USE OF PLASTIC FOR POROUS ASPHALT MIXTURE DESIGN

CECATA Group Pontificia Universidad Javeriana - Universidad Militar Nueva Granada Geotechnical Research Group - Fredy Reyes Lizcano* - Jorge Alberto Rodriguez - Oscar J. Reyes Ortiz*** - Janeth Vargas******

**Civil Engineer, PhD LCPC*
Roads Geotechnical and Pavements Specialization Director
Associate Professor Department of Civil Engineering
Pontificia Universidad Javeriana.
Calle 40 No. 5-50
Bogotá, D.C.
Colombia

***Civil Engineer, PhD, NC State University*
Associate Professor Department of Civil Engineering
Pontificia Universidad Javeriana.
Calle 40 N°5-50
Bogotá, DC
Colombia

****Civil Engineer, Msc Universidad de los Andes*
Geotechnical Section Manager
Universidad Militar Nueva Granada
Carrera 11 No. 101-80
Bogotá, D.C.
Colombia

*****Civil Engineer*
Pontificia Universidad Javeriana
Calle 40 No. 5-50
Bogotá, D.C.
Colombia

ABSTRACT*: This article describes the objective, methodology, analysis and conclusions of a laboratory research to determine the feasibility and mechanical properties of a Porous Asphalt Mixture using plastic waste (milk bags strips).*

The research was conducted in four steps. First, materials characterization (Asphalt, granular and plastic waste), second the determination of the Optimum Asphalt percentage using Marshall Design and Cantabro Methods, third Dynamic tests were carried out and fatigue laws established, ending with interpretation and conclusions from the laboratory tests.

The results obtained for the research demonstrate that the use of plastic waste in porous asphalt mixture improve the fatigue law and dynamic modulus properties, permeability, thermal susceptibility. It also mitigates the environmental impact of plastic waste, since degradation time of this waste products is more than 80 years.

KEY WORDS*: porous mixes, Cantabrian method, Marshall design, dynamic module, fatigue laws, waste plastic.*

1. Introduction

The most important means for transportation of people and consumer goods today, is the use of vehicles trough highways and roads. The increased traffic and loads, and in some cases the use of inadequate materials has produced a large number of failures in the rolling layers that have been made in the last years generating a decrease in the service levels of the national roads.

Recent research in pavements have headed to look for new materials and additives to produce asphalt mixtures with improved behavior to the traffic demands and atmospheric conditions, reducing pavement failures such as: permanent plastic deformations reflected by the appearance of crocodile skin cracks, fatigue cracking, thermal fatigue cracking, aging and oxidation due to atmospheric agents, and loose of the asphalt cement thin-film that wraps the aggregate material.

This recent asphalt mixtures research tries to determine the mechanical properties of the asphalt concrete, as well as the improvement in strength with the addition of polymers (plastics or strips). One of the new design methodologies is the Cantabrian method for asphalt porous mixtures with plastic waste additions.

2. Background

In the last years in the country the flexible pavement structures design and construction have had a significant development, proof of it is the introduction of modified binders, evolution of the asphalt emulsions, use of industrialized polymers, use of rational design methodology, calculation of dynamic module and fatigue laws, use of the fatigue carrousel, use of porous and discontinuous mixtures and test tracts among others; always searching the way to introduce new methodologies, more comfortable durable and safe roads, and to create structures that support the current loads, traffic and weather inclemency, at smaller costs and with the use of available materials ,trying also to mitigate the environmental impact.

The porous mixtures are asphalt mixes used as a rolling layer, that are characterized to have a high percentage of interconnected voids (18 to 25%), whose function is to allow water flow through the layer toward the berms, gutters or other drainage elements avoiding the formation of a sheet of water in the surface of the road when it rains even with intense precipitation. The problem with these mixtures is its durability. Indeed, because of being open and to the lack of asphalt, these mixtures are more exposed than traditional mixtures to such phenomena as premature aging (great part of the mixture is in contact with air, sun, etc.), outburst of particles (less contact exists with the surrounding particles) and the action of the water that circulates inside it. The type and percentage of binder will play a fundamental part in the durability of the mixture.

