Technical, Environmental, and Economic Advantages in the Use of Asphalt Rubber

Mariáh P. S. P. Soares, Niander A. Cerqueira, Felipe Fraga de Almeida, Afonso R. G. Azevedo, and Markssuel Teixeira Marvila

Abstract The correct disposal of tires is a major concern for the environment. A part of the waste is used to manufacture rubber asphalt, providing environmental, technical, and economic advantages. In the present work, it was identified that the permanent deformation at 60 °C in 10,000 cycles for CAP 50/70 (traditional asphalt) is 4.7%, while rubber asphalt is 2.5%. In addition, the permanent deformation at 60 °C in 30,000 cycles for CAP 50/70 is 6.2%, and for rubber asphalt, it is 3.2%. Thus, the pavement with rubber asphalt is more durable compared to the pavement with CAP 50/70. So, even though rubber asphalt is a little more expensive, in the end, it becomes more economical because it has greater durability. Moreover, over the years the CAP 50/70 will need more maintenance, while rubber asphalt promises a much lower amount of maintenance.

Keywords Asphalt rubber · Composites · Environmental effects · Sutainability

Introduction

The increase in population, the advancement of new technologies, and the growth of the economy have resulted in an increase in the disposal of solid waste in nature. In 1999, with the approval of CONAMA Resolution 258/99 [1], there was a significant growth in the recycling of waste tires in Brazil.

The CNT (National Confederation of Transport) Survey of Highways 2019, states that the road modal is the main one for the movement of cargo and people, but it does not receive significant investments for the growth of highways to accompany

M. P. S. P. Soares · N. A. Cerqueira (✉) · F. F. de Almeida · A. R. G. Azevedo · M. T. Marvila
Sociedade Universitária Redentor, Redentor, BR 356 Km 25, Itaperuna, Rio de Janeiro, Brazil
e-mail: prniander@gmail.com

A. R. G. Azevedo
Universidade Federal Fluminense—UFF, Rio de Janeiro, Brazil

M. T. Marvila
Universidade Estadual Do Norte Fluminense Darcy Ribeiro—UENF, Rio de Janeiro, Brazil

J. Li et al., *Characterization of Minerals, Metals, and Materials 2021*,
The Minerals, Metals & Materials Series,
https://doi.org/10.1007/978-3-030-65493-1_59

the economic growth of the country. The quality and maintenance of most roads are not satisfactory.

Combining economic development and environmental issues, rubber asphalt brings simple and effective perspectives in the short, medium, and long term related to the durability and quality of the pavement, automobiles, the environment, and even the health of citizens. This technology occurs through the range of useless tires with no destination, with promising innovation for the paving part.

Tire Collection and Recycling in Brazil

Although the tire has been very useful since it was created, it is also a big problem when it comes to the environment, because when the tire wears out completely it becomes unusable. According to Reciclanip in 1999, to meet CONAMA resolution 258/99 [1], the National Waste Collection and Disposal Program began, which was created by ANIP (National Association of the Pneumatic Industry), over time the program was expanded and they decided to create Reciclanip, in 2007, which is an institution focused on correctly collecting and disposing of waste tires in the country. It was founded by the new tire manufacturers Bridgestone, Goodyear, Michelin, and Pirelli. Subsequently, Continental and Dunlop joined the group.

Reciclanip has been working on reverse logistics, giving waste tires a correct destination. In 2019, they had more than 1026 collection points and correctly disposed of 471 tonnes of waste tires. Between 1999 and 2019, correctly collected and disposed of more than 5.23 million tons of waste tires, which corresponds to 1.04 billion passenger tires [2].

Lagarinhos [3] says that before the CONAMA Resolution, the country only recycled 10% of tires. Soon after the legislation was passed, companies registered to collect waste tires grew considerably. In Brazil, there is no government incentive in favor of tire recycling. Reverse logistics is paid for by new tire manufacturers and importers.

The Road Modal in Brazil

In Brazil, the main mode of transportation of people and cargo is the road, data from the CNT Highway Survey 2019, show that only 12.4% of the highways are paved. Despite being a very important modal, there are still few paved stretches [4]. And road conditions are not satisfactory.

The search [4] shows that the growth of the vehicle fleet is greater than the growth of the road network, the road mode is the most appropriate for short and medium distance journeys and there is an overload of vehicles circulating on the highways, with these aspects, combined, make it necessary for investment levels to expand and maintain roads to be significant.

