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Are GCR-modified asphalt roads the solution to the problem of road mesh in Bogotá (Colombia)?

¿Son las vías de asfalto modificado con GCR la solución para el problema de la malla vial en Bogotá (Colombia)?

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In synthesis, this article consists of a brief investigation about the mixture of GCR (Recycled Rubber Granule) with asphalt as a new alternative for the solution of the problem of the road mesh in Colombia, especially in the capital of the country. The research emphasizes the origin of its components, the processes that must be carried out to obtain such mixture, among other important aspects of it.

Keywords: Asphalt, Bogota, Environment, GCR, road problem, roads, rubber, tires

En síntesis, este artículo consiste de una breve investigación acerca de la mezcla de GCR (Granulo de Caucho Reciclado) con asfalto como una nueva alternativa para la solución al problema de la malla vial en Colombia, especialmente en la capital del país. La investigación hace énfasis en el origen de sus componentes, los procesos que se deben llevar a cargo para conseguir dicha mezcla, entre otros aspectos importantes del mismo.

Palabras clave: Ambiente, asfalto, Bogotá, caucho, GCR, llantas, problema vial, vías

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Introduction

We propose to expose the problems that have afflicted the capital city for a long time, the road network and its poor condition, and the disposal of used tires (Mancini, Nicosia, Luciano, Viotti, & Fino, 2017). In the first place, it is well known that the great number of holes in the main roads of Bogota cause daily quite heavy traffic and on the other hand the piles of tires that can be seen in many public places of Bogota (Colombia). And not only this, the burning of them causes very serious environmental damage. A joint solution to these two problems has been found, thanks to the asphalt mixture known as GCR (Recycled Rubber Grain), resulting from the mixing of asphalt with crushed tires (Boston, Leshchinsky, Kemp, & Wortman, 2017; Sulaeman, Hamdan, & Bin, 2016). With this mix, much more resistant and durable roads can be built, which would solve the problem of the road network in the capital, and would be giving an adequate use to the tires that are discarded daily in the city (Behnood & Olek, 2017; Sunil, Sahithi, Reshma, & Hemanth Raja, 2017).

Introduction to GCR

Used tires

With the great fire that occurred in a warehouse in Fontibón, with more than 600,000 tires accumulated, the contamination of the sector exceeded five times the maximum stipulated by the World Health Organization (WHO). The burning of tires disintegrates the rubber releasing carbon monoxide and dioxide, sulfur dioxide, which in the atmosphere can be converted into acid rain.

Because of all the environmental damage caused by tire burning, the District Secretary of the Environment asked the National Environmental Licensing Authority to plan a meeting to decide what should be done about it, to make plans for both the recycling and management of used tires in Bogotá.

Recycling tires

When discarded, the tires that have completed their cycle, visually contaminate, threaten public health by being buried, stored, or destroyed by incineration, and generate danger by being a generator of fires. Direct burning emits gases with harmful particles to the environment. Furthermore, storage not only implies a loss of space, resources, and energy, but also spaces that allow the proliferation of rodents and insects, especially mosquitoes that transmit dengue fever, yellow fever, and equine encephalitis. Likewise, in sanitary landfills, tires prevent waste compaction and generate instability due to the partial chemical degradation they suffer, since they take more than 100 years to degrade. The world has become aware of the importance of collecting and classifying waste for recycling. Such is the importance of this type of practice that some countries have taken initiatives that end up being reflected, in-laws. In Colombia, a great part of the tires is stored in clandestine deposits, roofs, house yards, lakes, rivers, and streets. Also, used tires increase the difficulties of open-air dumps, and the country's municipalities with waste disposal: Doña Juana in Bogotá, Don Matías in Medellín, and Navarra in Cali. In Bogotá alone, the Institute of Urban Development (IDU), points out that on average 18,861 tons of tires are generated per year, of which 71.9% have energy use (as fuel in the panela production ovens in the northwest of Cundinamarca), 17.2% are retreaded, 6.2% is used for handicrafts, 2.3% are used for re-grinding and the rest are used for other purposes. Faced with the public threat, the Technical Administrative Department of the Environment DAMA, as the competent entity within the urban perimeter of the City of Bogotá, since 2000 has begun schemes to address the problems generated by used tires.

Due to the above and the need to assign it to use that reduces the environmental impact generated by the bad disposal of used tires. There are different uses for used tires in Bogotá, but we will focus mainly on asphalt modified with recycled rubber grain (GCR) (Martínez & Martínez, 2012).

