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ASSESSING OPEN-GRADED ASPHALT'S RESISTANCE TO DEGRADATION VIA CANTABRO TEST IN HOT-MIX COLD LAID ASBUTON

*Sri Gusty[1], Israil[2], Siti Nurjanah Ahmad[3], Miswar Tumpu[4]

[1]Magister in Environmental Infrastructure Engineering, Graduate Faculty, Fajar University, Makassar, Indonesia
[2]Civil Engineering Department, Faculty of Engineering, Muhammadiyah University, Makassar, Indonesia
[3]Civil Engineering Department, Faculty of Engineering, Halu Oleo University, Kendari, Indonesia
[4]Disaster Management Study Program, The Graduate School, Hasanuddin University, Makassar, Indonesia

*Corresponding Author, Received: 11 March 2024, Revised: 06 June 2024, Accepted: 13 June 2024

ABSTRACT: Petroleum asphalt, also known as Asbuton, can be substituted with natural asphalt sourced from Buton Island. This natural asphalt, known as Asphalt Buton (Asbuton), is abundant in rock deposits on Buton Island and nearby areas. The significant reserves of natural asphalt on Buton Island make it an ideal binder for asphalt mixtures. Various efforts have been undertaken to enhance the effectiveness of Buton asphalt as a binder in asphalt roads. One such effort involves the technological advancement of Buton asphalt pre-mix, which includes the addition of fluxing ingredients (modifiers) to ensure that the Asbuton bitumen attains the necessary properties as a binder in the asphalt mixture. By incorporating fluxing ingredients, the asphalt mixture can achieve durability and be spread and compacted at lower temperatures. This is particularly advantageous in regions with limited access to asphalt mixtures from Asphalt Mixing Plants (AMPs), such as remote and small islands in Indonesia. The production of pre-mixed Buton asphalt is carried out at the manufacturing AMP, where mixing takes place. Subsequently, the mixture can be stored or packaged, and cold temperatures can be utilized for rolling and compaction procedures in the field. Results from the Cantabro test demonstrate that the combination meets the standards for asphalt porosity mixture as outlined by the Road Engineering Association of Malaysia (REAM), with a maximum porosity of 20%, achieved at a 5.5% BGA and 3.5% flux oil level.

Keywords: Open-graded asphalt, Hotmix cold laid, Asbuton, Cantabro test

1. INTRODUCTION

The end result of a dosed mixture of stone aggregates, asphalt cement, and mineral filler is asphalt concrete [1, 2]. It is employed in flexible pavement systems for the shape of the tread surface, asphalt, and intermediate bases [3]. The grain distribution, which will give it a distinctive mechanical behavior, will play a significant role in how it functions within the pavement structure [4]. It must also be highly stable, resistant to rutting, displacement, or other surface distortions, have a high coefficient of friction to prevent sliding, and give good traction in addition to being safe and noiseless [5].

Open-grade porous asphalt has interconnected gaps that let water to pass from the material to a binder course. Benefits of porous asphalt mixes in terms of safety and the environment have long been acknowledged [6]. Using porous asphalt mixtures helps to improve contact while removing water from the surface. As a result, the risk of accidents and fatalities during inclement weather is minimized, while at the same time, traffic noise levels are decreased [7]. The difference in porosity between dense-graded asphalt and open-graded asphalt is shown in Fig. 1. On a wet day, the densely graded asphalt surface has a significant water film, whereas the open-graded asphalt surface does not. Because of its high porosity, open-graded asphalt allows water to pass through the top layer, as seen in Fig. 1. Open-graded asphalt surfaces have steadily become more popular all around the world as a result of these advantages [8-10].

Fig. 1 Water transport differs between mixes with open and dense grades

Reduced glare and greater pavement marker visibility are additional advantages related to increased safety. Smooth pavements, enhanced driver confidence during rain events due to a reduction in potential hydroplaning, less splash and spray, reduced glare, and reduced risk for permanent deformation are further advantages associated to improved driver comfort [11 – 13]. Two of the key properties of open-graded mixtures that are necessary to provide particle interlock and acceptable resistance to permanent deformation are one-on-one contact and particle interlock in the coarse aggregate fraction.

Like the thick or traditional asphalt mixtures, the porous asphalt mixtures are made up of a combination of stone aggregates, asphalt cement, and mineral filler, if necessary [14]. The main characteristic of such mixtures is having a sufficiently high void content, as a result of their particle size distribution, to enable the water byproduct of rainfall falling on the road to escape quickly by infiltration and be conducted later toward the porous and sub-porous elements, avoiding their stay on the wearing course's surface even under intense and prolonged rainfall.

