Utilization of Plastic-Coated Aggregates for a Proposed Green Road

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Abstract – **The University of Mindanao, Matina Campus plans to add a bypass road connecting the motor pool area to the Maa entrance gate to transport goods and materials efficiently. In seeking for greener approach, the study was brought to designing a pavement using plastic waste to cover its aggregates for bitumen mix. Several tests were performed, such as AASHTO T85-91, AASHTO T852 or ASTM D570-98, and AASHTO T-96 or ASTM D4060 - 19 at the University of Mindanao Civil Engineering Laboratory. The laboratory results show that plastic-coated aggregates passed the AASHTO standards. Thus, this innovation effectively constructs adequate roads and reduces plastic waste.**

***Index Terms*— green road, plastic-coated aggregates**

I. Introduction

For 73 years, The University of Mindanao has provided its students with a dynamic and supportive academic environment by adhering to a quality management system. The school has a high-standard facility; one of its leading facilities that help maintain the grounds is the Facilities Development and Maintenance Division. Still, since the main entrance was transferred to Maa Gate in the past years, the division has experienced delivery concerns that hinder its ability to function well. This division is far from its main entrance in the motor pool area. Due to this, delivery trucks cause disturbance to the students and sometimes experience delays since the University only has one road for the students, employees, and delivery trucks. The University has long been planning to improve its facility by adding a bypass road connecting the motor pool area to the main entrance. Due to this, the researchers are inspired to help the University by designing the bypass road but using conventional materials for the road will not be enough. Since then, the University has always cared for the environment by providing sustainable development to its facilities. Thus the researchers will design a "GREEN ROAD," which uses plastic waste to cover its aggregates for bitumen mix.

Waste plastics, both by domestic and industrial sectors, can be used in the production of asphalt mix. Waste plastics, mainly used for packing, are made of polyethylene, polypropylene, and polystyrene [1]. On heating at 100-160'C, polyethylene, polypropylene, and polystyrene soften and exhibit good binding properties. Blending it with bitumen results in an appropriate mix for road laying [2] [3]. The use of polyethylene, polypropylene, and polystyrene for coating aggregates of the bituminous mix is found to improve the performance of the pavement in terms of abrasion, slip resistance, increased durability, and fatigue life. Bituminous mix with recycled plastics mainly made of low-density polyethylene replacing 30% of 2.36 - 5mm aggregates have shown a 250% increase in marshall stability test [4] [5]. Mix density was reduced to 16%, in addition to improving Indirect Tensile Strength (ITS) [6]. Waste plastics' content plays a significant role in increasing the mixture strength. As plastic content increases up to 10% low-density polyethylene, 10% polypropylene, 25% polystyrene, and 2% high-density polyethylene, the stability increases, and the flow value decreases, which appears to result in longer pavement life [7] [8]. These properties make plastic necessary as an aggregate-enhancing agent to innovate the pavement design mixture.

The objective of the study is to assess the existing roadway condition of Maa gate to the motor pool area of The University of Mindanao, design a bypass road by using plastic-coated aggregates for the pavement mixture, test the newly innovated pavement by using the seven-laboratory test in accordance to AASHTO and ASTM standards, and compare the test results with conventional pavement design mix. Furthermore, this study will prove that using plastic-coated aggregates will make the design more efficient, economical, and sustainable.

This study will benefit the University of Mindanao by giving alternative access for its supply and delivery trucks going to the motor pool area. Also, it will help the environment by using non – biodegradable plastic waste,

reducing the amount of garbage produced annually. Hence, this "GREEN ROAD" will provide a sustainable and innovative solution to the University's problem.

The design will be made specifically for The University of Mindanao. The physical and geometrical properties and Design mixes will be specialized for the proposed road pavement. Thus other uses for this will need further studies. The design asphalt mix will use recycled soft plastics collected by various local government units to coat its aggregates and shall not use newly processed plastics. Laboratory tests will be done in a manner approved by ASTM and AASHTO, and standards made by other associations will be ignored. Test results will be compared with the conventional design mix. Thus other design mixes will not be considered.

II. Materials and Methods

A. Conceptual Framework

This study followed a technical and standard process in designing the bypass road, starting by collecting data for the road design and asphalt mix. Conventional surveying and testing methods were done to get these data. The data was used to design the geometrical properties of the road and the optimum bitumen–plastic content of the mixture. Thus, the conceptual framework in Fig. 1 presents these processes.