In addition to acting to solve the environmental impact caused by the disposal of tires in Bogotá, the feasibility of using used tires to improve the road network in the capital has been studied, since it is well known that traffic in the capital city is a total disaster and one of the many factors that influence this is the holes that fill the asphalt of the capital. Approximately 90% of the road network in Bogotá is in terrible condition, according to a report by the Comptroller's Office. According to the IDU, Bogotá has nearly 16,000 km of roads, 19% of which need to be repaired, and 43% of which require total intervention. The answer to the reason for this situation is that the constant growth in the acquisition of automobiles by citizens has contributed to the deterioration of the roads, since, principally, the roads in Bogotá were not designed to support so much weight. In addition to this, heavy-duty vehicles further worsen the condition of the roads in a more notorious way.

The GCR

The GCR is a possible innovative alternative to the asphalt mix that is so much in a state of deterioration. Not only does it influence the stability level for the construction of roads, but also the use of it is environmentally friendly.

The GCR (recycled rubber grain) modified asphalt is a binder formed by water and carbon or simply a hydrocarbon binder, product of the mixture of asphalt cement, recycled rubber grain (rubber particles obtained from a process of heating the rubber of the tire with sulfur to obtain a more resistant product) and some other indispensable additives for the use of the binder in pavement works.

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This alternative arises to stop the misuse of tires or wheels, which have lost value, at the economic level and use of it (Salamanca, 2007). Since these tires have a destiny not very controlled environmentally like: sanitary landfills, thermal plants, open-air garbage dumps, among others, that generate important environmental damage. At the same time, GCR is a product with high resistance to short-term deformation, effective in containing heavy traffic in our capital.

The use of it as an asphalt modifying agent allows an effective mix for the road mesh in Bogotá DC (Salamanca, 2007). This mixture is a binder formed by water and carbon, which provides resistance while allowing the use of additives to modify the qualities, capacities, and characteristics of the asphalt according to the interest of the project needs.

Due to the different studies that have been carried out, it has been determined that the asphalt modified with recycled rubber grain is a much more resistant, elastic, and durable mixture than the traditional mixtures that are frequently used in the capital. These characteristics already mentioned benefit Bogotá's road network, since, thanks to its high resistance, the roads are in better condition; its elasticity will provide a better reaction to the weight that must support the roads of a capital where the number of cars increases exponentially reducing a large number of holes and improving traffic and mobility in Bogota and its durability will save us the constant closure of roads for maintenance, which also causes unbearable road congestion for the large number of citizens who move through the city daily.

Although its satisfactory response as a binder in the asphalt mix is notorious at first sight, the Chamber of Commerce provides a graphic representation of the great difference between a road built with the recycled rubber grain asphalt mix (Fig. 1) and the traditional mix (Fig. 2).

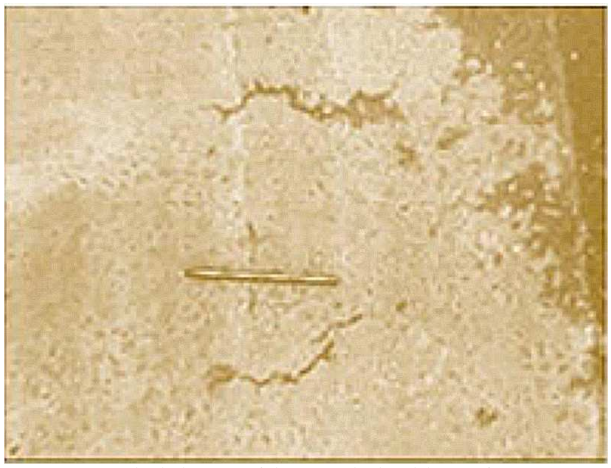

Figure 1. Asphalt layer with recycled rubber mix.

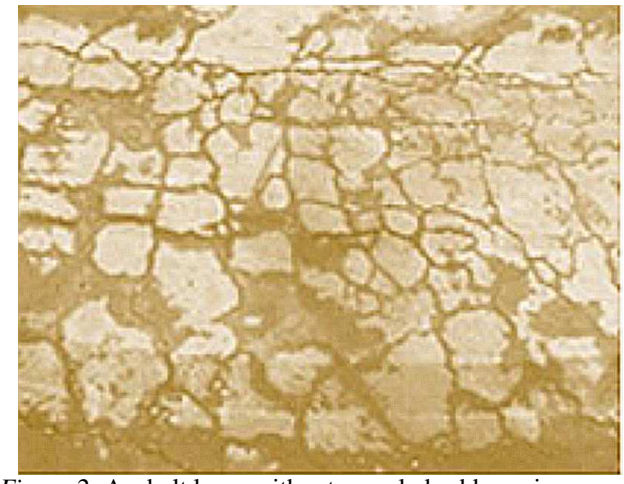

Figure 2. Asphalt layer without recycled rubber mix.

Obtaining the rubber grain

The recycled rubber grain can be obtained in different processes such as (INVIAS, 2010):

- Recapping.
- Room temperature grinding.
- Cryogenic grinding.