In other words, they create a framework made of multiple layers of construction materials that allows water to flow through it. Their sole purpose is to evacuate water to the sides, not to allow storage in the pavement's bottom levels [15, 16]. To avoid water seeping into the lower levels or accumulating in the files, they must be constructed on entirely impermeable asphalt bases with excellent planimetric, geometric, and porous criteria [17]. The loss of adhesion or even contact between the tire and the road surface, known as hydroplaning, and decreased driver visibility are two of the most frequent issues that arise when it is raining. In some cases, the cross-slope's inability to completely evacuate the water thin film also contributes to these issues. This situation could become dangerous if the driver is driving at a high speed, creating the perfect conditions for vehicles to flip over when their tires lose traction with the ground [18].

Indonesia needs to import the remaining 1.2 million tons of oil asphalt needed to build new roads each year because domestic asphalt production is only capable of producing 600,000 tons annually. Using Indonesian Buton asphalt (Asbuton-Indonesia), which is the country's natural asphalt, is one way to lessen the demand for oil asphalt. Natural asphalt from Buton Island can be used in place of petroleum asphalt, among other things. Reduced petroleum bitumen usage can support the growth of local and national road infrastructure by maximizing the use of butane asphalt products. Asbuton reserves in Indonesia are thought to be exceptionally abundant, amounting to 24 million barrels of petroleum bitumen [19]. Petroleum bitumen is anticipated to be replaced in part or entirely by Asbuton [20]. Numerous research on bitumen produced from Buton natural asphalt have demonstrated that this bitumen has similar physical characteristics to petroleum bitumen [21-23].

Even though hot mix asphalt is being produced at the Asphalt Mixing Plant (AMP), its application is actually very limited in rural areas or those that are far from the AMP location. The lowest mixing temperature required to generate hot mix asphalt is 120–160°C. Of course, it will be quite challenging to finish if the asphalting place is far from the AMP. The primary factors are the asphalt mixture's viscosity and workability, which are directly related to the road's service life and naturally have a substantial impact on the mixture's quality. The asphalt mixture hardens and bleeds as the temperature drops below or stays over the threshold needed for mixing in the field.

The quality of pavement construction is negatively impacted by inadequate compaction of the asphalt mixture. This effort is part of an ongoing investigation to determine whether bitumen in Asbuton may be used to compact hot mix at 50°C, a low temperature, and form a hot mix. Hot mix is a cold-lay pavement that uses asphalt as a surface within the pavement structure. It is used as an alternative to hot-mix asphalt pavement. An Asbuton and aggregate mixture was modified using flux oil to maintain its workability.

The addition of flux oil at the same amount of 3.5% as the added material over open-graded asphalt using 5.5% Buton Granular Asphalt (BGA) follows compaction at freezing temperatures. The obtained porosity values from the Cantabro test result meet the REAM's standards.

2. RESEARCH SIGNIFICANCE

The inadequate compaction of asphalt mixtures significantly diminishes pavement construction quality. This study forms part of an ongoing investigation into the viability of utilizing Asbuton bitumen for the production and compaction of hot mixtures at a low temperature of 50°C. Cold-lay pavement, integrating Asbuton on the surface within the pavement structure, emerges as an alternative to conventional hot-mix asphalt. To preserve workability, flux oil was utilized to modify a blend of Asbuton and aggregate.

3. SAFETY-RELATED ENVIRONMENTAL BENEFITS

Drivers are inconvenienced by standing precipitation on the road surface, which always happens during the rainy season. This phenomenon is supported by the characteristics of flexible pavement, which are impermeable to water and have poor drainage. As a result, less rainwater seeps in, and road degradation progresses more quickly. One of the technologies to maximize rainwater infiltration and decrease road puddles is porous asphalt.

Porous asphalt is typically used on roads with less traffic, such tennis courts and parking lots. Porous asphalt is an open-graded combination with a high proportion of coarse aggregate and a low proportion of fine aggregate, which creates a lot of air gaps in small lanes that are only used by light vehicles. This air space should allow water in the top layer to flow into the asphalt cavity both vertically and horizontally, where it will be directed into the pavement drainage system [24]. The physical state of the road, including the asphalt's degree of roughness, the presence of puddles on the surface, the volume of road noise, etc., has an impact on how comfortable road users are. Ideally, the asphalt would be permeable to water, have Marshall properties, and have a high permeability value [25].

