Polyurethane Expanding Foam Application: A Proposed Alternative Solution for Cracks on Local Concrete Roads in The Philippines

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Abstract: - This study examined the use of polyurethane expanding foam as a potential solution for repairing cracks on local concrete roads in the Philippines. The researchers conducted the study in Pangatlan, Mexico, Pampanga, for a period of six weeks. The polyurethane foam was applied in different crack width categories to monitor its performance as a viable repair, observe physical and chemical changes, and assess its adhesiveness. The crack widths are subdivided into three categories: category I (1 to 15 mm), category II (16 to 30 mm), and category III (31 to 45 mm), with three samples per category. The results showed that the foam is applicable for all categories, with widths ranging from 3.60 to 41 mm. Polyurethane foam changed its color due to environmental factors but remained adhered to concrete, with a rough outermost layer, and some areas shrank due to vehicular loads. As a result, this study suggests that polyurethane expanding foam can be used as a temporary solution for repairing local concrete roads in the Philippines wherein urgent repair is needed due to its ability to adhere with the concrete pavement. This study recommends a longer observation period, which could be beneficial for capturing the long-term effects and durability of the polyurethane foam on the concrete pavements.

Key Words: — ***Adhesiveness, Concrete Pavement, Cracks, Polyurethane Expanding Foam.***

I. INTRODUCTION

Transportation is significantly vital in people's daily lives since it makes traveling much easier, provides convenience, and opens up many opportunities. It also feeds the global economy by transporting people and things from one location to another, as they act as the workforce and consumer items. Following the economic principle of supply and demand, this commuting process makes the conveyed entity more productive and valuable than it was in its original location, making it very significant in the national and local economies and its development. To maintain the sustainability and long-term viability of road transportation, it is crucial to emphasize the significance of diverse transportation options and the integration of multiple commuting modes. This is particularly important in a country, like the Philippines, with vast land areas and densely populated urban centers.

In the Philippines, there are two main modes of land transportation which are roads and railways transport. According to Boquet (2013), due to the lack of adequate rail transportation, the country mostly relies on road transportation. In fact, road transport accounts for 98% of passenger traffic and the transportation infrastructure has been developed and spread about 215,000 kilometers of roads in the entire country. The road transport mode includes use of the public and private utility vehicles, buses, motorcycles, and so on.

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According to the Department of Public Works and Highways (DPWH), roads are classified as national roads, provincial roads, city roads, municipal roads, and barangay roads. However, the primary focus of this study will be on barangay roads, also known as local roads. Barangay roads are rural roads located outside of urban areas.

It is indeed that roads are important public assets. Transportation would be extremely difficult and time-consuming without good roads. However, the quality of roads in the country is currently in dire need of improvement.

One of the major issues of the road conditions in the Philippines are road cracks caused by several factors like low quality of workmanship and poor maintenance. Based on the study of Tarawneh & Sarireh (2013), concrete pavement damages and cracks are serious problems of roads and traffic highway sector; the construction of new roads, replacement and rehabilitation, and maintenance can cost hundreds of millions of pesos and can be time-consuming. Furthermore, the increased road unevenness and roughness caused by the existence of cracks make traveling on the road problematic for road users; reduces road safety; increases vehicle wear and tear, which raises vehicle operating costs; and increases travel time, resulting in a loss of useful man-hours to the local economy (Chamia et al., 2017).

Road infrastructure is critical in a community and a country because society relies on it. Barangay roads are essential to the development and the economic growth of its municipality and city. According to the DPWH, they act as feeder or farm-to-market roads, wherein they are being used as a way to transport farm goods to the municipality proper and marketplaces. Proper maintenance, as well as a solution for barangay road problems such as road cracks, are necessary. As a result, the study aims to use the concept of using polyurethane expanding foam to repair cracks in local concrete roads in the Philippines. Polyurethane expanding foam is commonly used for insulation, soundproofing, filling gaps, and sealing cracks in walls and floors, as well as for other applications such as concrete pavement leveling and soil subsurface stabilization.

1.1 Study Area

The researchers conducted the study in the road of Barangay Pangatlan, Mexico, Pampanga. The study area has 1 kilometer of road, which serves as the route for motorists and residents traveling from the neighboring barangays to the municipality proper. The area is also a primary route for students coming from the surrounding barangays since it is close to three schools: two primary schools and one secondary school. The chosen location is also known as a roadway for farmers and tractors since the area is surrounded by rice and corn farms, as well as truck drivers because it is close to warehouses and quarries. The area is susceptible to heavy traffic of highly loaded trucks, especially during peak working hours and harvest season. According to Municipal Ordinance No. 002 of Mexico, Pampanga, all trucks, whether private or public trucks, are only banned from passing through the Gapan-Olongapo Road along the town proper and at Barangays San Antonio and Sto. Cristo and as a result, the road in barangay Pangatlan is prone to damage and cracks.