These three processes with increasing cost in the order in which they have been exposed, represent different alternatives of obtaining rubber grains, having each one of their characteristics. In Mexico, Colombia, Chile, and Peru a high use of GCR has been observed coming from the processes of recapping or retreading, whereby mechanical means, such as grinders or wearers, GCR is obtained without further contamination. It is then ground at room temperature and granulometric ranging from millimeters to 10 millimeters is obtained.

Process of elaboration of the GCR-modified asphalt

Dry process. As for the mixing, mixtures are made with fine aggregate. It generally acts as an aggregate, with the particularity that given its low weight per unit of volume it is essential to make a volumetric assessment since the contributions over GCR can produce segregation, losses by excessive abrasion, and higher contents of voids (Fig. 3) (Ramirez, 2008).

Wet process. Dispersers, or emulsion-type plant colloid mills, generate a more homogeneous dispersion, stable over time, with the rejuvenated GCR becoming wetted with the oily fraction of the binder. The strong cutting energy delivered allows the generation of adequate flow for dispersion (Fig. 4) (Villamizar, 2016).

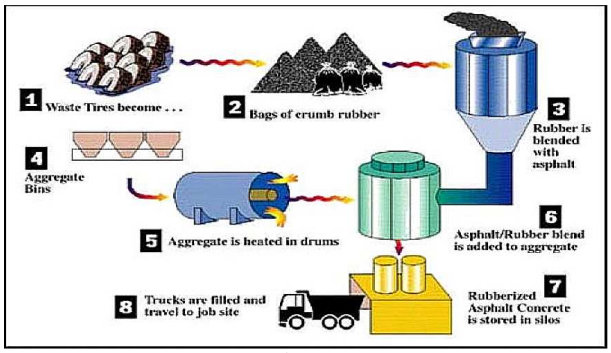

Figure 3. Dry process (Ramirez, 2008).

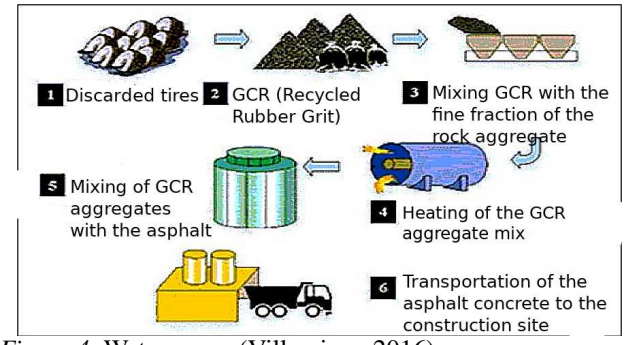

Figure 4. Wet process (Villamizar, 2016).

Properties and composition

Physical properties. It is a semi-solid bituminous product at room temperature, prepared from natural hydrocarbons through a process of purification and separation of its components, or distillation, which contains a very low proportion of products that change easily and unpredictably (volatile), has binding or mouldable, and resistant properties, and is essentially soluble in trichloroethylene. This is a visco-elastic-plastic material, which means that its behavior is directly related to the temperature and frequency with which it is charged, with recoverable (elastic) and non-recoverable (plastic) deformations (Díaz & Castro, 2017).

It is a plastic substance that gives great controllable flexibility to the aggregate mixtures (union of materials with different sizes) with which it is combined. Its color is lead (dark gray), of solid, semi-solid, or liquid consistency, depending on the temperature to which it is exposed.

Chemical composition. To guarantee a good performance in paving, it is important to know the chemical composition of the asphalt to control the physical properties. The chemical composition of asphalt is very complex, like crude oil, it is a mixture of numerous hydrocarbons, paraninic, aromatic, and heterocyclic compounds. The hydrocarbons that are part of the asphalt form a liquid solution in which a group of heavy hydrocarbon molecules (asphaltenes) are dispersed in a lighter oily medium (maltenes) composed of saturated hydrocarbons, resins, and aromatics, with no separation between these two phases but rather a transition (Díaz & Castro, 2017). When the assault is dissolved in n-heptane, the hard materials are precipitated, these materials are called asphaltenes, a name proposed by Boussingault in 1837. There are other asphalt fractions precipitated by other solvents, but this is the best way to distinguish these materials as insoluble in pentane.

Introduction of asphalt mixing with GCR in Bogotá

The accumulation of used tires is not a problem that discriminates against our country and especially against the capital of the republic. The magnitude of this problem can be seen by observing tires in pairs on-road spacers, parks, gardens, sidewalks, etc.

In the city of Bogotá, an average of 2.5 million used tires are generated annually, and it is estimated that 30% of these are thrown into public space. The illegal disposal of used tires negatively impacts the quality of life of people, because they deteriorate the landscape, cause fires, and the proliferation of mosquitoes and rodents.

