Characterization and design of asphalt mixtures with asphaltites from Boyacá for use in low traffic volume roads

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Abstract. The high availability of asphaltites in Boyacá and their low cost make this material a viable alternative for low traffic road paving; nevertheless, the traditional way in which this material is used generates, in cases, pavements with deficient behavior. This investigation, presents the results of the mixture design using asphaltites from the municipality of Pesca-Boyacá as well as coarse and fine aggregates produced in the region, 70-80 asphalt cement and slow-break asphalt emulsion. Working formulas for dense mixing in hot and cold and particularly MDF-2 and MDC-2 are presented from the characterization information; as benchmarks to define technical viability for use in low-traffic volume roads, according to NT1 regulation from INVIAS. The mixture design was performed according to the procedures defined in the RAMCODES and MARSHALL methodologies.

1. Introduction

The deficiency in vial infrastructure is a factor that reduces competitiveness in a region, affecting its development and limiting its inhabitants regarding the possibility of improving their life conditions, this is why it is necessary to seek for viable alternatives for cost reduction in paving works, thus obtaining higher coverage of roads in optimal conditions for communities and ultimately, contribute to the economic and social development of the region.

Keeping in mind the proper use of asphaltites form the municipality of Pesca in the department of Boyacá, this research, undertaken by the research group GRINFAVIAL from the “Masters in Engineering with emphasis in Infrastructure” at the Universidad Pedagógica y Tecnológica de Colombia, intends to perform the characterization of the exploited material in the quarries of Santa Teresa and La Emilia in this municipality, in order to identify the physical and chemical characteristics of this material and thus being able to propose an asphaltic mixtures design for use in low-traffic volume roads.

2. Asphaltic mixtures

Asphaltic mixtures in hot are defined as the combination of a hydro-carbonated binding agent, aggregates such as mineral dust and, eventually, additives, in such a way that all the particles in the aggregate are thoroughly covered by a uniform film of binding agent. The asphaltic mixture in cold is a mixture of mineral aggregates with or without mineral fillings, along with emulsified or diluted asphalt; the whole process is carried out at environment temperature, (Jimenez, 2009).

In the asphalt mix design include the following materials:

- The asphaltic cement 70-80 for MDC-2 and for MDF-2 type is slow-break cationic emulsion.
- Natural asphalt (asphaltite) from the defined quarries in the municipality of Pesca-Boyacá.
- The coarse aggregates required for granulometric stabilization are obtained as a product of triturating.

The design of hot and cold dense mixtures for roads with low-traffic volume will be obtained using the protocols defined by the MARSHALL and RAMCODES methods; this is done in order to obtain the working formula with optimal percentage of asphalt and that also adjusts to the quality parameters defined by the INVIAS-07.

3. Material characterization

It is in this chapter that we show the results of characterization of materials used for asphaltic mixtures with natural asphalt form the Santa Teresa and La Emilia quarries in the municipality of Pesca. This way we define the investigation in four work groups, two per quarry, in such a way that a group performs the design of the dense mixture in cold MDF-2 and the other one the dense mixture in hot MDC-2 for each quarry.

3.1. Asphaltite characterization

The information obtained from the laboratory shows a fine, improperly gradated material, composed by sandstone impregnated in asphalt, divided in 96% and 4% proportions approximately; this material is fit for the design of asphaltic mixtures, given its physical properties and according to the specifications defined by INVIAS art. 400-07 (see table 1).