It is possible to increase the contact between the wheels of moving vehicles and the road surface with the next development of porous asphalt. Additionally, porous asphalt minimizes glare from the road surface and fog from behind the car, improving visibility of the road surface both during the day and at night. Porous asphalt technology is therefore developed as a component of flexible pavement that can minimize the negative effects of transportation facilities in order to improve road services for the user.

Low sand concentration asphalt is used to create porous asphalt, which has a high pore space. It should absorb water because to the high pore space density. This form of porous asphalt pavement is a very inventive road coating technique since it is simple to allow water to enter the pavement vertically and horizontally through capillary air pores or by using side channels and pavement layers as a drainage system.

As illustrated in Fig. 2, the macro- and micro-texture of porous asphalt pavements could improve mean profile depth and dynamic friction. Micro-texture refers to the surface texture of the aggregate particle and the tiny sand-sized particles in the exposed asphalt mortar, and macro-texture refers to the form, size, and general arrangement of the particles. Skid resistance is greatly influenced by both macro- and micro-textures; as a result, porous asphalt pavement will increase friction, particularly in wet weather. The usage of this porous asphalt combination provides a number of advantages in the sectors of the environment, the economy, and the built environment. While some highway noise is generated by the cars themselves, the majority of it is caused by the friction of the tires with the pavement. The effect of a sound-absorbing porous pavement is depicted in Fig. 3.

A porous pavement allows the sound energy released when a tire makes contact with a surface to escape. Particularly when the highway speed exceeds 70 kph [26, 27]. The requirement for noise reduction is highest in metropolitan areas because of how near companies and residences are to the highway.

Fig. 2 Porous asphalt mixes' macro- and micro-texture after about ten years of use

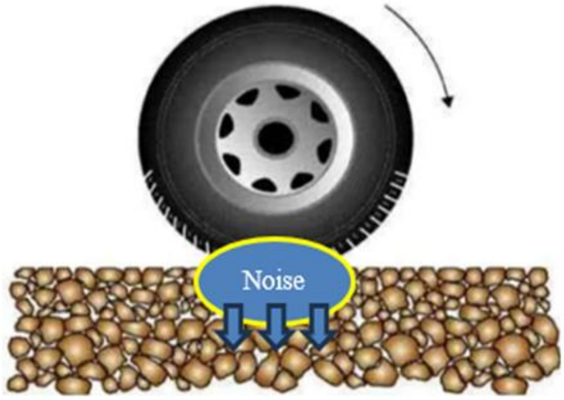

Fig. 3 An illustration of porous asphalt's ability to absorb sound and slow its spread

The population's quality of life is the most evident justification for the need for noise reduction. Porous asphalt pavements often attenuate noise above 1,000 Hz caused by pavement-tire interaction [28-30]. A study also demonstrates that the noise absorption coefficient is thickness-sensitive. The risk of contaminants seeping into the earth can be decreased by using porous asphalt. These pollutants may originate from either the hydrocarbons present in the actual asphalt ingredients themselves or from contaminants such as motor oil.

Table 1 Pollutant reduction on porous asphalt

Study location	Total Suspended Solids (TSS)	Total Phosphors (TP)	Total Nitrogen (TN)
Prince William, VA	82	65	80
Rockville, D	95	65	85

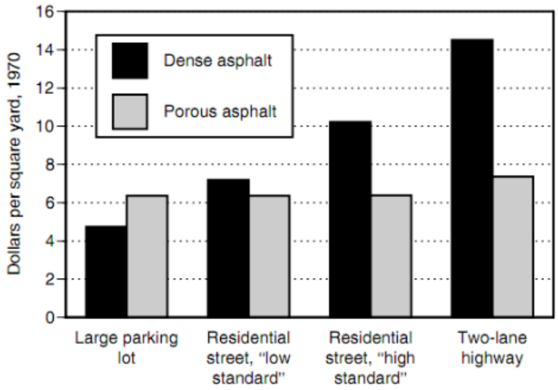

Fig. 4 Porous asphalt has advantages over traditional paving

The findings of the study on pollution reduction brought on by the usage of porous asphalt are displayed in Table 1. Porous asphalt is more cost-effective from a construction standpoint than traditional pavement. Figure 4 illustrates this. The ability of porous asphalt to function as a cool pavement to reduce urban heat island effect is another recent environmental benefit that has been noted.