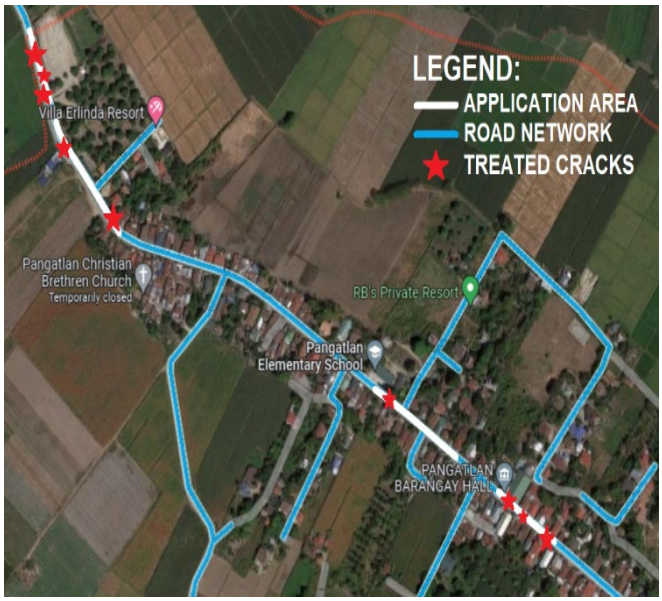


Fig.1. Vicinity Map of the Study Area

II. METHODOLOGY

2.1 Research Design

In this study, an experimental method was used. The experiment was about using polyurethane expanding foam as a crack repair solution. The researchers chose road cracks in concrete pavement to treat in order to test the performance of the polyurethane expanding foam. To make data collection easier, these specified cracks were subdivided into three width categories: category I: 1–15 mm, category II: 16–30 mm, and category III: 31–45 mm. The categories were made based on

DPWH D.O. No. 45, Series of 2006, and an article by Davis (2022), in which the department order shows the minimum

width requirement for road crack repair and the author of the article introduced a crack width categorization system. Category I was defined as hairline to small width cracks, while category II included medium- to large-width cracks. The addition of category III aimed to determine if PU foam is still applicable to larger crack widths. This categorization system provides a useful framework for understanding and addressing different types of cracks in various structures. By identifying the specific category of crack, engineers and builders can choose the appropriate repair method, which can help ensure the longevity and safety of the structure. Furthermore, this system helps avoid redundancy and repetition in repair work by providing a clear roadmap for addressing different types of cracks.

After being divided, the cracks underwent cleaning to remove dust and impurities. Then, the sample cracks were treated with polyurethane expanding foam. The applied polyurethane expanding foam was monitored and observed to see if there were any color changes since it can cause distraction to the road users that may result in an accident. Physical changes were also monitored, such as texture changes, deformities and damages, and its adhesiveness was assessed. The experiment was made based on the observation of road cracks in Pangatlan, Mexico, Pampanga, in particular the transverse cracks.

2.2 Preparation of Materials

The following are the tools and materials needed for the study.

2.2.1 Materials

Polyurethane Expanding Foam. It is a type of insulating material that is created from a two-component liquid system that expands and solidifies into a foam. It is commonly used for insulation, soundproofing, filling holes and gaps in walls, floors, and ceilings, as well as concrete leveling and soil subsurface stabilization.

2.2.2 Tools

Brush. A tool composed of bristles typically set into a handle and used especially for sweeping, smoothing, and scrubbing.

Hand Broom. A cleaning tool consisting of usually stiff fibers attached to, and roughly parallel to, a cylindrical handle.

High-pressure Water Spray. A water spray with a pressure pump used mostly for cleaning glass windows. It is also used to water plants as well as spray fertilizers and insecticides.

Micrometer Caliper. A precision measuring tool used to determine the size of small objects or the separation between two points. It is frequently used to measure linear dimensions, such as the thickness of a material or the diameter of a small part.

Trowel. A tiny, handheld tool with a flat, pointed blade that is usually used to distribute plaster or cement.

2.3 Research Locale

The researchers identified the location of the barangay road based on the existence of cracks. The proponents used a micrometer caliper to measure the widths of each transverse crack and determine its category based on the measurements. The researchers then used the polyurethane expanding foam to treat the fractures in the concrete pavement.