The advantages of the porous asphalt mixtures are:

– Elimination of hydroplaning and increase of adherence: Having a high void ratio, it avoids the formation of a sheet of water in the surface and increases the adherence between the tires of the vehicle and the pavement structure under rain, making the roads safer for the users.

– Reduction of the projection of water: because these mixtures allow the surface of the pavement to be free of water when it is raining, it prevents effects like rising ('splash') and pulverization ('spray') of the water with the passage of vehicles improving the user's visibility notably.

– Reduced dazzle from the vehicles light: the drivers that circulate in the opposite direction during the night are faced to the dazzle due to the reflection of light in the traditionally wet pavements (smooth surface), on the other hand, the rough texture disperse the light and reduce the dazzle problem allowing better sight of the horizontal signaling.

– Reduction of noise with the passage of vehicles: the porous mixtures have the ability of absorbing the noise made at the contact between the tire and the pavement when the vehicle is in movement. The interconnected voids allow the passage of the air, attenuating the sound effects.

The technology of the porous asphalt mixtures began approximately 10 years ago in Europe in an experimental way; just only in the International Technical Congress of 1997 (ref?) was possible to share these experiences in flexible pavements. Likewise, in Argentina in 1997 (ref?)the first test tract was made with a length of 20 km, with results so satisfactory that in 1998 several more were built (ref?).

To improve the adhesiveness and a higher strength to aging is necessary to cover the aggregates with a thick binder film. This involve to work with high percentages of binder without glide, but this is very difficult to achieve with traditional asphalts, preferring for the production of porous mixtures the use of asphalts modified with elastomeric polymers that generate three effects that are shown in Figure No. 1.

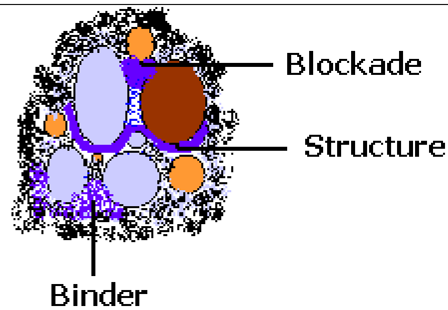


Figure 1. *Effect of the plastic inside an asphalt mixture*

– The binder effect: The true breakup or the dispersion of the fused plastic material in the mixture increases the viscosity of the binder.

– The structure effect: The fibers or plastic strips create between the grains a structure that increases the cohesion.

– The blockade effect: The plastic strips (in the grains) can fill the voids of the granular skeleton when it is compacted.

The individual or combined effects of plastic additions produce a decrease in thermal susceptibility and energy consumption for the bituminous mixture production and increase the compaction and strength.

It should also be pointed out that the level of environmental contamination in the world is such that approximately each person produces 1 kg of garbage daily, of which 14% of the weight is plastic, elastomeric type (bottles of PVC or PET, polyethylene bags, trays and protector boxes of white cork), as a result, the idea of including waste plastics in the pavement, besides helping to increase the mechanical properties, reduce the environmental impact and the costs in the structures construction, and it will generate employment.

The design of porous mixtures is based basically on two approaches: disintegration strength and permeability. To improve cohesion and avoid mixture disintegration it is usually necessary to increase the fine fraction and binder, but, on the other hand, if we want to increase the permeability and porosity we have to increase the percentage of coarse aggregate and reduce the fine fraction. The design of a porous mixture will have to solve the problem of achieving the maximum void content possible compatible with a good strength to the traffic loads without disintegrating, with the use of aggregates and a high quality asphalt, a special sieve and a suitable dosage in laboratory.

3. Methodology

The work started with the selection and characterization of the asphalt, aggregates material and plastic waste, with the results shown in table 1, 2 and 3 respectively.