Urban regions experience urban heat islands, a temperature phenomenon. Solar radiation is absorbed by buildings, sidewalks, pavements, and rooftops. Due to these types of structures near proximity to one another in an urban environment, the sun's energy may be reflected or radiated from them, raising the surrounding temperature. On hot, dry days, the air inside urban centers can get up to 50°C hotter than it does in surrounding, more rural locations. The use of "cool pavements" can help to lower heat islands. Open-graded mixes are thought of as cool pavements, whether they are porous asphalt or porous pavement parking lots.

4. MATERIALS AND METHOD

4.1 Certain characteristics of BGA

Asbuton primarily consists of two different sorts of elements: asphalt (bitumen) and minerals. The performance of the intended asphalt pavement will be impacted by the use of this element in asphalt operations. According to the findings of a study on large-scale testing conducted in Kolaka, Southeast Sulawesi, Indonesia, Asbuton can replace oil asphalt and enhance the performance of asphalt mixtures. Asbuton contains between 10% and 40% bitumen. There is also Asbuton, which can contain up to 90% bitumen, in a number of places. The hardness of Asbuton bitumen varies greatly. While Asbuton from Lawele typically has bitumen with a penetration value above 130 dmm and contains light oil up to 7%, Asbuton from Kabungka typically has bitumen with a penetration value below 10 dmm.

The bitumen penetration value in Asbuton Lawele falls below 40 dmm if the light oil is evaporated. According to chemical constituent composition, Asbuton bitumen contains a higher proportion of nitrogen compounds and a lower proportion of paraffin compounds than oil asphalt, suggesting that it may adhere to surfaces more effectively than oil asphalt. The "Globigerines limestone," a highly fine limestone produced by the microbial remains of long-extinct foraminifera, dominates the Asbuton mineral. It is suitable as a filler for asphalt concrete because of its fine characteristics, hardness, and high calcium carbonate concentration.

The national asphalt Buton factory in the Lawele region produces the BGA that was employed in this study. The market has it for sale. Contains 73.58% minerals and 24.58% bitumen, making it. BGA has a water content of 1.11% with grains smaller than 9.5 mm. BGA attributes are displayed in Table 2.

Table 2 Certain characteristics of BGA

Characteristics	Testing result
Bitumen volume, %	24.58
9.5 mm passing sieves, 3/8", %	99.99
Water volume, %	1.11
Asphalt's atomic composition, %	73.58
Bitumen penetration, dmm	35.96
Melted bitumen point, °C	58.89
Flashpoint prior to extraction, °C	198.19

4.2 Physical Characteristics of Aggregates

The physical characteristics of coarse and fine aggregates are shown in Table 3. Crushed stone, gravel, and sand are all types of aggregate and can either be mined or processed.

Table 3 Some properties of aggregate

Characteristics	Testing result
Coarse aggregate	
Specific gravity of the bulk	2.53
Specific gravity of the SSD	2.60
Specific gravity of the apparent	2.71
Abrasion in Los Angeles machine	22.62%
Oval and flat particles	8.20%
Absorption of the water	2.38%
Fine aggregate	
Specific gravity of the bulk	2.55
Specific gravity of the SSD	2.61
Specific gravity of the apparent	2.72
Absorption of the water	1.90%
Value of sand equivalent	84.14%
Filler	
Specific gravity of the bulk	2.57
Specific gravity of the SSD	2.62
Specific gravity of the apparent	2.73
Absorption of the water	2.30%
Value of sand equivalent	0.70%

The majority of the road pavement layer, roughly 90%–95% by weight or 75%–85% by volume, is made up of aggregate. A granular natural rock or mineral material is called aggregate. Generally speaking, aggregates are structures of the earth's crust that are hard and thick. According to ASTM, aggregate is a substance made up of big masses or small fragments of solid minerals.

The coarse and fine aggregates used were crude river stone and river sand, respectively. Prior to mix creation and analysis, aggregate testing was done in this study.

4.3 Aggregate Gradation and Mixtures Design

The value of the plan aggregate composition ratio is multiplied by the proportion of the value that passed the filter analysis to arrive at the combined aggregate proportion. Sieved analysis is then utilized to total up the data for all components, including coarse aggregate, fine aggregate, and filler, to obtain the predicted combined percentage. The REAM requirements were followed in determining the mixed aggregate gradation.

Table 4 displays the aggregate gradation limits for hollow asphalt composites. The obtained component of the combined aggregate is also corrected to the value of the specified interval.

When examining the composition of the combination, the minerals present in BGA were taken into consideration. The grain size distribution is shown in Table 5.