2.4 Viable Solution for Cracks on Actual Concrete Road

2.4.1 Inspection Stage

The researchers were at the road of barangay Pangatlan to assess the concrete road and look over the existence of cracks. However, the researchers first requested permission from the barangay captain to conduct the study through a letter validated and certified by Don Honorio Ventura State University (DHVSU). The researchers then checked the road for the existence of cracks.

2.4.2 Measurement of Widths of Road Cracks

- Using the micrometer caliper, measure the width of the crack.
- Determine the width category of the crack.

2.4.3 Application of Polyurethane Expanding Foam on Actual Concrete Road

- Scrape and brush the sand that has gathered inside the crack with the trowel, hand broom, and brush.

- Rinse and clean the crack with water using a high-pressure spray to remove any dust and impurities.
- Let until the crack has dried for at least an hour before applying the polyurethane expanding foam to ensure complete adhesion to the concrete road.
- Fill the crack with polyurethane expanding foam. Spray from the bottom most part of the crack to ensure that the foam expands and molds into every corner of the fracture.
- Allow it to dry and settle for about 30-45 minutes until it reaches 90% of its strength.
- Using the trowel, level the surface of the polyurethane expanding foam-sprayed area and remove any excess expanded foam.

2.5 Monitoring Stage

The researchers monitored the applied polyurethane expanding foam for 6 consecutive weeks to determine the following:

Physical and chemical changes on the applied polyurethane expanding foam

To monitor every week for a span of six weeks to see whether there are any color or texture changes, as well as any deformities, shrinkage, or damages.

Ability to adhere of the polyurethane expanding foam to the Concrete Pavement

To monitor every week for six weeks straight to see if the applied polyurethane expanding foam is still in place and completely adhering to the concrete pavement.

2.6 Evaluation

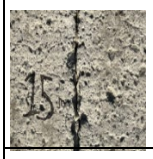
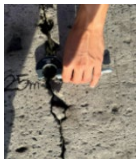
The evaluation was conducted after the monitoring stage based on the data collected over a period of six weeks. The results were assessed to determine the performance of polyurethane expanding foam and its viability as a solution for fixing cracks in concrete pavement.

III. RESULTS AND DISCUSSION

3.1 Results

3.1.1 Determination of the width range of road cracks

Table.1. Categories and Width Range of Road Cracks

Crack Sample	Category	Crack Width	Applied Foam	Result
	I	3.60 mm		Applicable
	I	12.00 mm		Applicable
	I	15.00 mm		Applicable
	II	16.00 mm		Applicable
	II	21.00 mm		Applicable
	II	25.00 mm		Applicable
	III	32.00 mm		Applicable
	III	37.80 mm		Applicable
	III	41.00 mm		Applicable

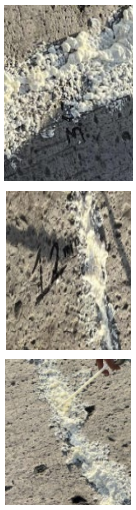
The following data represents the allowable widths of road cracks in the application of Polyurethane Foam. The road cracks are subdivided into three categories, each with three sample cracks: category I, that measures 1-15mm, category II, that ranges from 16-30mm, and category III, whose width ranges 31-45mm. The results showed that applying polyurethane expanding foam is applicable to all the given categories of crack widths.

3.2 Weekly Monitoring

3.2.1 Week 0: Day of Application of Polyurethane Expanding Foam on Concrete Roads

Based on the observations which are documented in Table 3, the polyurethane expanding foam adhered well when applied to concrete road cracks. It also shows that the foam's initial color is white upon drying. Since the applied foam has not yet been subjected to any vehicular loads, no deformations or damages have been observed.

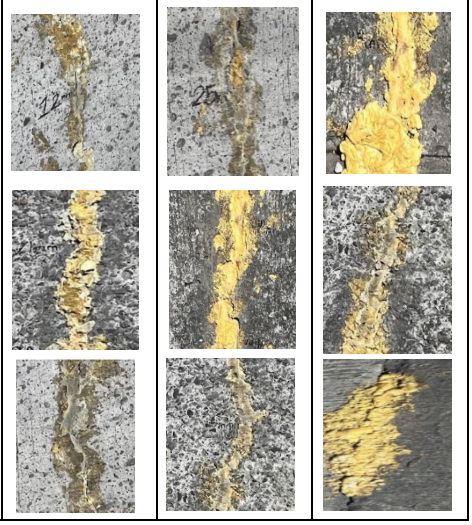
Table.2. Day of Application of Polyurethane Expanding Foam

Categories	I	II	III
Documentations			

3.2.2 Week 1: First week of Observation and Monitoring

The table below illustrates that a week after applying polyurethane expanding foam to concrete road cracks, the color changed from white to yellow with random black spots. The discoloration was caused by environmental variables such as sunlight, air, and water exposure, as well as the constant contact of the foam to car wheels. Although the topmost layer of the foam was flattened due to vehicular loads and it became rough and brittle due to environmental factors, it remained adherent to the concrete without wearing.

