almost twenty two folds.

Lastly, when data were grouped to corresponding charging time (15 mins – red, 30 minutes – green and 60 minutes – blue), the sixty minutes charging time has the largest impact with regards to the utilization of charging time versus percent strontium aluminate.

As stated earlier, the individual trend for the luminance emitted vs time follows a power function of the form $f(x) = ax^n$ where $x$ is in minutes. This was strongly shown in the data provided to us by the manufacturer of the strontium aluminate. Attached below is the data acquired from the company for its luminance testing. Using scatter plot and a trendline, the comparison of exponential $f(x) = ae^{nx}$ and power $f(x) = ax^n$ function was clearly observed.

Figure 3.15 Averaged total luminance emitted vs percent strontium aluminate added (showing the trend of the grouped data by charging time and its correlation)

Figure 3.16 Graph provided by the manufacturer
Figure 3.17 Luminance data provided by the manufacturer

Figure 3.18 Graph of the data provided with comparison of the two trendlines

Abrasional Testing

Figure 3.19 Millimeters of paint removed vs Percent Strontium Aluminate (Dry and Wet)
After subjecting the paint to wear by modifying a drill bit and attaching removable adhesive sandpaper then grinding the sample for five seconds, half of which are dry and half of which are poured with water, the researchers came up with the results. The researchers found out that after subtracting the final thickness from the illustration board thickness, some exhibit negative values which are shown in red which totally removes the paint from the surface. To correct this problem, they have set the abraded thickness of paint as the maximum since the illustration board has a different rate of degradation compared to paint. This correction was shown on the next table, after which it is then plotted versus the percent strontium aluminate in dry and wet, dry and wet conditions.

3.2 Qualitative Analysis

The researchers interviewed two government professionals. One from Department of Public Works and Highways National Capital Region office and the other person was from the Main Office. During the 1980s, a new material was introduced to the public works for the purpose of application of the traffic markings. It was famously known as Starmark or the taperoll. This material was three times costlier than the other material used. It has a lifespan of 5-7 years compared to thermoplastic which lasts for 2-3 years. On the other hand cold applied traffic paint...
only lasted for 2-3 months and also needs to be painted on certain weather conditions. If the weather is unfavorable (e.g. rainy), then the paint theoretically lasts only for a few months or weeks due to impairments present.

The design for highway lighting and other safety features on the road is based on many factors like the AADT of the road, number of lanes, road capacity, nature of the road, geometric design and other considerations. For those reasons, there is no exact estimate for the lighting and safety features of the road. Lighting is a very important aspect of road safety, it compliments other safety features like cat’s eye, chevron markings, or any other additional safety appurtenances provided in the design. Depending on the specifications, the Bureau of Design, Highway Division would be in charge for those concerns. Also the cost for designing such features is calculated through bidding and project based. Cost may also depend on the supplier if it is the sole distributor of the product. If the lifespan of the strontium aluminate mixed traffic markings is one year, then this would be a game changer for the roads in the country. – Engr. Carolyn A. Leyesa (Engr. V, Bureau of Quality and Safety, DPWH Main Office)

On the other hand, the cost estimate for highway lighting depends on the man days or the number of people required to install a post, design provided, the width of the road, size of wire and conduits, height of the lamp post, wattage and specification of luminaires and depending on the design of the road. The reason for not installing roadway lightings are that first, no one assumes the responsibility for the power consumption; lastly the road is either provincial or local in which jurisdiction of the public works is focused on national roads. It is the prerogative of the local government to install such safety features. The estimate for labor is computed by 10-15% of fabricated materials, 20% for electrical devices and wires and 30-35% for conduits. The computation for other expenses like logistics is not considered in the costs. – Engr. Sigfredo Revesencio (Engr. II, Planning and Design Division, DPWH National Capital Region)

3. 3 Costs Analysis

* Using the exchange rate of 1$=45php

** Unit price based from
IMPROVEMENT/REHABILITATION OF
PAYATAS ROAD
(INTERRMITTENT SECTIONS) QUEZON
CITY, K0022+ (-721) - K0022 + (-121); +
066- K0027 + 556, (SO5179LZ)(CONTRACT ID
NO. 14O00001)

*** Assuming the mixture lasts for 2-3 months

<table>
<thead>
<tr>
<th>Cost Item</th>
<th>Unit Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>Customs</td>
<td>P 1337</td>
</tr>
<tr>
<td>Shipping</td>
<td>$115 or P 5175</td>
</tr>
<tr>
<td>Strontium Aluminate</td>
<td>$150 or P 6750</td>
</tr>
</tbody>
</table>

