WARM MIX ASPHALT BASED ON BITUMEN EMULSIONS

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ABSTRACT

Bituminous emulsions are used traditionally for surface treatment and cold mixes, but nowadays, formulation technology allows to obtain products that can be used successfully in the field of the WMA. The goal of this technology is to design emulsions to achieve mechanical properties in the WMA as close as possible of those of the hot mixes, and far away from those usual in cold mixes.

In this document the results obtained in the study of a WMA produced using a specially developed emulsion are discussed. For the study accomplishment, a previous laboratory characterization of the WAM has been carried out, and later a field trial of that WMA was performed in order to gain more experience, where practical information about the production and placement behavior has been compiled. No control HMA has been taken as a reference.

The study is made by means of conventional mechanical tests (Marshall, Stiffness, Wheel Tracking Test,…etc) of both laboratory and plant produced WMA, and also the characterization of the original and recovered binder has been carried out.

Keywords: wma, emulsion, additives

1. INTRODUCTION

A number of new technologies have been developed, to reduce the production and placement of asphalt mixes temperature, these technologies are referred to as Warm Mix Asphalt (WMA), and they are a promising alternative to Hot Mix Asphalt (HMA), because they have proved to be more environmental friendly and energy saved, without a decrease in the security and performance characteristics during service.

The range of production temperatures within warm mix asphalt vary from 110ºC to 140ºC, which is 20-40ºC lower than those used in HMA. For that purpose, several technologies based on emulsions, bitumen foams, waxes and organic additives have been developed. One of the most promising methods is to introduce it in the mixer with the aggregates a bituminous emulsion.

In this paper a special bituminous emulsion has been used to carry out a WMA field trial of a AC 22 surf S. In a first stage, the optimum binder content have been determined according to the aggregates gradation proposed. After that, a laboratory characterization of the mix properties has been carried out. Finally, after the field trial, the asphalt mix produced in the plant has been also tested.

2. EMULSION CHARACTERISTICS

The characteristics of the emulsions used in WMA differ from typical emulsions for cold mixes and surface treatment, in the bitumen type and additives that help in the mixing process. The experience obtained by Repsol, shows that a high bitumen content is necessary, which has to be a hard grade, and also specific emulsifiers, that help in the coating process, reducing the surface tension of the bitumen. By using these parameters the final characteristics reached in the pavement are expected to be near the HMA.

The properties of the emulsion used in the trial are shown in table 1.

Table 1 : Emulsion characterization

Test	Unit	Standard	Result
Bitumen content	%	EN 1428	68,8
PH		EN 12850	5,7
Efflux time (50ºC, 4 mm)	s	EN 12846-1	7
Settling tendency (70ºC, 7 days)	%	EN 12847	4

The settling tendency was determined at 70ºC, because this temperature is closer to that used in the practice and represents the real behavior during storage. At 25ºC the emulsion presents a semisolid like aspect with no settling tendency.

The bitumen used in the emulsion was a 50/70 grade, with a specific needle penetration of 57 (0.1 mm) . To obtain proper coating of aggregates a suitable emulsifier was necessary. This emulsifier was chosen in a previous coating study, from a list of emulsifiers commonly used in bituminous emulsions.

The coating study realized is simple. It consists in mixing the aggregates (at 110ºC) with different bituminous emulsions (at 80ºC) varying the type and quantity of emulsifier used. The mix process is carried out in a manual way, and after that, the aggregates coating degree is checked visually. The emulsifier chosen produces a fully coated aggregate easily, following this process.