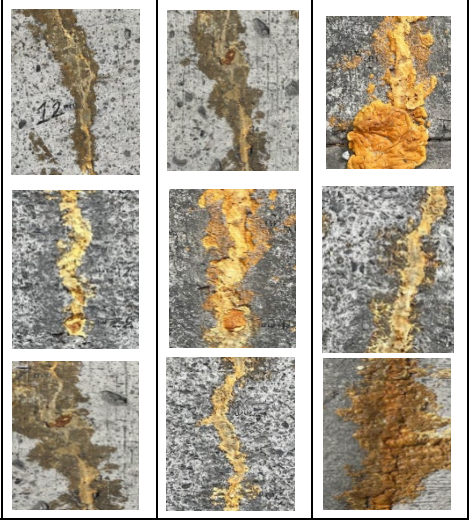
Table.3. First Week of Observation and Monitoring

Categories	I	II	III
Documentations			

3.2.3 Week 2: Second Week of Observation and Monitoring

The table below presents how some parts of the polyurethane expanding foam changed its color from yellow to orange and dark orange with random black spots and the surface started to flatten two weeks after applying it to concrete road fractures due to environmental factors and daily contact with car wheels. Although the foam's outermost layer increased its brittleness, it retained its adhesion to the concrete without wearing.

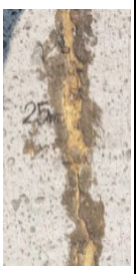
Table.4. Second Week of Observation and Monitoring

Categories	I	II	III
Documentations			

Week 3: Third Week of Observation and Monitoring

The table shows the continuous discoloration of the polyurethane expanding foam. The color had become a mixed spot of orange, brown and some black caused by weather exposures and contact from different vehicle wheels. Meanwhile, due to vehicular loads, certain areas of the foam began to settle and shrink. Despite this, no wearing or any damage was observed, and the polyurethane foam is still adhered to the concrete pavement.

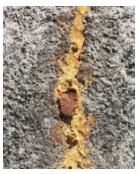
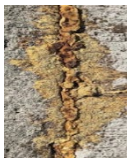
Table.5. Third Week of Observation and Monitoring

Categories	I	II	III
Documentations			
			
			

Week 4: Fourth Week of Observation and Monitoring

The table exhibits that some parts of the polyurethane expanding foam continued to shift its color making it darker in tone and appear color brown because of the continuous exposure to the environmental factors and hot weather conditions. Aside to the wear and tear from the loads it endured over the course of a week, the foam constantly shrinks and settles. Despite issues in other areas, the material was still adhered to the road crack surface.

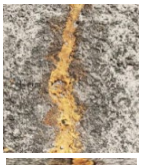
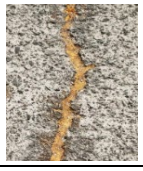
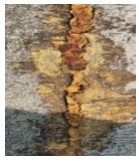
Table.6. Fourth Week of Observation and Monitoring

Categories	I	II	III
Documentations			
			
			

Week 5: Fifth Week of Observation and Monitoring

Following the trend from previous weeks, the polyurethane expanding foam suffered a considerable color change, darkening to a brown hue as a result of extended exposure to external variables and high temperatures, as presented in Table 8. Furthermore, the flattened surface of the foam shows a little shrinkage, as a result of the strain brought on by the weights it carried throughout the week. But the polyurethane expanding foam remained intact and still adheres to the concrete road crack despite these setbacks.

Table.7. Fifth Week of Observation and Monitoring

Categories	I	II	III
Documentations			
			
			

Week 6: Sixth Week of Observation and Monitoring

Table shows that after the span of 6 weeks, the polyurethane expanding foam was able to withstand vehicular loads and exposure to weather having only minimal deformities, damages, and changes in its surface texture. Even though some parts of the foam's color continuously darkened over time to color brown and some black spots, the foam is able to adhere in the concrete pavement.

Table.8. Sixth Week of Observation and Monitoring

Categories	I	II	III
Documentations			

3.2 Discussion

3.2.1 Observation of Physical and Chemical changes of the applied polyurethane expanding foam for 6 weeks.

The applied Polyurethane Expanding Foam was monitored to determine the change in its color and surface texture, as well as any deformations and damages. Below is a table that shows the results from the observation.