| Standard INVIAS-07 | Test                                | Standard Value | MDC-2 Santa Teresa | MDC-2 Santa Teresa | MDC-2 La Emilia | MDC-2 La Emilia |
|--------------------|-------------------------------------|----------------|--------------------|--------------------|----------------|----------------|
| E 133-07           | Sand equivalent Soils and Fine aggregates (%) | 50% Min   | 66                 | 67                 | 91              | 95              |
| E 222-07           | Specific gravity of fine aggregates (Gsb) | Absorptión % | 2.44               | 2.5                | 2.35            | 2.23            |
| E 222-07           | Specific gravity of fine aggregates (Gsb-ss) | Absorptión % | 2.53               | 2.57               | 2.44            | 2.292           |
| E 222-07           | Specific gravity of fine aggregates (Gsa) | Absorptión % | 2.69               | 2.7                | 2.58            | 2.386           |
| E 222-07           | Absorption %                         | 0.0365       | 0.04               | 2.86               | 3.83            | 2.86            |
| E 707-07           | Specific gravity of fine aggregates (Gb) – Lixiviado | N.A        | 1.09               | 0                  | 0.98            | 1.038           |
| E 732-07           | Extracción Cualitativa de Asfalto (%) | N.A          | 4.05               | 4                  | 3.89            | 3.9             |
| E 125-07           | Liquid limit                         | ≤40          | 17.18              | 15.27              | 16.43           | 18.11           |
| E 126-07           | Plastic limit                        | 4 a 9        | N.P                | N.P                | N.P             | N.P             |
| E 706-07           | Penetration                         | 200 - 250    | 224.78             | 224.7              | 235             | 277             |
| E 723-07           | Distillation                         | N.A          | N.P                | N.P                | N.P.            | N.P.            |
| E 709-07           | Flash Point y Cleveland Open Cup °C  | ≥200°C       | 93                 | 97.28              | 188             | 92              |

Experiments performed for chemical characterization of asphaltites were carried out at the carbon laboratory in the UPTC. In this characterization the analysis was performed on asphalt-impregnated sandstone and the bituminous component extracted from asphaltites form the Santa Teresa and La Emilia quarries in Pesca-Boyacá. Likewise, the chemical analysis performed on the sand stones hows an ash-composed material in more than 90% in both quarries; it also shows a material that does not present dilatation or contraction at temperatures up to 520°C. Also, it does not present plastic behavior, maintaining its constant fluidity (30000 dial/min) up to a temperature of 500°C.
3.2. Aggregate characterization

Stony aggregates, bearing in mind that average measured parameters show results that fit the defined limits of technical specifications art. 400-07 INVIAS. All of the previous is focused on composition, cleansing, durability, geometry and specific gravity (see table 2).

Table 2. Stony aggregate characterization.

| Standard INVIAS-07 | Test Standard Value | MDC-2 Santa Teresa | MDF-2 Santa Teresa | MDC-2 La Emilia | MDF-2 La Emilia |
|------------------|-----------------|------------------|------------------|----------------|----------------|
| E 227-07 | Percentage of fractured faces (2 faces) | 60 % min. | 100 % | 100 % | 100 % |
| E 230-07 | Flattening index | Max 35 | 27.80 % | 37.91 % | 29.41 % | 37.10 % |
| E 230-07 | Elongation index | Max 35 | 26.27 % | 54.51 % | 25.98 % | 56.11 % |
| E 222-07 | Specific gravity of thick aggregates (Gsb) | N.A. | 2.53 | 2.60 | 2.57 | 2.60 |
| E 223-07 | Specific gravity of thick aggregates (Gsb-ss) | N.A. | 2577.00 | 2.63 | 2.62 | 2.63 |
| E 223-07 | Specific gravity of thick aggregates (Gsa) | N.A. | 2.65 | 2.69 | 2.71 | 2.69 |
| E 223-07 | Absorption % | 1.69 | 1.69 | 1.24 | 1.91 | 1.69 |
| E 218-07 | The wear resistance of machine of angeles aggregates | 30 % | 21.43 % | 21.22 % | 23.08 % | 21.60 % |
| E 125-07 | Liquid limit | Min 40 | 16.43 | 16.05 | 17.72 | 19.67 |
| E 126-07 | Plastic limit | 13.51 | 12.75 | 14.99 | 18.11 |
| E 125-07 | Plastic index | 4 a 9 | 2.92 | 3.30 | 2.73 | 1.56 |
| E 220-07 | Aggregates health against the action of sodium sulfate | Max 12 | 7.62 % | 8.00 % | 7.62 % | 2.60 % |

3.3. Bitumen characterization

Verified properties in bituminous products adjust to the requirements of technical specifications, defined by INVIAS art. 400-07 (see table 3).