The non-compliance with technical requirements related to the structure of the flexible pavements, which was also observed in the CNT Roads Survey 2019, points out that, both in the support capacity of the layers, as well as in the quality of the materials used in the coating, it results in a more accelerated deformation [4].

Transport in Brazil is an activity that is part of the base of the economy in the country, allowing functionality in several sectors, and should go hand in hand with environmental issues. The quality of the road network, its state of conservation, and its proper maintenance interferes mainly in safety, but also in costs and energy efficiency of transport, influencing the environment. When vehicles travel on roads in inadequate conditions, they generate some damage, such as accidents, higher fuel consumption, wear and tear on vehicle parts, among other factors [4].

In view of the current situation of the road network in the country, it is necessary to invest more in road infrastructure, both for paving new roads and for maintaining existing roads; so that economic growth goes hand in hand with environmental issues.

Rubber Asphalt

Rubber asphalt is the integration of rubber in the asphalt mixture, which in addition to offering desirable properties to the pavement, also presents a significant environmental perspective, since it enables a more sustainable destination for millions of scrap tires discarded every year [4].

Similarly, it is also defined as an asphalt binder that brings innovation, economy, and sustainability to the pavement generated through investments in research for a product of high durability and safety, which presents an attention to the reduction of environmental problems [5].

Brief History of Asphalt Rubber

According to Di Giulio [6], the first studies on the use of rubber tires on asphalt were around the 1950 s. However, it was only in the following decade that the technological development of the material was verified, when the engineer Charles Mc Donald traveled United States highways in a trailer, applied a mixture of rubber tire powder with asphalt to seal the cracks in the roof of his vehicle. Over time, he observed that the mixture did not oxidize, in the opposite way of those with conventional asphalt. From there, engineers began to experiment with the mix for plug-in services. In the United States, there is a law that requires the application of a minimum percentage of recycled rubber in asphalt mixtures.

Since the 1960s, countries such as the United States, South Africa, Portugal, China, and Australia have performed services with rubber asphalt. The first studies on rubber asphalt in Brazil took place in 1999 [5]. In the same year, article No. 2 of CONAMA resolution 258/99 [1], the article prohibits the disposal of waste tires in the environment, arising the need to give these tires a sustainable destination. The first test application of rubber asphalt in the country was in 2001, at kilometer 319 of BR116 in Rio Grande do Sul [7]. From then on, several other stretches were submitted to rubber asphalt, with positive results in the applications. In September 2009, DNIT publishes material and service specifications for rubber-modified asphalt with its wet use [8, 9].

Today rubber asphalt is a reality in several countries, in Brazil, several stretches were built, recovered or restored. More than 10 million scrap tires have been used in the production of rubber asphalt [5].

Getting the Rubber Powder

The rubber powder, used in rubber asphalt, is obtained by grinding the tire at recycling plants or companies specializing in tire retreading. There are three types of methods for obtaining this rubber powder [10]:

- Cryogenics: Addition of liquid nitrogen to ground rubber. The rubber is frozen and, after freezing, it is crushed until the desired granulometry is acquired.
- Regeneration: Extraction by means of solvent that separates the rubber from the other components, such as metals, fabrics, and others. The ground chips of the tire are subjected to water vapors together with chemicals, such as alkalis and mineral oils, until the desired product is acquired.
- Cold grinding: Most common and cheap, a process in which the tire is ground and sieved, then passed through magnets that remove the remaining metal parts.

The most used method of the three is cold grinding, as the other two methods have a higher cost.

Methods for Obtaining Asphalt Rubber

There are two methods of incorporating tire rubber powder into asphalt mixtures [11, 12]:

- Dry route: consists of the mixture of crushed rubber particles as an aggregate of the mixture, producing the so-called aggregate-rubber. In this method, rubber is added to the mixture as part of the stone aggregate and not as part of the asphalt binder;
- Wet way: represents the mixture of small fine particles of rubber with asphalt, giving rise to the so-called asphalt-rubber. The small rubber particles act as a modifying agent and are added directly to the heated CAP (Asphalt Petroleum).
- This method has two types of manufacturing process; it can be stock or non-stock.