Table.9. Observation of Physical and Chemical Changes of Polyurethane Expanding Foam Applied to Road Cracks in a Period of 6 Weeks

Week	**0**	**1**	**2**	**3**	**5**	**6**	**7**
Color	White	Yellow and some black spots	Yellow, orange, dark orange, and some black spots	Orange, brown and some black spots	Orange, brown and some black spots	Orange, brown and some black spots	Orange, brown and some black spots
Surface Texture	Smooth	Rough	Rough	Rough	Rough	Rough	Rough
Deformities	No deformities	Flattened surface layer	Flattened surface layer	Flattened surface layer and shrinkage occurs	Flattened surface layer and shrinkage occurs	Flattened surface layer and shrinkage occurs	Flattened surface layer and shrinkage occurs
Damages	No damage	No damage	No damage	No damage	Abraded Surface	Surface abrasion and cuts occur	Surface abrasion and cuts occur

Based on the performed observation that is recorded in Table 10, the color of the applied Polyurethane Expanding Foam shifted from white to brown throughout the course of 6 weeks. The foam's surface texture is smooth after application to concrete, but it becomes rough due to environmental variables and frequent contact with vehicles. The sprayed foam had no deformities for the first two weeks, but starting in the third week and continuing through the remaining weeks, the foam began to shrunk and settle due to vehicle loads. The applied polyurethane expanding foam surface layer became brittle and rough due to environmental factors, and on its 4th week the brittle surface started to break and showed cuts on its last week. Throughout the span of 6 weeks the applied foam also shows that it can prevent debris and water from entering the crack.

3.2.2 Observation on the Adhesiveness of the applied Polyurethane Expanding Foam in a span of 6 weeks.

The adhesiveness of the polyurethane expanding foam was investigated by monitoring if the foam that was applied to the concrete road fracture remained adhered and in place. The results of the observation are shown in the table below.

Table.10. Observation on the Adhesiveness of the applied Polyurethane Expanding Foam in a span of 6 weeks

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Week	0	1	2	3	4	5	6
Adhesiveness	Adhered to the concrete	Adhered to the concrete	Adhered to the concrete	Adhered to the concrete	Adhered to the concrete	Adhered to the concrete	Adhered to the concrete

Based on the information gathered in Table 11, the Polyurethane Expanding Foam remained intact and adhered on the concrete road crack after 6 weeks.

IV. Summary, Conclusions and Recommendations

The summary of results, the conclusion, and the recommendations for the development of the investigation are presented in this chapter.

4.1 Summary

This summary provides a brief overview of the main findings of the study:

- Polyurethane expanding foam was found to be applicable to various widths of road cracks. It is

suitable for categories I, II, and III, with crack widths ranging from 3.60mm to 41.00mm.

- The color of the polyurethane expanding foam changes over time due to environmental factors such as sunlight, air, water exposure, and daily contact with car wheels. The color changes from white to yellow, then to orange, dark orange, and finally to brown with random black spots.
- The outermost layer of the polyurethane expanding foam becomes rough over time due to exposure to environmental factors and loads.
- Certain areas of the polyurethane expanding foam begin to settle and shrink progressively due to vehicular loads, resulting in minimal deformities and damages.
- Based on the observations, polyurethane expanding foam adheres well to concrete road cracks and maintains its adhesiveness over time despite exposure to environmental factors and loads.

4.2 Conclusion

To conclude and draw final insights from the results, the use of polyurethane expanding foam as a viable solution for repairing cracks on local concrete roads in the Philippines shows that it adheres well to the concrete surface, which is an important factor in the longevity of any repair work. The study revealed that using polyurethane expanding foam as a repair for road cracks could prevent debris and water from entering the cracks that could cause more damage to the concrete pavement. It was also concluded that the polyurethane expanding foam could be utilized as a temporary solution in situations where immediate repairs are required but the resources to complete a full repair are unavailable.

4.3 Recommendations

These recommendations will suggest potential avenues for further research and improvements in the field of road crack solutions:

- Conduct a longer observation period, which could be beneficial for capturing the long-term effects and durability of the polyurethane foam on the concrete pavements.
- Explore the use of coatings or additives to enhance the polyurethane expanding foam's color stability and smoothness, as well as to minimize surface cuts and abrasions over time.
- Investigate and thoroughly analyze various road crack solutions to determine their long-term cost-effectiveness, durability, and environmental impact, as well as preventive measures to improve pavement conditions and reduce the occurrence of road cracks, and indicate how expanding foam will weigh against these methods.

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