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Resistance under Marshall monotonic load for asphalt concrete mixtures

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Resistance under Marshall monotonic load for asphalt concrete mixtures

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Abstract. The dense hot MDC-19 type asphalt mixes are considered, by the "Instituto Nacional de Vías" in Colombia, as continuous grading asphalt mixes (asphalt concrete). These constitute most of the surface course, in the structures of in-service pavements, being the object of study and research in different projects to ensure their durability. In the present investigation, unlike other investigations, the mechanical behavior under Marshall monotonic load was studied in the laboratory between MDC-19 dense type asphalt mixtures, comparing plant-produced and laboratory-produced asphalt mixtures. To carry out this process, samples of uncompacted asphalt mixtures were taken, produced in four fixed plants, with which Marshall-type briquettes were compacted. Likewise, samples of mineral aggregates and asphalt cement were obtained from the same plants, which constitute the mixtures raw material produced there. With these materials, briquettes with the same characteristics were mixed and compacted. Subsequently, the resistance under Marshall monotonic load was determined on the briquettes manufactured in plant and laboratory. The optimal asphalt cement content was compared between plant and laboratory-produced mixtures. An increase in Marshall Stability was found in the briquettes made with plant-produced mixtures, while these required a greater amount of asphalt cement for their production.

1. Introduction

Dense hot mixes are known in Colombia as asphalt concrete mixes following the standard of "Instituto Nacional de Vías (INVÍAS)" [1]. These are mixtures that are placed as layers of asphalt bases and surface course in flexible pavements, the latter being the most used worldwide (more than 90%) according to "Asociación de Productores y Pavimentadores Asfálticos de Colombia (ASOPAC)" [2], and European Asphalt Pavement (EAPA) [3,4]. These mixtures are characterized by having a percentage of air voids between 3% and 9%, which makes them waterproof, also presenting high resistance to traffic loads and weathering agents.

They are manufactured in fixed or road plants at a high temperature (depending on the viscosity of the asphalt binder to be used) and are made up of the union between asphalt cement and mineral aggregates that vary in size from passing 1" sieve to passing sieve No. 200 [1]. Among the factors that affect the behavior of asphalt concrete mixtures are the source of the aggregates, their distribution, size and shape, type of asphalt cement and its rheological characteristics, mixing temperature, compaction temperature, and mixing process in the plant and the laboratory. Authors who have studied some of these factors include [5-8].

In the present investigation, the study of asphalt concrete mixtures was deepened, considering the influence that the source of the mineral materials has on the resistance, under a monotonic load, of MDC-19 type mixtures, manufactured in the plant and the laboratory.

2. Materials and methods

Samples of MDC-19 type asphalt mixtures (loose, not compact) were obtained from four production plants (P1, P2, P3, and P4). These mixtures were subjected to a compaction process in the laboratory, to obtain 4" in diameter and 2.5" thick briquettes. The traffic was considered greater than 5.0 equivalent axles of 80 KN in the design lane, for INVÍAS [1], which required compaction at 75 strokes on each face [9]. Likewise, samples of mineral aggregate and asphalt cement type CA 60-70 mm/10 were obtained, with which the asphalt mixtures are produced in each plant. Plant P1 and plant P4 obtain the aggregate from the same source (F1), and plant P2 and plant P3 obtain them from sources F2 and F3 respectively.

The asphalt cement for the four plants comes from the same source. The mineral materials and asphalt cement type CA 60-70 mm/10 were evaluated in the laboratory considering the characteristic tests recommended by [1]. Subsequently, with the aggregates and asphalt cement from each plant, we proceeded to design and manufacture MDC-19 asphalt concrete mixtures in the laboratory, mixing and compacting 4" diameter, and 2.5" thick briquettes, at mixing and compaction temperatures referred to by the viscosity of the asphalt cement used. Table 1 shows the granulometry for the manufacture of an MDC-19. Each compacted briquette had an approximate weight of 1200 g.

Three briquettes were manufactured for each percentage of asphalt cement considered (4.5%, 5.0%, 5.5%, 6.0%, 6.5%). Both the compacted briquettes with the loose mixtures from each plant, as well as the laboratory-compacted briquettes, were subjected to the Marshall test to determine their resistance under monotonic load. This allowed us to calculate the optimum percentage of asphalt in the mixtures and the stability/flow ratio, known as Marshall stiffness. In Colombia, this test is regulated by the INVÍAS standard [1].

A more detailed description of this procedure can be found in American Association of State Highway and Transportation (AASHTO T 245) [10], asphalt mix design methods [11,12], American Society for Testing and Materials (ASTM D6926-10) [13], and "Una Norma Española (UNE-EN 12697-34)" [14]. The asphalt content extraction test [1] and aggregate granulometry test [1] were carried out on the loose asphalt mixtures from each plant, to determine the optimum percentage of asphalt.

Table 1. Granulometric distribution for an MDC-19 mixture.

Sieve	Sieve (mm)	Percent passing (%)
3/4"	19.000	100.0
1/2"	12.500	87.5
3/8"	9.500	79.0
No. 4	4.750	57.0
No. 10	2.000	37.0
No. 40	0.430	19.5
No. 80	0.180	12.5
No. 200	0.075	6.0

3. Results

Table 2 shows the results for the aggregate characterization of the four plants evaluated; variability is observed in the parameters for hardness, particle shape, and material cleanliness, even though two samples came from the same source. The foregoing is due to the process and site of exploitation of the materials. The tests were based on the INVÍAS standard [1]. Table 3 shows the results of the asphalt cement used in each plant to produce the asphalt mixtures, which corresponds to the same asphalt cement used for the manufacture of the briquettes in the laboratory. It can be noted that the asphalt cement CA 60-70 mm/10, complies with the parameters´ ranges proposed by the INVÍAS standard [1].