Table 4 Aggregate gradation by REAM

Sieve number	Sieve size (mm)	Aggregate passing percentage	
		Grading A	Grading B
¾	20.0	-	100
½	14.0	100	85 - 100
3/8	10.0	95 - 100	55 – 75
4	5.0	30 – 50	10 - 25
8	2.36	5 - 15	5 - 10
200	0.075	2 - 5	2 - 4

Table 5 Distribution of gradations in this study

Sieve number	Weight (gr)
½ (14 mm)	28.79
3/8 (10 mm)	481.49
No. 4 (5 mm)	430.51
Bitumen BGA	65.90
Mineral BGA	193.10

4.4 Mixture Preparation

Porous asphalt mix and hollow asphalt briquette composition are among the hollow asphalt specimens that will be tested. The compaction temperature was 50°C for each storage and compaction period was 4 hours. The steps involved in mixing the BGA, modifier, and aggregates are as follows:

1. Aggregates were heated to 170°C for around 1800 seconds before being added to the mixture. Each sample weighed 1,200 grams.
2. In all mixes, the hot modifier accounted for 3.5% of the aggregate content by weight. Hot modifiers were introduced to the aggregate mixture without first heating them.
3. Prior to blending with BGA, the aggregates and modifiers were mixed for around 60 seconds at a temperature of 130 ± 50°C.
4. For about 120 seconds, BGA was added to the mixture and well combined with the other ingredients.

4.5 Asphalt Porous Specification

Table 6 below shows the terms and conditions for the porous asphalt mix. Following that, Table 7 plots the specification interval and aggregates by REAM.

Table 6 Asphalt porous specification

No.	Planning criteria	Value
1	Cantabrian test loss (%)	Maximal 15%
2	Flow down with asphalt	Maximal 0.3%
3	Void in Mix (VIM) (%)	18 – 25%
4	Stability Marshall	Minimum 350 kg
5	Flow Marshall	2 – 4 mm
6	Marshall Quotient	Minimum 200 kg/mm
7	Collisions field number	50

4.6 Cantabro Test

The Cantabro test is used to assess the asphalt mixture's resistance to grain release, which can also be tested for abrasion. The samples were placed in the Los Angeles abrasion testing device and rotated 300 times without the use of iron balls after standing at room temperature for 7 days. The Cantabro Loss Formula (Eq. 1) is used to calculate the weight before and after the test.

$$\text{Lost Weight (L)} = \frac{Mo-Mi}{Mo} \times 100\% \quad (1)$$

Where:
Mo: Weight before abrasion (gr)
Mi: Weight after abrasion (gr), and
L: Percentage of weight loss (%).

Table 7 Aggregate combined gradation analysis

Sieve number		3/4	1/2	3/8	4	8	200
Coarse aggregate	% pass	100.00	88.33	66.00	0.00	0.00	0.00
85%	% batch	85.00	75.08	56.10	0.00	0.00	0.00
Fine aggregate	% pass	100.00	100.00	100.00	100.00	78.00	15.00
5%	% batch	5.00	5.00	5.00	5.00	3.90	0.75
Filler	% pass	100.00	100.00	100.00	100.00	58.50	22.00
10%	% batch	10.00	10.00	10.00	10.00	5.85	2.20
Combined aggregate		100.00	90.08	71.10	15.00	9.75	2.95
Specification (Grading B)		10.00	85 - 100	55 - 75	10 - 25	5 - 10	2 - 4

5. RESULTS AND DISCUSSION

5.1 Cantabro Test

After the specimen underwent the Los Angeles Machine's abrasion test, the weight loss of the specimen was measured using the Cantabro method. The test was run using the porous asphalt mixture at its ideal contents. This will establish how long porous asphalt mixtures will last. Table 8 displays the test outcomes. The Cantabro test is used to assess the asphalt mixture's resistance to the release of grains that can be used to test for abrasion. According to REAM's requirements, the maximum weight loss value limit for porous asphalt should not be greater than 15%. Figure 5 depicts the test object's morphology following wear testing.

The earlier parts of this article demonstrated how the Cantabro test can identify elements that are crucial to a plant's production control strategy and that are known to have an impact on performance, durability, and other properties. Prior to mix production, there is some value in quickly detecting and evaluating these components in the laboratory, but the true value is in controlling them during production (contractor) or making sure the right combination is placed (agency).