Sieve Opening Size	Passing %
¾ "	100
½ "	90
3/8 "	65
No. 4	23
No. 10	16
No. 40	9
No. 200	3
Bottom	0

Table 1. *Particle Size Analysis*

TEST	REFERENCE VALUE	OBTAINED VALUE

Specific weight 25°C / 25°C	1.026	1.02
Penetration, 100 g, 5 s., a 25°C, (0,1 mm)	60.13	78
Flame Point, (°C)	291	288
Ductility a 25°C, (cm)	+100	143
Softening Point (Ring and Ball) (°C)	47.55	50
Kinematical Viscosity, 135°C, (cSt)	272,84	270

Table 2. *Asphalt Properties*

Physical Properties	Method	VALUES
Density, g/cc	ASTM D-792	0.9230
Fusion Point, DSC °F (°C)	Dow	232 (111)
Tensile Strength. Kg/cm' (MPa)	DM-ASTM D-882 DT	240 (23) 160 (18)
Elastic Limit. Kg/cm^2 (MPa)	DM-ASTM D-882 DT	1.05 (10) 100 (10)
Elongation to Break, %	DM-ASTM D-882 DT	438 540
Wide Resistance, g	DM-ASTM D-1922 DT	470 315

Table 3. *Properties of the plastic waste*

With these defined variables, the optimum asphalt percentage was determined by the Cantabrian method and the use of the Marshall equipment. With the optimum asphalt percentage, new briquettes were built with different percentages and geometry shapes of plastic waste additions (See Figure 2), to quantify their mechanical behavior, permeability, disintegration and glide.

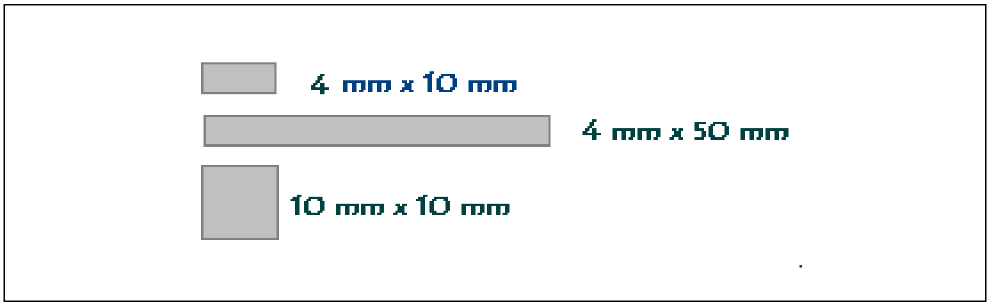
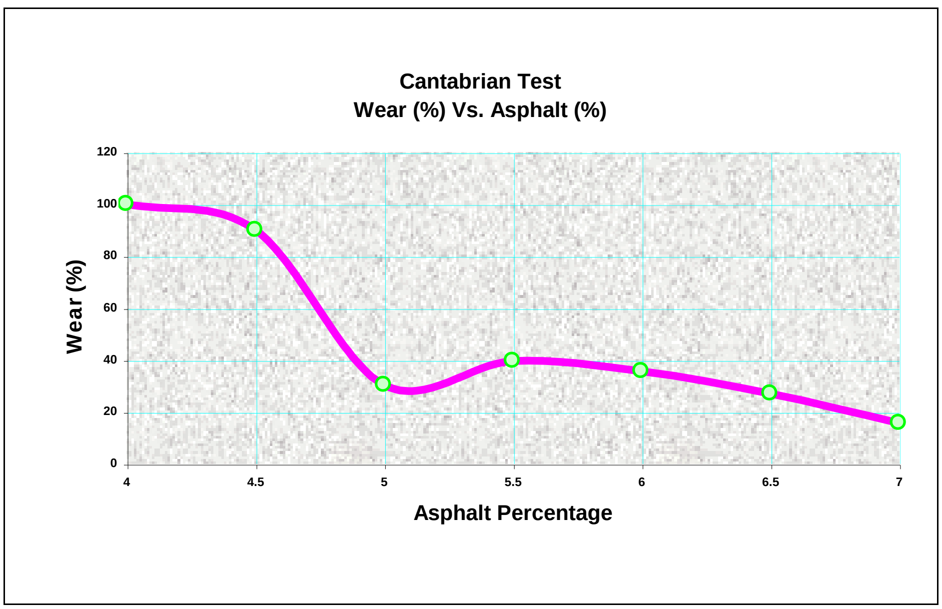


Figure 2. *Plastic Waste Shapes*

4. Conclusions OJO results should be presented first, then conclusions?

– Based on test results from the Cantabrian method, the optimum percentage of certain asphalt was obtained to be 7% as shown in graph 1.