A great example, of the immense danger that can lead to the precarious treatment that can be given to these tires, can trigger a fire, like the one of November 5, 2014, in a warehouse, located in the race 123 with street 14 c, which consumed about 600,000 tires. On this date, the District Secretary of the Environment declared an orange alert in six locations in Bogotá, creating chaos and concern about the exaggerated levels of gases that were released that day. Also, the warehouse, where the fire occurred, had been operating illegally since 2013 and was prohibited from storing tires, bringing to light the lack of control by the competent authorities over this problem.

These large fires generate dangerous acid rain, which in concept is any form of precipitation that presents high concentrations of sulfuric and nitric acid (National Geographic, 2010). It can also show up as snow, fog, and dry material particles that land on the earth. Decaying topsoil and erupting volcanoes release some chemicals into the atmosphere that can cause acid rain, but most of this precipitation is the result of human action. The biggest culprit in this phenomenon is the burning of fossil fuels from coal-fired power plants, factories, and car exhausts.

When humans burn fossil fuels, they release sulfur dioxide (SO2) and nitrogen oxides (NOx) into the atmosphere. These chemical gases react with water, oxygen, and other substances to form dilute solutions of nitric and sulfuric acid. Winds blow these acidic solutions into the atmosphere over hundreds of kilometers. When acid rain reaches the Earth, it flows across the surface, mixing with the wastewater and entering aquifers and farmland.

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Acid rain has many harmful consequences for the environment, but without a doubt, the most insidious effect is on lakes, rivers, streams, swamps, and other water environments. Acid rain raises the acidic level in aquifers, which allows aluminum to be absorbed and transferred from farmland to lakes and rivers. This combination increases the toxicity of the waters for crayfish, mussels, fish, and other aquatic animals.

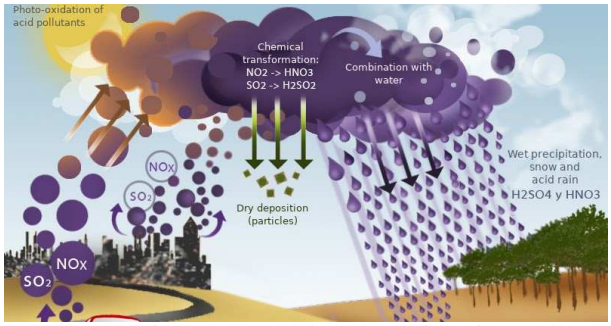

Figure 5. Environment and health: acid rain (Unknown, 2016).

Already demonstrated the risks of used tires, there is a program of post-consumption of these wastes in Bogotá, in this program, there is a very viable and optimistic solution to allocate these solid wastes, is the recycling of them, and the industrial production of GCR that as previously reiterated can be used as an additive for asphalt, creating a mixture with many advantages to address as:

- Less reflection of cracks.
- Decreases thermal susceptibility.
- Increases internal cohesion.
- Improves flexibility and elasticity.
- Improves fatigue behaviour.
- Increases the arid-binder adhesiveness.
- Greater durability and less maintenance.
- Environmentally friendly due to final disposal of disused tires.
- Reduction of layer thickness.

These advantages allow us to try to solve another problem of our city, which is the deterioration of the road network. According to the database of the IDU (Institute of Human Development) the road infrastructure of the city is in precarious conditions (Figs. 6, 7 and 8).

According to the District Planning Secretary, the road reserve zones are the strips of land necessary for the construction or expansion of public roads, which must be taken into account when carrying out processes of property allocation or the acquisition of real estate and in the construction of home public service networks (POT, 2004). We can conclude that the state of the arterial road network by 2013 was relatively good.

According to the District Planning Secretary, the intermediate road mesh is made up of a series of road

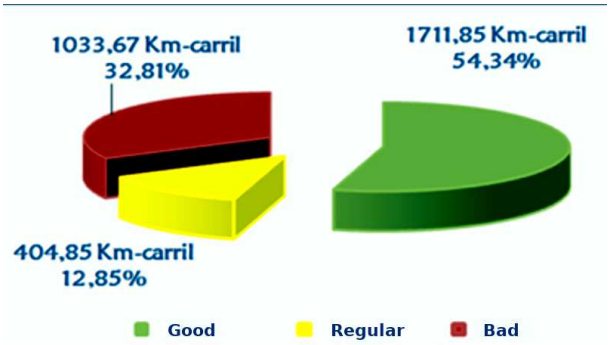

Figure 6. State of arterial road network 2013 (IDU, 2013).

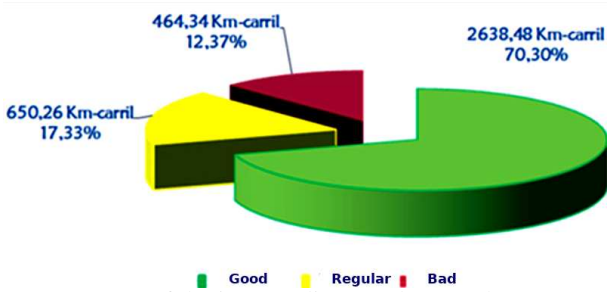

Figure 7. State of the intermediate road network 2013 (IDU, 2013).