Table 3. Bitumen Characterization results.

| Bitumen | Standard INVIAS-07 | Test Standard Value | MDC-2 Santa Teresa | MDC-2 La Emilia |
|---------|------------------|------------------|------------------|----------------|
| Asphalt Cement | E 706 – 07 | Penetration (1/10) mm | 70 -80 | 78.67 | 80.67 |
| E 723 – 07 | Distilation (%) | min 50 | 81 | 83 |
| E 707 – 07 | Specific Gravity Bulk Gbulk | N.A. | 1.131 | 1.069 |
| E 716/717-07 | Saybolt Furol viscosity (SSF) | 60-120 SSF | 60.5 | 61.01 |
| E 712 –07 | Softening point ring and bal (°C) | 30 - 200 °C | 59.1 | 50.9 |
| Asphalt Emulsion | E 763-07 | Saybolt Furol viscosity (SSF) | 0 - 200 | 25 | 24 |
| E 761-07 | Water content by volume (%) | Max 43 | 40 | 39 |
| E 767-07 | Loading particles | positive | Positive |
| E 762-07 | Distillation residues (%) | Min 57 | 60.0 | 62 |
| | P.H | Max 6 | 2.81 | 2.82 |
| | Retained sieve No 20 | Max 0.1 | 0.0135 | 0.014 |
4. Asphaltic mixture design
Starting from material characterization, granulometry was adjusted according to the INVIAS regulation for MDC-2 mixture and NT-1 traffic, thus defining the coarse aggregate and asphaltite percentages for the different groups. (Art 400-07).
For each proposed combination, we determined the optimal asphalt percentage using the Marshall method, according to Illinois methodology. Stability, flow, air voids, mineral aggregate voids and asphalt-filled voids were determined in this briquette; this was made with the intention of verifying with the values established by the INVIAS regulation. Values for stability and flow as main quality check parameters for this asphaltic mixture obtained for the MARSHALL and RAMCODES methods.
Once the optimal asphalt percentage, which included asphaltite, was obtained for each of the asphaltic mixtures and once the compliance of regulations was verified, the definite work formulas and the summary of design for mixtures in each group was summarized in table 4.

| Agregado          | MDC-2 Santa Teresa | MDF-2 Santa Teresa | MDF-2 la Emilia |
|-------------------|--------------------|--------------------|-----------------|
| Upper band        | Coarse aggregate % | 57                 | 58              | 65              |
|                   | Asphaltite %       | 43                 | 42              | 35              |
| Central strip     | Coarse aggregate % | 61                 | 52              | 70              |
|                   | Asphaltite %       | 39                 | 48              | 30              |
| Lower band        | Coarse aggregate % | 64                 | 48              | 87              |
|                   | Asphaltite %       | 36                 | 52              | 10              |

Mixtures made with an addition of natural asphalt as fine mineral aggregate and asphaltic contribution, show results on control parameters defined in the MARSHALL method, found within the parameter limit (INVIAS art 450-07) thus showing the effect of asphaltite presence, mainly in flow, since this parameter varies with asphaltite content in the work formula.

| Standard          | Criteria/Test               | Standard Value (NT-1) | MDC-2 Santa Teresa | MDF-2 Santa Teresa | MDF-2 la Emilia |
|-------------------|-----------------------------|-----------------------|--------------------|--------------------|-----------------|
| E 227-07          | Compaction (blows/face)    | 50                    | 50                 | 50                 |
| E 748-07          | Minimumestability (Kg)     | Min 500               | 603                | 570                | 641.5           |
| E 748-07          | Flow (mm)                  | 2-4                   | 3.74               | 6.5                | 3.861           |
| E 799-07          | Air gaps (Vv) Rolling      | 3-5                   | 4                  | 4                  | 3.6             |
| E 799-07          | Gaps in mineral aggregates (VAM) | 15               | 15.4               | 15.35              | 15.6            |
| E 799-07          | Voids filled with asphalt (VFA) | 65 - 80             | 74.1               | 73.8               | 77.2            |