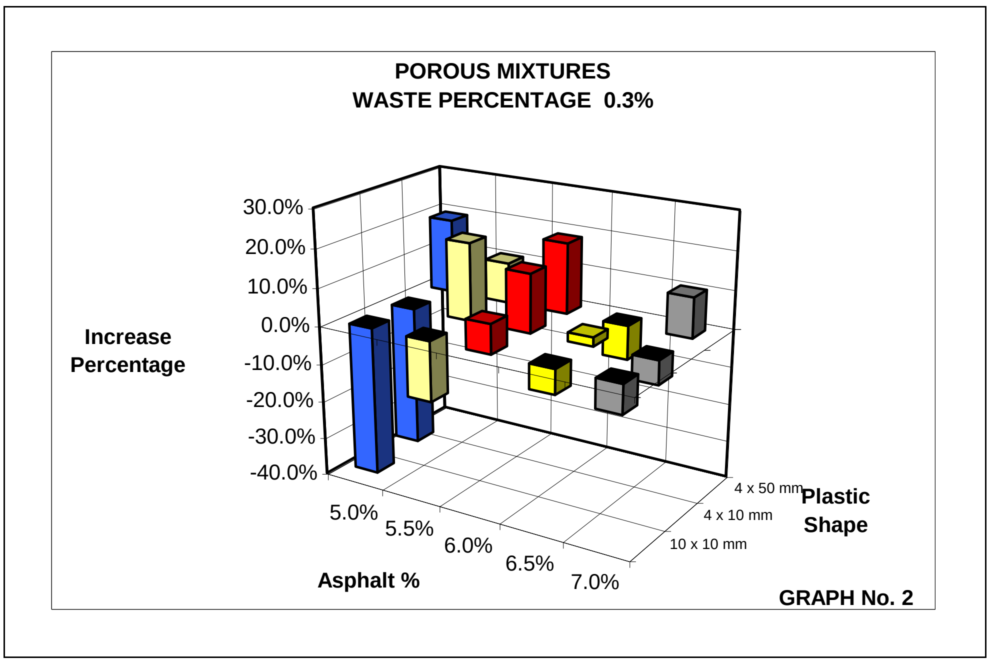
Graph 1. *Optimum Percentage of Asphalt obtained with the Cantabrian Method*

– Asphalt with penetration 60/80, whose properties are shown in Table 2 was used.

– The use of plastic waste in porous mixtures with the Particle Size gradation shown in table 1, improves the mechanical properties and permeability and decreases the thermal susceptibility.

– The data shown in graphs No. 2, 3 and 4, indicates that when introducing plastic waste in the porous mixtures the asphalt percentage decrease and the mechanical properties are improved regardless of the shape of the plastic inclusions.

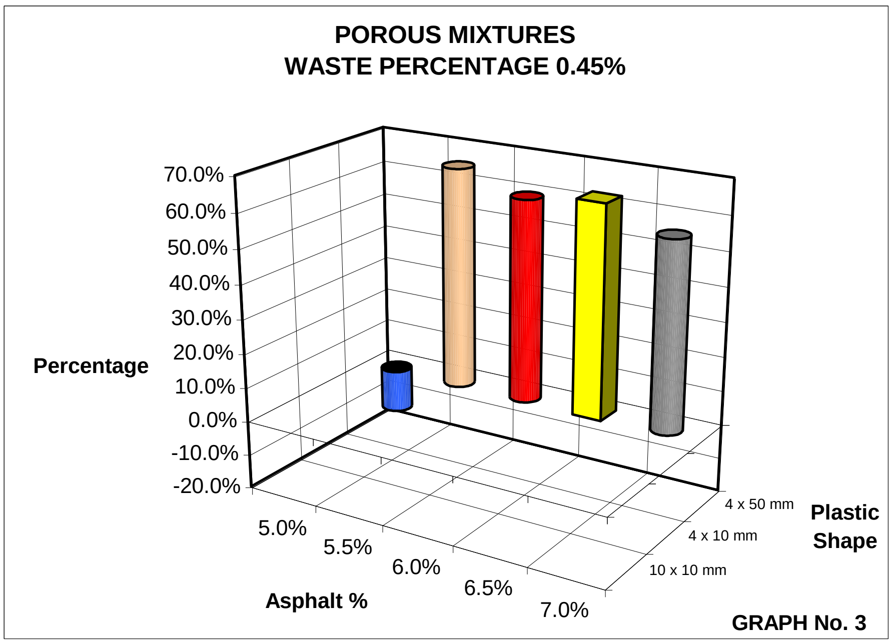
– OJO waste percentage is measured with respect to ?, values are very low?, Increase percentage is with respect to ? what are the mechanical properties that the graphs refer to