Table 2. Results of the characterization of the aggregate of the four plants.

Test	Recommended	P1	P2	P3	P4
Specific gravity/fine aggregate absorption	-	2.55/1.03	2.55/1.70	2.55/1.60	2.54/1.62
Specific gravity/coarse aggregate absorption	-	2.57	-	-	-
Fractured particles (1 side)	85% minimum	90.92	91.07	93.31	98.76
Flattening index	10% maximum	3.01	3.47	13.33	11.90
Elongation index	10% maximum	7.68	14.07	10.73	8.82
Plasticity index	Not plastic	NP	NP	NP	NP
Sand equivalent (%)	50 minimum	56.82	52.08	33.33	43.28
Abrasion in Los Angeles machine	25% maximum	34.90	24.67	36.92	37.03

Table 3. Results of the characterization of asphalt cement CA 60-70 mm/10.

Test	Unit	Recommended value	P1	P2	P3	P4
Specific gravity (Kg/m^3)	-	-	1011	990	1011	1010
Penetration (25°C-100 g-5 s)	mm	6-7	61	63	63	65
Penetration Index	-	-1.2/+0.6	-0.79	-0.90	-0.65	-0.80
Viscosity (60°C)	Poise	1500 minimum	2340	2120	2120	2140
Softening point	°C	48-54	49.8	48.9	50.0	49.2
Ductility (25°C-5cm/min)	cm	100 minimum	136.5	140.0	130.0	145.0
Flash point	°C	230 minimum	298	296	304	278

Table 4 and Table 5 show, respectively, the mean of the granulometry and the mean of the percentage of asphalt cement obtained from the characterization of the asphalt mixtures, in a loose state, produced in the four plants. Variation can be noted in the percentages of material that pass the sieves with the highest denomination, and an equal trend in the sieves that pass No. 4 sieve. An average value of the asphalt cement is observed oscillating around 5.37%.

Table 4. Average granulometry in asphalt mixtures in plants.

Sieve	Percent passing (%) [1]	P1	P2	P3	P4
¾”	100	100.00	100.00	100.00	100.00
½”	80-95	80.01	82.23	90.42	90.31
3/8”	70-88	65.21	72.00	80.84	78.81
No. 4	49-65	48.19	44.50	53.94	54.32
No. 10	29-45	37.06	32.74	35.96	39.21
No. 40	14-25	24.91	17.62	21.91	26.22
No. 80	8-17	18.13	10.14	13.14	16.75
No. 200	4-8	11.45	6.28	7.10	8.91

Table 5. Average asphalt cement in asphalt mixtures in plants.

Plant	P1	P2	P3	P4
Asphalt percent (%)	5.17	5.48	5.51	5.33

Table 6 shows the results of the stability/flow test (S/F) carried out on the compacted briquettes with the mixtures from each plant and on the briquettes produced in the laboratory with the materials (mineral aggregates and asphalt cement) from the same plants. Compliance with the parameters required by the regulations is observed.

Table 6. Stability/flow test results.

Parameters	P1		P2		P3		P4	
	MP	ML	MP	ML	MP	ML	MP	ML
Stability S (N)	13750	13100	16234	13700	16357	12000	18835	13400
Flow F (mm)	3.10	2.98	3.50	2.80	3.40	2.60	3.52	3.05
S/F (KN/mm)	4.44	4.40	4.64	4.89	4.81	4.62	5.35	4.39

MP is mix in plant, and ML is mixing in laboratory.

Table 7 shows the percentages of asphalt cement found in the extraction test carried out on the mixtures made in the plant, and the percentages of asphalt cement obtained by the stability/flow test and analysis of gravimetric and volumetric relationships carried out on the mixtures produced in the plant and those made in the laboratory. It is noteworthy that there is a greater requirement for asphalt cement in the mixtures manufactured in the plant, with respect to the mixtures prepared in the laboratory.

The above, because the aggregates in the laboratory were separated into each of the sizes indicated for an MDC-19 (From pass 3/4" sieve to pass No. 80 sieve), and subsequently washed and dried; contrary to the process applied in the plant, where the materials are separated into fractions (coarse, medium and fine), and these are not washed and dried. This makes the finer materials adhere to the thick ones, requiring more amount of bitumen. The asphalt cement content obtained by the extraction process on the mixtures produced in the plants is lower than the optimal percentages obtained in the Marshall design.

Table 7. Percentages of asphalt cement CA.

Plant	P1	P2	P3	P4
CA% by extraction	5.17	5.48	5.51	5.33
CA% Plant-produced mix	5.50	5.88	5.75	5.70
CA% mixtures produced in the laboratory with materials from each plant	5.20	5.40	5.20	5.50

4. Conclusions

The Marshall test on the mixtures produced in the plant and the laboratory determines that the aggregate preparation process, as well as the source of the material, influences the determination of the optimum percentage of asphalt cement in asphalt mixtures; the present study ranged around 5.71% for mixtures produced in the plant, and around 5.32% for mixtures produced in the laboratory, which represents 0.4% of additional consumption in the plant. Greater consumption of asphalt is required in the plant due to the higher content of fines in the mix, pass No. 200 sieve.

Marshall stability is above the minimum estimated by the standard of “Instituto Nacional de Vías”, with higher values found in the plant. The higher the content of fines, the higher the consumption of asphalt cement, and the higher the resistance under Marshall monotonic load. It is recommended to adjust to the asphalt mix design in the plant, considering that the aggregates are not separated, nor are they washed before mixing them. In future research it is recommended to determine on asphalt mixtures manufactured in plant and laboratory, the resistance under cyclic load and the resistance to permanent deformation.

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