Total of 2652.4 php per kg of strontium aluminate

a. Comparison of material cost over 3 years

- ReflectORIZED Thermoplastic Pavement Markings (White) P 962.15 per sq.m
- Traffic Paint Mixed with Strontium Aluminate at 30% mixture P 127.32 per sq.m
Cost Incurred after 3 years
Thermoplastic – P\textcurrency 962.15 to P\textcurrency 1279.66 per sq.m
Traffic Paint – P\textcurrency 1527.78 to P\textcurrency 2291.67 per sq.m**

From the cost analysis, the cost of installing traffic paint is 1.59 to 1.80 times more expensive compared to thermoplastic paint and more hassle to reapply but due to the repetitive installation of the paint, the glow in the absence of light would be well maintained. The installation should be easier since it has a low initial cost.

b. Comparison with the total cost of a construction project **

<table>
<thead>
<tr>
<th>ITEM NO.</th>
<th>DESCRIPTION</th>
<th>UNIT</th>
<th>QTY.</th>
<th>UNIT COST</th>
<th>TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>I ROADS (Sta. 21+340 to 21+940)</td>
<td>Removal of Existing Concrete Pavement</td>
<td>sq.m.</td>
<td>6,777.00</td>
<td>139.21</td>
<td>P\textcurrency 943,426.17</td>
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<tr>
<td></td>
<td>Removal of Existing Asphalt Pavement</td>
<td>sq.m.</td>
<td>6,777.00</td>
<td>185.61</td>
<td>P\textcurrency 661,028.58</td>
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<td></td>
<td>Roadway Excavation (Common)</td>
<td>cu.m.</td>
<td>2,478.00</td>
<td>22.73</td>
<td>P\textcurrency 55,041.21</td>
</tr>
<tr>
<td></td>
<td>Subgrade Preparation (Common)</td>
<td>sq.m.</td>
<td>6,777.00</td>
<td>903.44</td>
<td>P\textcurrency 61,041.21</td>
</tr>
<tr>
<td></td>
<td>Cement Treated Base Course (CTB)</td>
<td>cu.m.</td>
<td>2,072.00</td>
<td>1,850.04</td>
<td>P\textcurrency 3,776.08</td>
</tr>
<tr>
<td></td>
<td>PCC Pavement, (t=360mm, 7 days – 3500psi)</td>
<td>sq.m.</td>
<td>6,777.00</td>
<td>2,054.04</td>
<td>P\textcurrency 13,920,229.08</td>
</tr>
<tr>
<td></td>
<td>ReflectORIZED Thermoplastic Pavement Markings (White)</td>
<td>sq.m.</td>
<td>232.00</td>
<td>962.15</td>
<td>P\textcurrency 223,218.80</td>
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<tr>
<td>II ROADS (Sta. 27+066 to 27+556)</td>
<td>Removal of Existing Concrete Pavement</td>
<td>sq.m.</td>
<td>3,430.00</td>
<td>139.21</td>
<td>P\textcurrency 477,490.30</td>
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<tr>
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<td>Removal of Existing Asphalt Pavement</td>
<td>cu.m.</td>
<td>1,917.00</td>
<td>185.61</td>
<td>P\textcurrency 355,814.37</td>
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<td>Roadway Excavation (Common)</td>
<td>sq.m.</td>
<td>3,430.00</td>
<td>22.73</td>
<td>P\textcurrency 77,963.90</td>
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<tr>
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<td>Subgrade Preparation (Common)</td>
<td>sq.m.</td>
<td>162.00</td>
<td>903.44</td>
<td>P\textcurrency 146,357.28</td>
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<td>Cement treated Base Course (CTB)</td>
<td>cu.m.</td>
<td>1,029.00</td>
<td>1,981.12</td>
<td>P\textcurrency 2,038,572.48</td>
</tr>
<tr>
<td></td>
<td>PCC Pavement, (t=360mm, 7 days – 3500psi)</td>
<td>Sq.m.</td>
<td>3,430.00</td>
<td>2,054.04</td>
<td>P\textcurrency 7,035,616.00</td>
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<td></td>
<td>Concrete Curb &amp; Gutter</td>
<td>l.m.</td>
<td>980.00</td>
<td>752.87</td>
<td>P\textcurrency 737,812.60</td>
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<tr>
<td></td>
<td>Concrete Sidewalk</td>
<td>Sq.m.</td>
<td>980.00</td>
<td>643.96</td>
<td>P\textcurrency 631,080.80</td>
</tr>
<tr>
<td></td>
<td>ReflectORIZED Thermoplastic Pavement Markings (White)</td>
<td>Sq.m.</td>
<td>172.00</td>
<td>962.15</td>
<td>P\textcurrency 165,489.80</td>
</tr>
<tr>
<td>III OTHER GENERAL REQUIREMENTS</td>
<td>Provision of Field Office</td>
<td>Mo.</td>
<td>10.00</td>
<td>27,574.75</td>
<td>P\textcurrency 275,747.50</td>
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<td></td>
<td>Construction Safety &amp; Health</td>
<td>l.s.</td>
<td>1.00</td>
<td>233,766.95</td>
<td>P\textcurrency 233,766.95</td>
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<tr>
<td></td>
<td>Traffic Management</td>
<td>l.s.</td>
<td>1.00</td>
<td>466,997.90</td>
<td>P\textcurrency 466,997.90</td>
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<tr>
<td></td>
<td>DPWH Project Billboard</td>
<td>Pc.</td>
<td>4.00</td>
<td>7,005.00</td>
<td>P\textcurrency 28,020.00</td>
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<tr>
<td></td>
<td>Mobilization/Demobilization</td>
<td>l.s.</td>
<td>1.00</td>
<td>509,634.63</td>
<td>P\textcurrency 509,634.63</td>
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<tr>
<td></td>
<td>COA Billboard</td>
<td>Pc.</td>
<td>2.00</td>
<td>7,005.00</td>
<td>P\textcurrency 14,010.00</td>
</tr>
<tr>
<td>TOTAL</td>
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<td>- - -</td>
<td>- - -</td>
<td>- - -</td>
<td>P\textcurrency 33,661,140.57</td>
</tr>
</tbody>
</table>
Taking an example from a government project, the costs of installing thermoplastic pavement markings takes up about 1.15% of the whole project. Replacing this with an initial installation of glow in the dark traffic marking, it reduces the costs to 51,437.28 PhP from its original 388,708.6 PhP. Funding the whole reinstallment of the paint would cost anywhere from P 617,223.12 to P 925,834.68 which consumes about 1.82% - 2.71% of the total budget.