Graph 2. *Relationship between Plastic inclusion shape, Asphalt Percentage and mechanical properties with 0.3% of Plastic Waste***.**

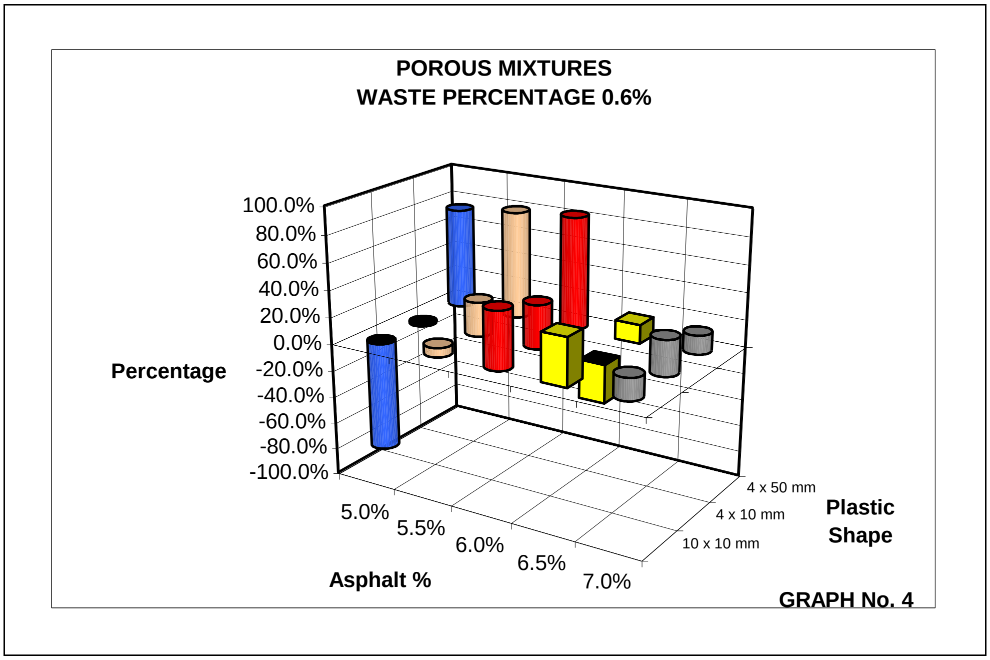
– Graph 2 shows that for a percentage of 0.3% of plastic waste and for the different asphalt percentages, an improvement of the waste variable is generated approximately between the 20 and 66%, except for 6.5%. This for the shape of 4 x 50 mm.

– Graph 3, show that for a shape of 4 x 10 mm, a superior increment exists to 50% for asphalt percentages between 5.5 and 7%.



Graph 3. *Relationship between Plastic Shape, Asphalt Percentage and mechanical properties with 0.45% of Waste*