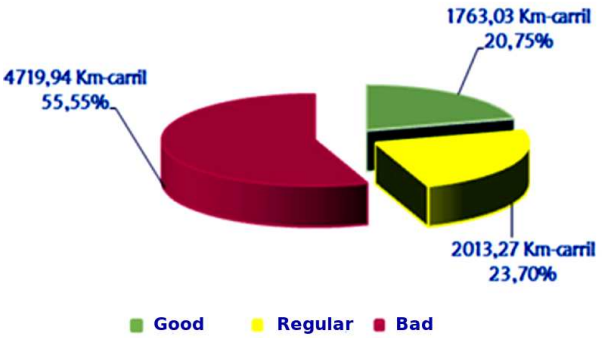

Figure 8. State of the local road network 2013 (IDU, 2013).

sections that permeate the grid that makes up the main and complementary arterial meshes, serving as an alternative for circulation to these. It allows access and fluidity of the city on a zonal scale (POT, 2004). In comparison to the above, we can see that the intermediate road mesh of 2013 is much better.

According to the District Planning Secretary, the local road network is made up of road sections whose main function is to allow accessibility to housing units (POT, 2004). As for the state of the local road network of 2013 is evident that compared to the arterial road network and the intermediate road network is in worse condition.

Why the rupture of the road network in Bogotá?

In our city, there is a belief that the deterioration of the streets of the capital is due to the bad conditions of the soil of the savannah, but according to engineers and experts in the field, ensure that these problems are minor and with modern technology and engineering are almost negligible, then the deterioration of the roads in the capital may be by over-saturation of vehicles and traffic in the city. The latest technology in asphalt, such as GCR, shows promise in combating the gaps in the city with quality roads designed based on this innovative product. Because in laboratories it has a great advantage over common asphalts.

Thanks to its greater plasticity this mixture shows excellent results against plastic deformation (Fig. 9), we conclude how hopeful this product can be when facing face to face the gaps in the capital of the republic.

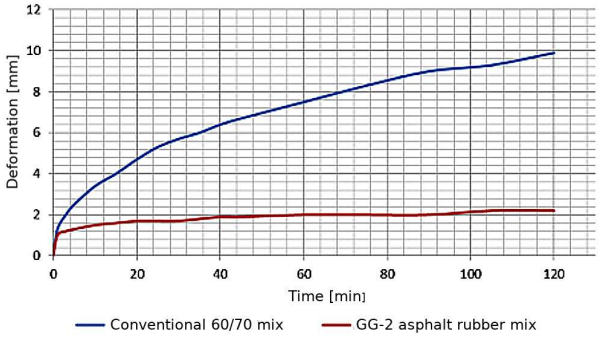

Figure 9. Resistance to plastic deformation through laboratory test track INV-756-07.

Advantages and disadvantages of GCR in Colombia

As a starting point for this topic, it is worth mentioning some of the Latin American countries in which GCR, as a new alternative infusion with the pavement, has left a great effect on society and the construction environment. It allows a new solution for these countries, both environmentally and in terms of mobility.

In Argentina, there are experiences in the city of Buenos Aires, through AUSA, in the city of La Plata, through the Municipality, in Santa Fe, Chaco, Neuquén, and in the Province of Buenos Aires, with fissure sealing works and hot asphalt concrete (Vargas & Rodríguez, 2014). In Mexico, Brazil, Costa Rica, Colombia, Chile, Peru, and Ecuador, we have participated in the use of these technologies with more than encouraging results from mechanical behavior, durability, economy, and less environmental impact.

The incorporation of rubber in road works in different regions of Latin America has allowed the design of products and mixtures with an adequate level of performance. The reduction of landfills for used tires can be substantially reduced.

In Argentina, there is a Program for the Recycling of Materials in Road Works (PROCQMA) of the SCYT of the UTN with 15 research centers that promote the execution of technical specifications and ordinances for this purpose.

The Recycled Rubber Grain - GCR, has a variety of uses such as in the manufacture of auto parts, carpets, synthetic grass, athletic tracks, soccer fields, playgrounds, sports centers, building entrances, horse tracks, riding schools, insulating bands, toys, shoe soles, mixed with asphalt for roads (modified asphalt).

The use of the tire is used as a raw material for the production of asphalt pavement or modified asphalt with rubber grain of asphalt pavement. Recycling - GCR, with recognized success in countries such as Canada, the United States, and all of Europe, among others, based on the addition of pulverized rubber (20 mesh/30 mesh) during manufacturing.

Advantages of GCR in Colombia. As we know, the problem of mobility in Colombia is not only influenced by the exponential growth at the population level that the country has had in recent years, but also as a root of this problem is the paving material which has looked to a new horizon by opting for the GCR as an element that benefits the resistance of the road network in Colombia (Fig. 10).