3. AGGREGATE GRADATION

After a determination of the size of the different aggregate fractions, the optimum composition for the AC 22 gradation, was the following:

12/18 fraction: 33%
6/12 fraction: 10%
4/6 fraction: 22%
0/4 fraction: 35%

Table 2 : Aggregate gradation

Sieve (mm)	Percent Passing	AC 22 S gradation
32	100	100
22	100	90-100
16	83	70-88
8	58	50-66
2	28	24-38
0,5	12	11-21
0,25	9	7-15
0,063	4,8	3-7

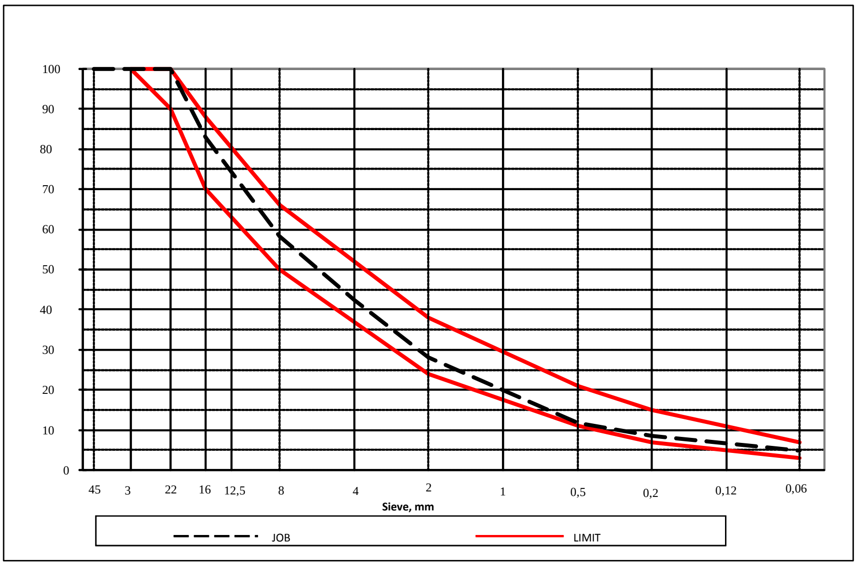

Figure 1. Gradation used

The aggregates relative density obtained for this gradation was 2766 Kg/m^3.

4. EMULSION OPTIMUM CONTENT DETERMINATION

The optimum binder content was calculated following the equation defined by Duriez.

$Pb=K.\alpha. \sqrt[5]{A}$

Where:

Pb= Binder content
K= richness coefficient
α= 2,65/bulk relative density of the aggregates
A= Conventional specific surface area of the aggregate, defined as 0.25 G + 2.3S + 12s + 135f (G:Proportion by weight of aggregates larger than 6.3 mm; S = Proportion by weight of aggregates between 6.3 and 3.15 mm; s = Proportion by weight of elements between 3.15 and 0.80 mm; and f = Proportion by weight of elements smaller than 0.80 mm)

The K value used in the formula was 3,1 according to our experience in cold mixes design. The theoretical optimum bitumen content calculated , expressed as percentage of total mass of the mixture was 4,27%. The percentage calculated is under the minimum specified for a AC 22 surf S (4,30% with the density correction factor). Consequently, the minimum binder content chosen for the study of the WAM was 4,30%.

5. LABORATORY STUDIES

Using the optimum binder content, a study of the WMA properties was carried out in the laboratory. To prepare the specimens , a gyratory compactor was used. This method was chosen because simulate more closely the compaction that takes place in service, and it allows a reorientation of the aggregates similar to that produced in the in-situ compaction. The conditions of the mix and compaction process can be seen on table 3.

Table 3: Compaction data

Characteristic	Unit	Value
Aggregate temperature	ºC	110-115
Emulsion temperature	ºC	80
Compaction temperature	ºC	90-95
Consolidation pressure	KPa	600
Contact angle	º	0,82
Speed	rpm	30
Emulsion percentage	%	6,25
Bitumen percentage	%	4,3

In the first trials, the number of gyrations needed to reach an air void content appropriate for that kind of gradation (4-7%) have been higher than expected, with a medium value of 190. Finally, because 190 gyrations were used, the final results in air void content obtained have been under the minimum value.