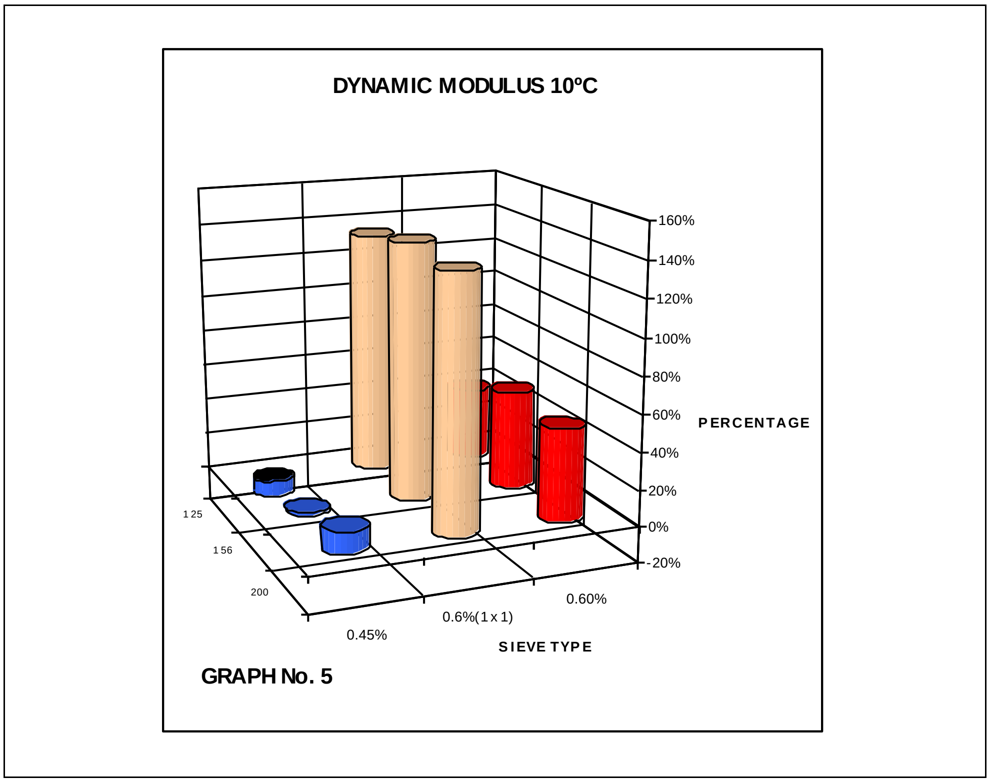
– Graph 4, show that regardless of the asphalt percentage and for the plastic inclusions shape of 4 x 50 mm, an increment on what exists from 13 to 83%



Graph 4. *Relationship between Plastic Shape, Asphalt Percentage and mechanical properties with 0.6% of Waste*

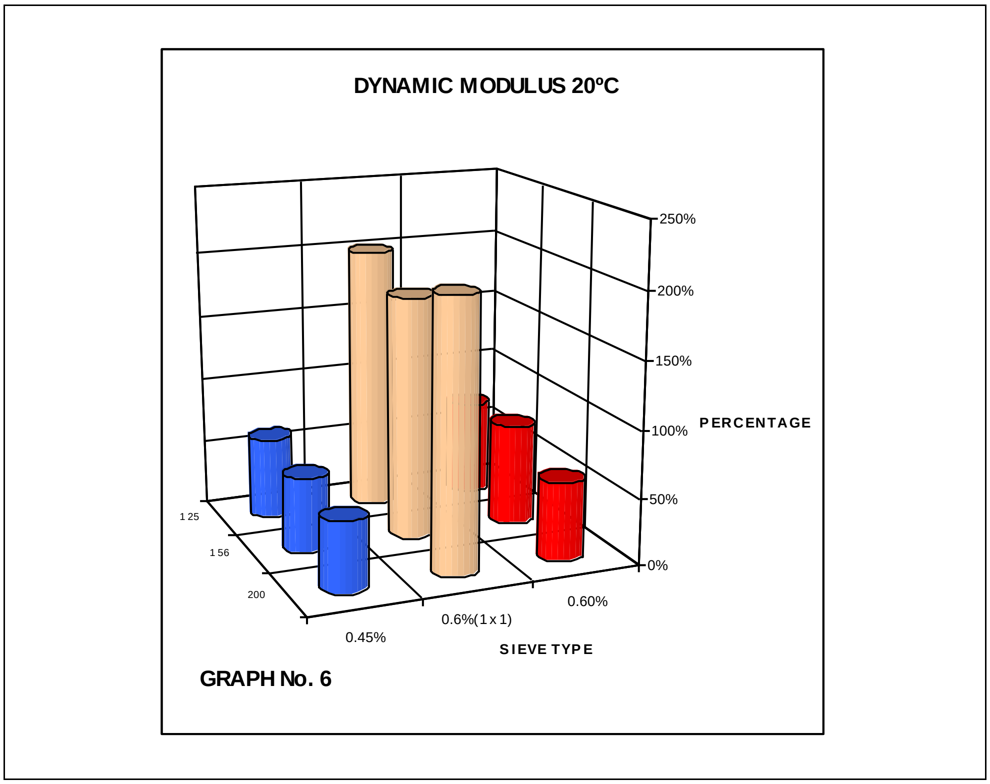
– Graphs No. 5, 6 and 7 show that the optimum addition shape of plastic strip that brings a better dynamic modulus without caring the temperature is the 1 cm x 1 cm size.