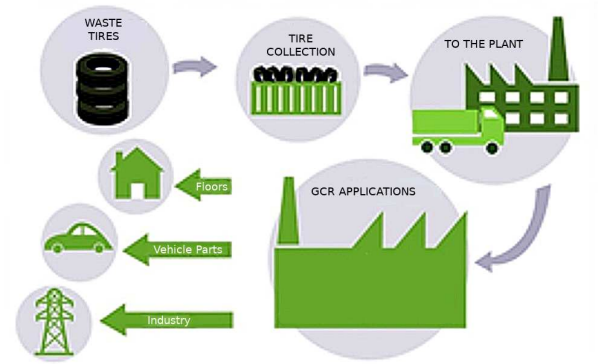

Figure 10. Tire diagram.

The recycled rubber grain in the asphalt cement acts as an aging inhibitor, prolonging its cohesive capacity over time (Díaz & Castro, 2017).

The mixture when modified becomes more flexible at low temperatures and at high temperatures it becomes less plastic. Carbon black from GCR prevents wear from tire-pavement friction, reinforces the asphalt, and reduces oxidation and aging. GCR provides flexibility and improves thermal susceptibility, as well as mechanical properties.

Disadvantages of GCR in Colombia.

- The cost of manufacturing this type of mixture exceeds that of conventional and modified mixtures.
- The manufacturing process of the mix has an impact on higher costs due to the increase in the amount of asphalt

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cement required, as well as the increase in compaction times on site.

- The wet modification process requires additional equipment and the replacement of pumps and pipes, as well as an increase in energy to heat the mix with longer mixing times.
- The absorption of oils from the asphalt by the GCR negatively affects the cohesive and adhesive properties of the binder, turning the mix into a dry mix.

Recycled rubber granule in Bogotá

Discarded tires in Bogotá

The population of Bogota has been in constant trouble, in terms of the disuse of car tires, not including that of bicycles. This situation is out of their hands because of the great pollution it generates.

The illegal dumping of tires pollutes ravines, forests, deserts, and vacant lots that led many passes to pass tire disposal regulations that require proper management. Unfortunately, tire storage and recycling are sometimes linked to illegal activities and lack of environmental awareness (Ecología Hoy, 2016).

Many of these also end up in collective wastelands or garbage dumps and cause great pollution because they are very resistant and their highly toxic components are not quickly degraded. For this reason, the objective of recycling them is a good initiative to find a suitable place to place them.

As mentioned earlier in this article, with the exponential increase in the number of disused tires in the capital it has become evident that over time tires as waste are taking over public spaces, affecting the city environmentally and visually. This problem reaches such a point that it is representing a sanitary concern since the piling up of these tires generates the arrival of mosquitoes and rats, the main carriers of diseases and infections, generating illnesses for the citizens who are close to these environments. This problem affects all regions of the country, clearly not in the same way (table 1).

Table 1
Table of data for regions (MinAmbiente, 2007).

Region	Percentage	Tire Tons
Cundinamarca	28.22%	53.760
Antioquia	18.31%	34.881
Eje Cafetero	6.78%	12.916
Costa Atlántica	13.72%	26.137
Valle	17.27%	32.900
Otras Regiones	15.70%	29.909

As can be evidenced in the exposed image no region of the country is saved from the *invasion* of the disused tires, being Cundinamarca the region mainly affected. Because this article deals with the solution to the problem of the road network in Bogotá, we will focus more on the values and statistics of this one (table 2).

Table 2
Data table for vehicles (MinAmbiente, 2007).

TIPO DE VEHÍCULO	A	B	C
			A x B
PARTICULAR (91%)	Número de vehículos	Llantas / Vehículo[1]	Total llantas en uso
Automóvil R–13	637,637	4	2,550,548
Automóvil R–14	63,063	4	252,252
Camión	18,200	6	109,200
Camioneta	81,900	4	327,600
Campero	72,800	4	291,200
Motos	36,400	2	72,800
SUB – TOTAL	*910,000*		*3,603,600*
PÚBLICO (9%)	Número	Llantas / Vehículo	Total llantas en uso
Taxi R–13	49,959	4	199,836
Taxi R–14	4,941	4	19,764
Bus	11,700	6	70,200
Buseta	9,900	4	39,600
Camioneta	5,400	4	21,600
Campero	3,600	4	14,400
Microbus / Colectivo	4,500	4	18,000
SUB – TOTAL	*90,000*		*383,400*
TOTAL	**1,000,000**		**3,987,000**

The table shows in more detail the number of tires in use in Bogotá, this total value of tires in use could mean the number of tires discarded in the capital in the future. Recycling helps to reduce the number of tires in storage that generate all these problems.