5. Conclusions
The information obtained from the characterization experiments in the materials that conform the asphaltic mixture with asphaltite allow us to state that natural asphalt is a material that shows acceptable conditions for cold and hot asphaltic mixture elaboration, with the intention of use in asphalt roads NT1, since the compliance with quality standards was verified, according to regulations from the INVIAS.
Parameters determined for quality control in the asphaltic mixture (stability, flow, air voids, voids in mineral aggregates and asphalt filled voids) comply with values established in the INVIAS.
regulation, both in the MARSHALL and RAMCODES method, which allows us to state the technical viability of natural asphalt usage from Santa Teresa and la Emilia quarries in Pesca- Boyacá for the design and construction of MDC-2 and MDF-2 rolling layers for NT1 traffic roads.

Resulting work formulas for the designed mixtures allow us to ensure that the range defined by the granulometric strip are covered by the technical characteristics observed in the experimented briquettes, thus providing reliability regarding the unavoidable variations of size in aggregate particles and asphaltite.

The results obtained allow us to conclude that asphaltite is a material that proportionally affects quality in a mixture, since its higher volume percentage in the mixture produces higher values in flow, which can generate inadequate behavior from the mixture in the presence of heavy vehicles, slow traffic or high temperatures.

References

[1] Camacho C 1989 Estudio de Asfaltos Naturales de Boyacá como Capa de Rodadura (Tunja: Universidad Pedagógica y Tecnológica de Colombia)
[2] Chavarro H y Gómez F 1980 Utilización de una Mezcla Asfalto-Asfaltita en Pavimentos para Vías (Bucaramanga: Universidad Industrial de Santander)
[3] Fundación Laboratorio Nacional de Vialidad 2003 Diseño de Mezclas Asfálticas en Frio Empleando Emulsiones
[4] Guevara M, Méndez J y Pimentel J 2010 Diseño de Mezclas Asfálticas Densas en Frio Basado en el Método Marshall Modificado de la Universidad de Illinois (Salvador: Universidad de Salvador)
[5] Instituto de Desarrollo Urbano de Bogotá 2006 Especificaciones Técnicas para el Diseño y la Construcción de Capas Estructurales de Pavimentos con Asfaltos Naturales en Frio
[6] Instituto Nacional de Vías 2007 Especificaciones de Materiales para la Construcción de Carreteras
[7] Macucci F y Pinto A 2000 Estudio Técnico de Asfalto Natural (Tunja: PAVICOL)
[8] Mayorga A y Obregón R 1990 Utilización de Asfaltitas en Pavimentos (Bucaramanga: Universidad Industrial de Santander)
[9] Pérez G 2008 Materiales para Ingeniería Apuntes de clase (Tunja: Universidad Pedagógica y Tecnológica de Colombia Facultad de Ingeniería)
[10] Rematoso C y Villabona H 1979 Estudio para el Mejoramiento de Capas de Pavimentos con Asfalto Natural de Pesca (Bucaramanga: Universidad Industrial de Santander)
[11] Sánchez F J, Garnica P, Gómez J A, Pérez N 2003 RAMCODES: Metodología Racional para el Análisis de Densificación y Resistencia de Geomateriales Compactados (Queretaro: Instituto mexicano del Transporte)
[12] Sánchez F J 2004 Aplicación de RAMCODES en el diseño y control de compactación de suelos 4as Jornadas Internacionales del Asfalto Corasfaltos (Colombia: Cartagena)
[13] Sandoval J A 2007 Estudio geológico y Caracterización de las Asfaltitas de la Vereda Paloblanco en el Municipio de Vélez - Santander (Sogamoso: Universidad Pedagógica y Tecnológica de Colombia)