– OJO how is ti concluded that the 1x1 cm is the best if there is no data on other shapes?

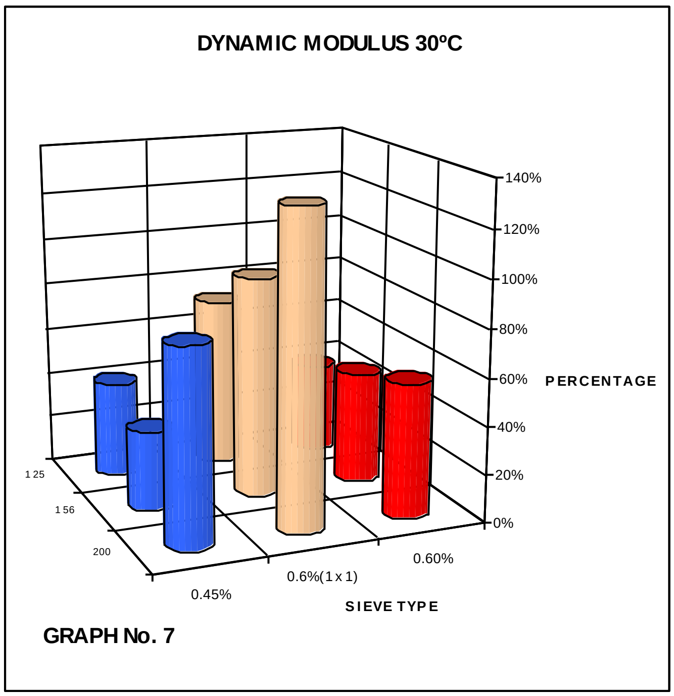


Graph 5. *Dynamic Modulus at 10° C*

OJO what is sieve type?, percentage refers to ? There are two 0.6% set of data?



Graph 6. *Dynamic Modulus with 20° C*



Graph 7. *Dynamic Modulus at 30° C*

– The results obtained indicate that the higher values of dynamic modulus are obtained for temperatures between 10° and 20° C. This is a very important result because it will perform best when used in cities with an annual average temperature around 15° C, as is the case in Bogotá.

5. Reference

5.1. Bibliography

[ASE 90] ASEFMA. (Asociación Española de fabricantes de mezclas asfálticas). *Seminario sobre mezclas bituminosas drenantes*. Madrid. Edita Asociación técnica de carreteras. October, 1990.

[PUJ 99] PONTIFICIA UNIVERSIDAD JAVERIANA. -LIDIC 2. *Caracterización de mezclas bituminosas drenantes utilizando asfaltos modificados con agregados de la sabana de Bogotá aplicando tecnología NAT (NOTTINGHAM ASPHALT TESTER*). Bogotá. October, 1999.

[ROO 97] REYES ORTIZ; OSCAR JAVIER. Tesis de grado: *Mejoramiento de las propiedades mecánicas de una capa de asfalto con desperdicio plásticos*. Bogotá. Universidad de los Andes. 1997.

[ROO 98] REYES ORTIZ; OSCAR JAVIER. Tesis de grado: *Uso de desperdicios plásticos para mejorar las propiedades mecánicas de la estructura del pavimento*. Bogotá. Universidad de los Andes. 1998.

[RLF 03] REYES LIZCANO, FREDY. *Diseño por Métodos Racionales*. Tomo I. Bogotá. Pontificia Universidad Javeriana. 2003.

5.2. Internet

- http://www.aashto.org/bookstore/
- http://www.asphaltinstitute.com
- http://www.arrb.org.au/material/asphalt.htm
- http://www.carreteros.org/drenaje/
- http://www.cedex.es/
- http://www.cfnavarra.es/obraspublicas/info/pdf/asist-lab-tec.pdf
- http://www.cpasfalto.org/congreso
- http://www.e-asfalto.com
- http://www.elsamex.com

– http://www.hotmix.org/insiders/pubcat.htm
– http://www.imt.mx/Espanol/publicaciones.html