Used tire post consumer program

Used tires are not considered hazardous waste in Colombia, however, they need to be returned to producers to encourage recycling, use as asphalt aggregate or retread, and avoid being burned in open spaces and as fuel in informal activities (MinAmbiente, 2017).

Appropriate sites. Facilities belonging to used tire collection systems must comply with technical and safety requirements to ensure that the waste is handled safely and appropriately.

- They have fire safety measures.
- They store tires in an orderly manner, in covered places (not outdoors).

• They have visible advertising and documentation that allude to the systems and they are responsible.

Inappropriate sites. Unauthorized tire collection sites or persons can be identified primarily because:

• They pile up the tires in uncovered places.
• They do not have fire safety measures.
• They do not have advertising or material alluding to the Selective Collection System.

Since it is not easy for a consumer to know which companies or containers belong to a selective collection system, it is recommended to visit the link of systems presented before taking used tires somewhere.

How are used tires delivered?

To deliver the used tires must be taken into account:

1. Once the tires must be replaced, or you have any in your possession that must be discarded, check within the list of systems presented and according to the trademark or trusted supplier, an establishment that has an authorized collection point.

2. Once on-site, hand over the used tire or allow a technician, operator, or employee to take it to the storage site located inside the establishment.

GCR in Bogotá

In the manufacturing process, 100% of the tires are not used (Fig. 11).

Gross weight of a used truck tire	50.0 kg
20% steel	10.0 kg
6% nylon fibers	3.0 kg
Rubber that can be reused	37.0 kg
Gross weight of a used car tire	7.0 kg
7% steel	0.5 kg
10% nylon fibers	0.7 kg
Rubber that can be reused	5.8 kg

Figure 11. Industrial tire grinding process data.

According to 2014 records of the use of the asphalt mix made by Incoasfaltos, 800 tons of mix manufactured by this company were produced during 7 months, the product was used for the construction of important roads in Bogota, in this process, approximately 7200 used tires were recycled.

With the 800 tons of GCR manufactured, 5300 m^3 of compact asphalt mixes have been produced, with which the rehabilitation of 16.5 km/lane on the roads of towns such as Fontibón and Puente Aranda in the city of Bogotá has been achieved.

In the image, you can see the final product, which will be the object of studies to analyze the viability of its use and how good it is compared to the traditionally used mixture.

On the other hand, projects have been presented for the care and repair of the road network in Bogota and the rest of the country, with which the president of the National Agency of Infrastructure (ANI), Luis Fernando Andrade says that the rubber pavement of recycled tires has the advantage that it is more durable (less need to be repaved) and gives better traction for the tires. Even though the mixture is more expensive, it is a better long-term investment, because the pavements last longer. Well, as Andrade said, we would have before our eyes the possible solution to one of the main problems that beset the capital, which is the deplorable state of the road network in Bogota, and the large number of tires that are occupying public spaces in the capital.

At least 400,000 of the many millions of used tires are expected to be an asphalt manufacturing component.

GCR recycling plant in Bogotá

The big beneficiaries of the GCR in Bogotá are low-income people, honest people, the environment, the cities (Reciclair, 2017).

Making use of technological means not only for the search and collection of tires but also to change the habit of citizens implemented information where you can make the disposal of such waste since ultimately people throw them away because they are not informed of where or what they should do with these tires.

Consequently, used tire recycling plants will be generated around the capital. To minimize environmental pollution and the misuse of these tires. Currently, the most recognized used tire recycling plant is located in Mosquera (Cundinamarca). We are talking about the used tire recycling plant called Reciclair.

Regulations

Urban Development Institute (IDU). Resolution 3649 of September 16, 2009, issued by the Institute of Urban Development resolves in its Article Two to adopt the technical specification for the application of recycled rubber grain (GCR) in hot asphalt mixtures (wet process). The objective of this specification refers to the placement of the GCR in the asphalt mixtures as an asphalt modifying agent, this produces very good quality results if it is based on well-studied materials and correct design and construction methods. GCR may be the product of scraping vehicle tires in the retread process or slicing tires. The modification of the pure binder with GCR must be done with equipment that is capable of providing a homogeneous asphalt-rubber mixture.

The production of asphalt mix with a GCR-modified asphalt shall be equal to that stipulated for a

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polymer-modified asphalt, the mixing temperature of the aggregates and the asphalt-rubber shall be that which indicates the viscosity-temperature curve of the modified asphalt. Mix design shall be following 510.3 of Section 510.5 Dense, semi-dense, and thick hot mix asphalt. In Bogota, according to studies carried out by the IDU, through test sections using MDC-2 type asphalt mixtures and asphalt with low percentages of rubber, it was found that this improves the rigidity, resistance under monotonic load, to rutting, fatigue, aging, and decreases thermal susceptibility, this thanks to the fact that within its components are various types of polymers, such as Latex, SBS, SBR, and carbon black.