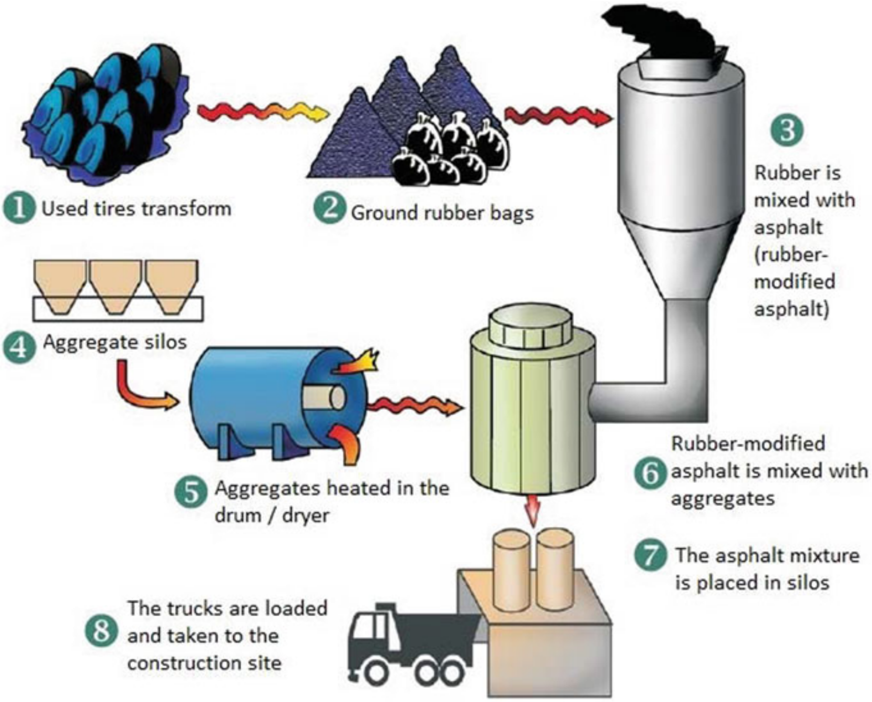

Fig. 1 Scheme of manufacture of rubber asphalt by the wet process by the stocking mixing process (blending terminal) *Source* Bernucci et al. [11]. (Color figure online)

- The non-stocking process, also known as continuous blending, is produced on site with a mixing equipment and needs to be applied at the same time, due to its instability. The stocking process, which is known as the blending terminal, is appropriately mixed in a special terminal, resulting in a stable and relatively homogeneous binder. Then having a more reliable quality control. Subsequently, the asphalt binder is transported to each site.

Figure 1 shows a scheme for manufacturing rubber asphalt using the stockpile manufacturing process, which is the process standardized by DNIT 112/2009−ES [9].

Standards and Technical Characteristics of Rubber Asphalt

In 2009, developed the first Brazilian standards for rubber asphalt were by DNIT. The DNIT Standard 111/2009-EM [8] has the purpose of specifying the material used for paving with asphalt cement modified by rubber from unserviceable tires by the wet process of the terminal blending type. The standard defines wet asphalt rubber as "Petroleum asphalt cement modified by the wet process addition of ground rubber from unserviceable tires (particles passing through sieve No. 40), resulting in a mixture in which ground rubber generally represents 15 to 20% of the binder mass."

This regulation presents some specific conditions that the asphalt rubber must have, such as: the ground rubber must represent a minimum rubber content of 15% by weight, incorporated into the asphalt binder by the wet method and it is also necessary to check in advance if the results of the tests match the characteristics of the two rubber asphalts, AB-8 and AB-22, as shown in Table 1.

In addition, the DNIT 111/2009-EM [8] standard indicates that the wet-blending process of the terminal blending type is that which obtains the stockpile rubber asphalt, where the elements are mixed in a special terminal by agitation with high shear and subjected to high temperatures, originating in a stable and homogeneous ligand. However, the standard in question does not indicate the maximum time between the production of rubber asphalt and its use in the field and leaves the manufacturer to define the conditions for storage and storage of rubber asphalt.