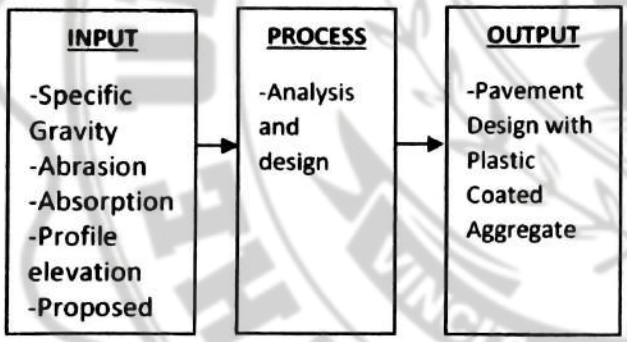

Fig. 1. Conceptual Framework

B. Materials and Resources

In this study, the researchers have used plastic-coated aggregates to enhance the design mixture of the asphalt concrete. Waste plastic will bind with conventional aggregates to make an innovative material that will increase the pavement's performance and extend its life. The innovated aggregates will undergo laboratory tests by AASHTO and ASTM standards [9]. Laboratory testing will follow AASHTO T85-91, AASHTO T852 or ASTM D570-98, and AASHTO T-96 or ASTM D4060 - 19 to determine the specific gravity, absorption, and abrasion capacity of the two different samples [10] [11].

C. Methods and Procedures

This research was broken up into two design stages. First is the road design stage. This stage is mainly concerned with the geometric design of the road. Open Compass Traverse and Profile Levelling were used to get the road's existing horizontal tangents and elevation. These data were plotted in Autodesk Civil 3D. Using this software, the researchers could design the bypass road's proposed profile and horizontal tangents. The proposed road was made in accordance with DPWH Standards and Specifications for Highways, Bridges, and Airports Vol. 1 Series of 2013 [12]. The road's alignment, profile, and cross-section followed the standard guidelines and sound engineering judgment to make it safe, comfortable, and appealing to the eye [13]. The second stage focuses on the creation of innovative pavement material by using plastic-coated aggregates. The innovative material has undergone standard testing to determine its design properties compared to conventional materials.

1. Open Compass Traverse

The location for the proposed road was subjected to open compass traversing to map the existing condition of the site to be road opened. The results were used to design the location and alignment of the proposed pavement.

2. Road Profile Leveling

The existing profile elevation of the location for the proposed road was determined using road profile leveling. The result was used to design the pavement's proposed profile elevation and determine the amount of soil profile to be excavated and filled.

3. Road alignment and elevation design using Autodesk Civil 3D

The data from the survey result was used to design the proposed pavement. Autodesk Civil 3D was used to get the optimum alignment and elevation with the most economical value.

The next stage of the study was the pavement material design stage. This is the experimental part of the study. By binding plastic with the aggregate mixture for asphalt concrete, the researchers created an innovative pavement material that will enhance the physical & ecological impact of the pavement [14]. The aggregate and pavement samples underwent laboratory tests by AASHTO and ASTM standards. The results were compared with conventional materials to check the physical advantages of the innovative material.

4. Physical Properties of Aggregates

Specific gravity, absorption rate, and abrasion loss are three of the most significant properties of aggregates to be used for road construction. Hence, two different aggregates samples were analyzed in this research, passing through a 19 mm diameter sieve.

The first sample is the typical aggregates used in laboratory testing. In contrast, the second one is an aggregate sample manually coated with an acceptable plastic content of 4% [15]. The soft plastic wastes were shredded and sieved using a 4.75 mm sieve. These samples were tested in the

civil engineering laboratory to be able to get the necessary data that is needed to calculate and identify the results.

III. Results and Discussions

The following presents the results and data gathered from the various methods and procedures. Survey data for the road designs were obtained through various survey methods. Road designs were then made through Autodesk Civil 3D. Various ASTM and AISC methods were used to develop the proper design mix.

A. Road Traverse

The existing traverse for the proposed area from Sta. 0+000 to Sta. 0+293.2 are unsuitable for highway design, as shown in Fig. 2, and must therefore undergo realignment and road opening.

Fig. 2. Road Traverse Illustration

B. Road Profile

The existing profile for the proposed area is constantly changing from Sta. 0+000 to Sta 0+293.2, as shown in Table 1. Earthworks and sub-grade preparation must be done to attain the proper slope by DPWH provisions and standards.

TABLE I.

Road Profile Data

Station	Difference in Elevation		
	Left	Center	Right
0+000	0	0	0
0+020	-1.52	-1.77	-1.64
0+281.7	-1.39	-1.62	-1.36
0+293.3	-1.92	-1.62	-1.49

C. Highway Design

The proposed design for the road was done through the use of Autodesk Civil 3D. Horizontal and Vertical curves were placed to correct the existing profile and traverse the area to make it suitable for highway design. The pavement design will be subjected to an asphalt overlay using innovative plastic-coated aggregates as an asphalt concrete mixture. A layer of aggregate subbase course will be provided as a foundation for the pavement to ensure stability since the existing soil strata are composed of silt clay. The proposed road is designed in accordance with DPWH Standards and Specifications for Highways, Bridges, and Airports Vol. 1 Series of 2013 with sound engineering and judgment to ensure safety, comfort, and quality [12]. The proposed traverse and cross-section are shown in Fig. 4 and Fig. 5.