The Cantabro test has three characteristics that make it a production-ready test: In the current DOT quality control and quality assurance (QC and QA) programs, specimens can be Cantabro tested as soon as volumetric measurements have been taken without the need for slicing. This means that (1) it takes hours, not days, to produce usable data from an asphalt mix; (2) the test duration is less than 10 minutes; and (3) specimens can be Cantabro tested without the need for slicing. A typical production day in most states results in four QC data points (or as many as four Cantabro measurements).

This study demonstrates that a BGA combination with a hot modifier might be crushed at 50ºC.The results of the Cantabro testing performed using the Los Angeles Machine are shown in Table 8. It demonstrates that the results of the Cantabro test for the mixture of porous asphalt with BGA 5.5% and flux oil 3,5% using 6 samples show that the mixture has a good level of durability and satisfies the criteria.

Relevant experience from the Netherlands has been published in order to implement characterization and define the impact on the mechanical behaviour of porous asphalt mixtures or have some climate weathering factors. This experience raises questions about the role of room temperature prior to the Cantabro test and how it may slightly affect the results of the abrasion loss rate in the Cantabro test for porous mixtures after 300 cycles in the Drum of the Angels. Low ambient temperature levels indicate a larger loss of abrasion [31, 32].

A device was put into place on the Kyoto Jukan Expressway to evaluate the robustness of a porous surface rolling. Asphalt binder modifier additives were either present or absent in the porous asphalt mixtures used to build some of the sections. As a result of its improved asphalt cement composition, the porous asphalt mix's surface fully complied with Kyoto's requirements and created no longitudinal cracks, according to the results. Additionally, it showed improved results for aggregate disintegration and asphalt binder aging. In contrast, the obstruction created by driving cars caused longitudinal fissures in areas built with unaltered asphalt cements and adhered to conventional criteria [33].

Other comparable incidents, this time involving workers who modified the asphalt binder by adding discarded ground rubber. China produced 280 million new tires in 2006, placing it first in the world for new tire production. These brand-new tires will eventually be thrown away because they could endanger both the environment and human health. The use of used tires in pavement construction can help reduce the negative impact that they have on the environment since the tire powder acts as a binder modifier in the asphalt or mix.

One of the most crucial elements of porous asphalt mixtures is the Cantabro. Particularly, planning ensures that the material holds together even after field spreading and compacting. Good water permeability is ensured by the big cavity included in this form of construction. Based on preliminary estimates, asphalt's adhesive qualities may be diminished by the lack of water or oil. The solidity, durability, and flexibility of asphalt concrete are bolstered by the adhesive qualities of asphalt.

Table 8 Results of the test Cantabro

No.	Flux oil content (%)	Buton Granular Asphalt (BGA)			Sample weight (Mo) (gr)	Void in mix (VIM) (%)	Cantabro test	
		Content (%)	Mineral weight (gr)	Bitumen weight (gr)			Sample weight (Mi) (%)	Abrasion value (%)
1	3.50	5.50	193.13	66.00	1218.00	25.73	1085.00	10.92
2					1210.00	26.22	1141.00	5.70
3					1233.00	24.81	1209.00	1.95
4					1193.00	27.65	1167.00	2.18
5					1212.00	26.51	1187.00	2.06
6					1194.00	27.60	1170.00	2.01

Fig. 5 Specimen morphology following an abrasion loss test (A. Before testing, B. After testing)

This kind of rubber-modified asphalt mixtures or ground-up waste tires has a number of advantages, including lowering traffic noise, lowering maintenance and rehabilitation costs, lowering susceptibility to temperature, and perhaps even boosting the structural strength of the asphalt mixtures in terms of rutting and cracking. However, there are two fundamental issues with the crumb rubber used to build pavement. The use of high temperatures in the manufacture of asphalt modified with crumb rubber mixtures presents the first and most significant of the two obstacles because it creates a sticky gel that raises the viscosity of the hot binder. Increased fuel use and greenhouse gas emissions may result from this [34, 35].

6. CONCLUSIONS

In this study, the advantages and disadvantages of using porous asphalt for paving construction and maintenance are reviewed and discussed. For a porous asphalt mix to be successful, design and construction methods must be carefully considered. Based on data from the literature review and laboratory testing, the following conclusions and suggestions are made:

- The average weight reduction rate of 4.14% demonstrates that a mixture with a lower Cantabro value will lose less mass, making it highly resistant to environmental factors such as weather, temperature, and rainwater acidity. The weight loss rates varied due to the thickness of the bitumen covering the various aggregates when combined.
- Porous asphalt pavements offer advantages such as reduced splash and spray and improved wet-weather frictional qualities.

7. ACKNOWLEDGMENTS

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