If this 0.67% - 1.56% increase in total costs is acceptable to the implementing agency, then the pavement marking would be instead of being reflectorized will now be luminescent (provided proper maintenance is implemented) which would further extend the driver’s vision on the horizon.

4. CONCLUSION

With the data processed, the entire graph (figure 3.14) shows a positive trend when relating the average luminance produced throughout the 720 minutes span versus the amount of strontium aluminate added. The data proves that adding more strontium aluminate to traffic paint increases its phosphorescent property thus its luminance output.

When segregated by varying charging time, (figure 3.15) (15 mins - red, 30 minutes - green and 60 minutes - blue), still all of the three exhibit a positive trend when comparing total luminance produced against the percentage of strontium aluminate. The slope of the trendline increases as charging time increases. The sixty minutes charging time has the steepest slope with regards to the utilization of charging time versus percent strontium aluminate. Performance evaluation of the created glow in the dark paint on a controlled environment classifies into two tests: dry and wet. Both simulate wear and the second rainy season (partially). In general, for every percent of strontium aluminate added to the mix, an additional 0.0004 millimeters of paint might be removed (figure 3.19). Since these changes are small, subjecting the paint to wet weather have no impact on the decrease on its thickness if the paint was applied properly.

From the interview, highway lighting and roadway safety goes hand in hand. The usage of roadway lighting is still one of the most effective methods to prevent roadway accidents. Integration of other safety features of a road is also part of the highway design. The integration of the mixed strontium aluminate and paint to the highway system together with the lightings seems ineffective as observed by the researchers since both emit light that produced silhouette, and it is obvious which one is more beneficial. This mixture works best when there are absolutely no lighting present at night since this only produces small amount of luminance. Nonetheless, this might have the potential to still save lives when worked properly.

5. RECOMMENDATION

If the lifespan of this mixture could lasts for more than or equal to a year, then this would be a big contribution to the roadway safety. The Bureau of Research Standards continues to innovate new or better materials in the field of civil engineering. With this advancement in research, this study has the prospect to be further improved, later might be adopted by the government.

The researchers recommend to further study the capabilities of Strontium Aluminate in terms of amount and luminance produced. As recommend by some of the researchers’ professor, partnering with other courses like chemical engineer, chemist and material science
engineer can improve the lifespan, luminance, and other performance aspects of the paint like its resistance to summer season and extreme heat. Cost of acquiring the material and the logistics associated with the strontium aluminate can also be studied to analyze the effects of long distance traveled with the cost of building the road and paint using Von Thunen’s model or any other models used for logistics.

6. REFERENCES

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