The DNIT 112/2009-ES [9] standard regulates the specification of the service and quality control of asphalt concrete with rubber asphalt, which must be manufactured in an appropriate plant, obtained through the wet process of the terminal blending type. The standard also recommends the use of two types of rubber asphalt for specific granulometric bands:

Table 1 Result of characteristic tests of rubber asphalt

Technical Characteristics	Unity	Asfalto Borracha		Test methods
		Type AB 8	Type AB 22	
Penetration,100 g, 5 s, 25 °C	0,1 mm	30–70	30–70	DNER ME 003/99
Softening point, min, °C	°C	55	57	DNER ME- 247/94
Brookfield Viscosity, 175 °C, 20 rpm, Spindle 3	cP	800–2000	2200–4000	NBR 15529
Flash Point, min	°C	235	235	DNER ME 148/94
Elastic Recovery Ductilometer, 25 °C, 10 cm, min	%	50	55	NBR 15086:2006
Storage stability, max	°C	9	9	DNER ME-384/99
Effect of heat and air (RTFOT), 163 °C:				
Mass variation, max	%	1	1	NBR 15235:2006
Softening Point Variation, max	°C	10	10	DNER ME-247/94
Percentage of Original Penetration, min	%	55	55	DNER ME 003/99
Percentage of Original Elastic Recovery, 25 °C 10 cm, min	%	100	100	NBR 15086:2006

Source DNIT 111/2009-EM [8]

- AB-8: for bands A, B, and C of DNIT and for discontinuous band type Gap Graded;
- AB-22: for Gap Graded discontinuous band.

Technical Advantages in the Use of Asphalt Rubber

The use of rubber asphalt results in a pavement with greater resistance to cracks and permanent deformations (wheel tracks), this is because the asphalt mixture gains part of the rubber's elastic capacity, consequently, the pavement reduces undesirable deformations, since modified asphalt has the ability to deform when vehicles pass and return to their initial position. Furthermore, rubber asphalt also shows late aging and oxidation, due to certain elements present in rubber, such as carbon black, which preserve the asphalt by combating the chemical wear caused by the exposure of the floor to ultraviolet and infrared rays [10].

A study carried out at USP (University of São Paulo) analyzed the behavior, in relation to permanent deformation, of conventional asphalt mixtures and asphalt mixtures modified by rubber asphalt. Those modified by rubber asphalt show values of deformation in the simulator much lower than mixtures with conventional binders. Coming to the conclusion that the modified mixture with rubber asphalt proved to be less vulnerable to the formation of wheel tracks. Figure 2 shows the two plates subjected to the test, the direct one is with rubber asphalt and only 5% was deformed after 30,000 simulation cycles and the left plate with conventional ligand was deformed 13% after 10,000 cycles [7].

CNT 2019 [4] also points out other benefits such as less thermal vulnerability; the reduction of noise when passing vehicles, improving the well-being of passengers and inhabitants of the areas adjacent to the highways; and the best grip between the tire and the pavement, making passengers safer.

Fig. 2 Two plates after being submitted to the traffic simulator *Source* Greca Asfaltos [7]

Environmental Advantages in the Use of Asphalt Rubber

With the approval of CONAMA Resolution 258/99 [1], there was a significant advance in the recycling of waste tires in Brazil. In 2009, CONAMA Resolution No. 416/09 [12] was approved, changing the formula for calculating production for the aftermarket. The new resolution obliges manufacturers and importers to allocate 100% of the tires that enter the aftermarket. That is, for each new tire sold in the aftermarket, importers, and manufacturers must give a correct destination for a waste tire [5].

The CNT [4] shows that between 2009 and 2019, there was an increase of 80.8% in the vehicle fleet in Brazil, generating more and more waste tires annually. The use of rubber from these tires on paving reduces the deposit of this material in landfills or other inappropriate places, and up to a thousand tires per kilometer can be used [6].

The incorrect destination of the tires endangers the health of the population, as it is a place for the development of parasites and insects that transmit diseases. In addition, if they are burned, they generate toxic smoke, also attacking the environment. Thus, a great alternative for the correct destination of these tires is to use rubber on pavements, where a large amount of waste tires will be destined [10]

Economic Advantages in the Use of Asphalt Rubber

In 2009, Greca asfaltos made a comparative study between a 30 km pavement restoration work, comparing the use of conventional asphalt with CAP-50/70 asphalt binder and rubber asphalt. The purpose was to show the use of the technical characteristics of rubber asphalt [7].

The section was reversed with a 5 cm thick conventional asphalt layer and 3.5 cm thick asphalt rubber layer, having the same strength and stability as the conventional asphalt section.