There are two techniques for using crushed tire grain (GCR) to modify the properties of asphalt mixtures, wet and dry. For the humid way, the dosage of the GCR is studied and for the design of the mixture, dynamic and volumetric criteria are used. In a dry way, the mixtures are designed by the Marshall method, considering as part of the design parameters such as the fatigue law, resistance to plastic deformation, and modules, the city has a specification for the application of recycled rubber grain (GCR) in hot asphalt mixtures (wet process), according to Resolution 3649 of September 16, 2009 (Instituto de Desarrollo Urbano 18 IDU and Alcaldía Mayor de Bogotá D.C., 2011).

According to the technical specification of the IDU, the GCR can be the product of scraping truck tires, or light vehicles in retreading processes or slicing tires, this should be uniform, free of metal, or other contaminants. (Institute of Urban Development IDU and Mayor's Office of Bogotá, 2011). It must be smaller than 595 μ. The following value ranges are recommended to modify the binder (tables 3 and 4).

Table 3
Specification of GCR-modified asphalts.

Caracteristica	UNIDAD	Norma de ensayo	minimo	maximo
Viscocidad Brookfield a163°C	Pa-s	ASTM D 4402/87	1.5	3
Penetracion a 25°C	0.1 mm	INV E 706	40	60
Punto de ablandamiento	°C	INV E 712	-	55
Pruebas al residuo despues de RTFOT				
Perdida de masa	%	INV E 720	-	1
Penetracion	%de la penetracion original	INV E 706	65	-
Recuperacion elastica	%		50	-

If at least one of the specified properties is not met, the optimal percentage of GCR for modifying a pure binder should be calculated through an experimental program following the recommendations. If the asphalt mixture is not used within the first 4 hours after the reaction time, it is reheated. This should be considered as one heating cycle, and the total number of heating cycles should not exceed two.

Table 4
Characteristic value range for modifying the binder with GCR.

VARIABLES	UNIDAD	MINIMO	MAXIMO
Cantidad de GCR	% sobre el peso del ligante	10	20
Tiempo de Reaccion	min	55	75
Velocidad de agitacion en laboratorio	min	100	750
Temperatura de mezclado	°C	155	170

As long as the mixture is kept at a high temperature, it should be kept in constant agitation, to avoid separation of the GCR and the asphalt cement.

The IDU together with the University of the Andes, developed research between the years 2001-2005, the objective of the research was to study the feasibility of the application, establish the benefits, and propose initial specifications. The corridor chosen by the IDU to carry out the project is located on carrera96, between 67A and 63 streets, better known as José Celestino Mutis Avenue. As for all road works, a complete characterization of the subgrade and the existing granular layers was carried out on the chosen corridor. Five types of mixtures with different binders were placed on the corridor, but with the same granulometry. Among the mixtures placed, two types of mixtures with commercial binders modified with polymers were included to serve as a comparison with the mixtures under study. Once the construction of the test track was completed, a year of monitoring and follow-up of the constructed sections began. Wet and dry processes were examined.

What does the law of the city of Bogotá say?. As of 2012, the Institute for Urban Development (IDU) has contractually incorporated an environmentally friendly technology, the recycled rubber grain (GCR), into the paving of Bogota's streets as an asphalt modifying agent within the hot asphalt mixtures used in the intervention of Bogota's road network; This decision is inspired by Resolutions 2397 and 6891 of 2011 of the District Secretary of Environment; the Territorial Ordering Plan that advocates for a sustainable, productive and high environmental quality urban ecosystem and the recommendations of the IDU's Technological Innovation and Clean Production Board. The new bidding documents establish that, from the study and design stage, the use of RAP should be included in no less than 10% of the total square meters and, at a minimum, 5% of GCR, that is to say, that the work contractors should use materials from the use of tires in a percentage of no less than 5% of square meters of the total of each work contract. The percentages will be increased annually by five points, until completing the 25% goal, as they are mandatory

percentages, whoever submits a proposal with them will not receive additional points.

Conclusions

In this article, we have tried to introduce the general public to an innovative and promising product, which may well be a short and long term alternative to face the deterioration of the road network in Bogotá. The GCR is a strong candidate for our city to finally have a high-quality road infrastructure, or at least not so susceptible to breakage and become almost anti-regulatory, the GCR, as has been reiterated is high-quality technology, and with the implementation that this article intends to give this product; If applied in a self-sustainable way, it would end up with a host of social, economic, environmental and mobility problems in the capital. This is due to the international background of cities that have put the GCR charter on the table of solutions, in conclusion, this alternative must be looked at by the district authorities with the highest seriousness of the case and to implement measures for an optimal application of the product at the district level, and finally to have a city without contamination by used tires, without fires by badly handling of these and with a road mesh according to the magnitude, and standards that this, our beautiful city deserves, and we deserve us the inhabitants of the city.

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