Fig. 3. Vicinity Map

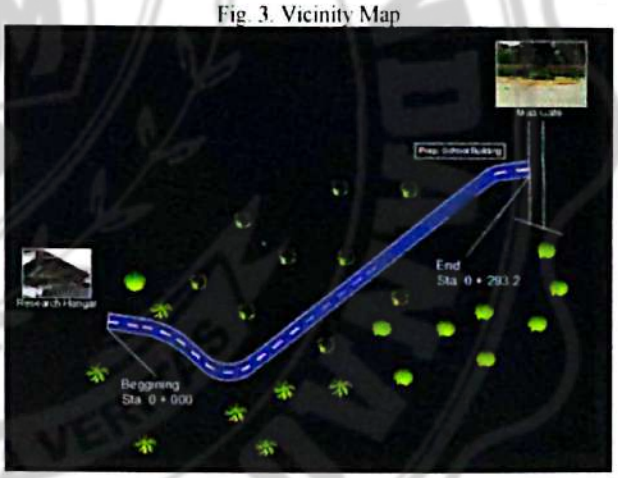

Fig. 4. Highway Design

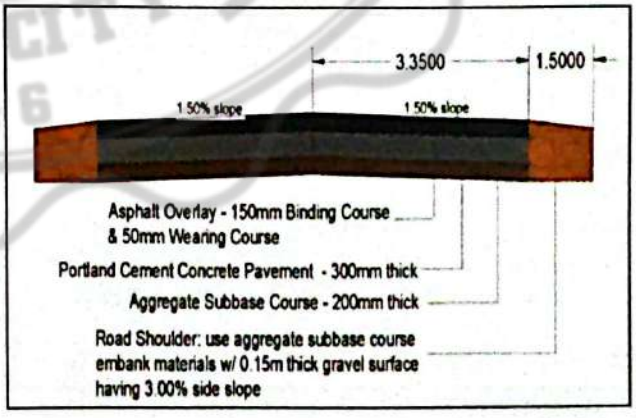

Fig. 5. Typical Highway Cross-Section

D. Physical Properties of Aggregates

a. Specific Gravity Test

Following AASHTO standards, the specific gravity of aggregates used in road construction ranges from 2.5 to 3.0.

Table 2 shows the Specific Gravity test result, indicating that the uncoated aggregates have a specific gravity of 2.53. In contrast, the plastic-coated aggregates have a specific gravity of 2.61. Thus, both of the samples have passed the standard requirements.

TABLE II

SPECIFIC GRAVITY TEST RESULTS

	Uncoated Sample	Coated Sample (4%)
Parameters	**Weight(g)**	**Weight(g)**
Mass of Oven Dry Sample in Air (M_A)	**920**	**941.2**
Mass of SSD Sample in Air (M_B)	**945**	**947.2**
Mass of SSD Sample in Water (M_C)	**581.5**	**585.6**
Specific Gravity	**2.53**	**2.61**

b. Absorption Test

Following AASHTO standards, the absorption rate of aggregates practically used in the construction ranges from 0% to 5%.

Table 3 shows the Abrasion test result, which states that the typical aggregates have an absorption rate of 2.71%. In comparison, the plastic-coated aggregates have an absorption rate of 0.63%. Hence, both of the samples have passed the standard requirements.

TABLE III

ABSORPTION TEST RESULTS

	Uncoated Sample	Coated Sample (4%)
Parameters	**Weight(g)**	**Weight(g)**
Original Weight of Aggregate Sample (W_1)	**1000**	**1000**
Weight of Aggregate Sample Retained (W_2)	**751.95**	**803.72**
Weight Passing 1.7mm IS sieve (W_p)	**248.75**	**216.28**
Abrasion Loss Rate	**25 %**	**29.6 %**

c. Abrasion Test

Following AASHTO standards, the abrasion rate loss typically used in the construction industry ranges from 25% to 55%.

Table 4 below shows the Abrasion test result, indicating that the uncoated aggregates have an abrasion rate of 25%. In comparison, the plastic-coated aggregates have an abrasion rate of 29.6%. Hence, both of the samples have passed the standard requirement.

TABLE IV

ABRASION TEST RESULTS

	Uncoated Sample	Coated Sample (4%)
Parameters	**Weight(g)**	**Weight(g)**
Mass of Oven Dry Sample in Air (M_A)	**920**	**941.2**
Mass of SSD Sample in Air (M_B)	**945**	**947.2**
Absorption Rate	**2.71%**	**0.63%**

IV. CONCLUSION AND FUTURE WORKS

The laboratory test results conclude that the specific gravity, absorption rate, and abrasion loss rate of the plastic-coated aggregates all passed the standard requirement for pavement construction; therefore, this type of material is better for asphalt mix than conventional aggregates in road construction.

Finally, the researchers are looking forward to more studies considering applying plastic-coated aggregates on concrete or masonry. More and more plastics will be used for road construction and hopefully will significantly impact conserving our mother nature.

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