The execution price of rubber asphalt costs approximately 15% more expensive than conventional asphalt. This is due to the fact that its manufacture requires high machining temperatures to increase the efficiency of compacting the coating.

Table 2 shows that considering only the execution of machining and application of CBUQ (Hot Machined Bituminous Cement) and the cost of the ton of conventional asphalt and rubber asphalt, it is concluded that in these two points the rubber asphalt has a higher value. However, when checking the work as a whole, taking into account the quantity of CBUQ applied, which is lower in the case of rubber asphalt and also its durability, the final cost of the work is less and the savings are in the long run.

Table 2 Comparison of cost between rubber asphalt and conventional asphalt

Quantities	Calculation	Unity	Asphalt Type	
			CAP 50/70	Rubber Asphalt (Ecoflex)
Mass quantity asphalt from CBUQ produced	–	ton	26,25	18,375
Machining Cost/ Application per ton of CBUQ applied	–	R$/ton	200	230
Mass quantity x Machining Cost/ Application	A X B	R$	5.250.000,00	4.226.250,00
Asphalt Content	–	% em peso	5	5,5
Asphalt Cost Per Ton	–	R$/Ton	1.150,00	1.550,00
Asphalt Cost at CBUQ	A x D x E	R$	1.509.375,00	1.566.468,75
Total Cost of Work	C + F	RS	6.759.375,00	5.792.718,75

Source Greca [7]

Conclusion

Due to the aforementioned facts, it can be realized that the use of rubber asphalt is considerably higher than that of conventional asphalt, since with the superior quality, costs are reduced because rework and intermittent repairs are not necessary. Runner asphalt decreases the amount of car maintenance related to defects or irregularities in the pavements. It guarantees the preservation of the environment and positively influences the health of citizens, due to the fact that it can have an adequate destination for waste tires, incorrect disposal is reduced, avoiding the proliferation of vectors in accumulated, burnt water, among others.

References

1. National Environment Council (Conama) (1999) Resolution nº 258, of August 26 (In Portuguese)
2. Reciclanip (2020) Volume of intended tires (In Portuguese). http://www.reciclanip.org.br/destinados/. Accessed 22 May 2020
3. Lagarinhos L, Tenório CAF, Jorge AS (2013) Reverse logistics for post-consumer tires in Brazil (In Portuguese). Polímeros 23(1), 49–58. Epub October 11, 2012. https://dx.doi.org/10.1590/S0104-14282012005000059
4. National Transport Confederation Cnt Highway Survey (2019) Management Report (In Portuguese). https://pesquisarodovias.cnt.org.br/relatorio-gerencial. Accessed 31 October 2019
5. Zatarin, APM, da Silva ALF, dos Anemam LS, de Barros MR, Chrisostomo W (2017) Viability of asphalt-rubber paving (In Portuguese). R. gest. sust. ambient Florianópolis 5(2):649–674, out.2016/mar

6. Digiulio G (2007) Environmental and economic advantages in using rubber on asphalt (In Portuguese). Inovação Uniemp, vol.3, pp. 12–15
7. Greca Asfaltos. ECOFLEX–Rubber Asphalt (In Portugues). http://grecaasfaltos.com.br/asfalto-borracha-ecoflex-asfalto-ecologico/. Accessed 22 May 2020
8. DNIT 111/2009–EM: Flexible paving–Asphalt cement modified by rubber from waste tires by the wet process, of the type "Terminal Blending"–Material Specification (In Portugues)
9. DNIT 112/2009–ES: Flexible floors–Asphalt concrete with rubber asphalt, wet, "Terminal Blending" type–Service Specification (In Portugues)
10. de Almeida, VS, GOMES ACC (2018) Conventional asphalt and rubber asphalt: a comparative study (In Portugues). Episteme Transversalis [S.l.], v. 9, n. 1, maio. ISSN 2236-2649
11. Bernucci, LB, da Motta, LMG, Ceratti, JAP, Soares JB (2008) Asphalt paving: basic training for engineers (In Portugues). (1ed.) Programa Asfalto nas Universidades, Petrobrás Distribuidora S.A., 2008
12. Camargo, Felipe Filizzola. Field and Laboratory Performance Evaluation of a Field-blended Rubber Asphalt (In Portugues) (2016) Thesis (Doctorate in Transport Engineering)- Polytechnic School, University of São Paulo, São Paulo. https://doi.org/10.11606/t.3.2016.tde-01072016-111905