Table 4 : WMA characterization

Test	Unit	Value
Bulk relative density, ssd	Kg/m^3	2495
Air void content	%	3,4
Voids in Mineral Aggregate	%	13,8
Stiffness	MPa	4462
Marshall stability	KN	8,7
Flow index	mm	3,4

The stiffness value has been determined by the indirect tensile strength method, according to EN 12697-26 C annex, while the Marshall stability and flow index has been calculated under the test method specified in EN 12697-34. According to our experience, the values obtained are lower than those obtained in similar mixes when manufactured at a temperature corresponding to a hot mix. This can be explained taking into account that, by this method, the binder suffers less hardening because the temperature is lower.

To determinate the water sensibility of the mix according to EN 12697-12, new specimens were compacted, with a target void content of 7%. In this case the number of gyrations obtained was 60. The test was carried out following the method A of the Standard.

Table 5 : Water sensibility results

Test	Unit	Value
Temperature	ºC	15
Indirect tensile strength (dry specimens)	KPa	2030
Indirect tensile strength (after water immersion)	KPa	1729
Indirect tensile strength ratio	%	**85**

As can be seen in table 5, the Indirect Tensile ratio obtained is 85%, that would pass the Spanish requirements for surface layers.

For the wheel tracking test, specimens have been prepared by the roller compactor, according to EN 12697-33, to reach a target void content of 5-6%.The results obtained in the wheel tracking test are presented in Table 6.

Table 6 : Wheel tracking test results

Test	Unit	Specimen 1	Specimen 2	Medium
Bulk relative density, ssd	Kg/m^3	2430	2430	2430
Air void content	%	5,9	5,9	5,9
WTS_{air}	$mm/10^3$ cycles	0,09	0,086	0,088
RD_{air}	mm	2,776	2,769	2,772
PRD_{air}	%	4,68	4,67	4,68

The value of WTS is higher than those required in Spain for this type of layers. Again, the lower values can be explained due to the lower hardening of the binder because of the lower temperature.

6. FIELD TRIAL

The emulsion arrived on site at a temperature of 85ºC and was offloaded into an storage tank and maintained at a temperature of 80ºC. No pumping problem was detected. The aggregates were heated to 110-115ºC in the plant, and then mixed with the emulsion, resulting in a discharge temperature of 87ºC. No modifications in plant were necessary.

During the mixing process, some steam was liberated, as can be seen in figure 2. But no troubles associated with moisture in the baghouse were observed.

Figure 2. Plant production

During the laying no fumes and or steam were detected, as can be seen in figure 3. The temperature measured in the asphalt concrete behind the paver screed was 77ºC (figure 4). The layer operation was very similar to HMA, but without fumes, and a more comfortable work atmosphere because of the lower temperature.

Figure 3. Paving without fumes

Figure 4. Asphalt concrete temperature

7. SAMPLES TEST

A sample of about 50 Kg of the WMA produced in the plant was taken, in order to study in laboratory the characteristics of the mix. The compaction method used was the gyratory compactor, applying the same gyrations obtained in the previous laboratory study (190), and the loose warm mix was reheated at a temperature of 90ºC. No curing conditions were applied.

Table 7: WMA characterization

Test	Unit	Value
Bulk relative density, ssd	Kg/m^3	2450
Air void content	%	5,8
Voids in Mineral Aggregate	%	17,2
Stiffness	MPa	4056
Marshall stability	KN	10,27
Flow index	mm	4,2

For the water resistant test, the same methodology was applied, but with 60 gyrations instead the previous 190.

Table 8 : Water sensibility results

Test	Unit	Value
Air void content	%	6,5
Temperature	ºC	15
Indirect tensile strength (dry specimens)	KPa	1830
Indirect tensile strength (wet specimens)	KPa	1520
Indirect tensile strength ratio	%	**83**

And in a similar way the wheel tracking test.

Table 9 : Wheel tracking test results

Test	Unit	Specimen 1	Specimen 2	Medium
Bulk relative density, ssd	Kg/m^3	2400	2400	2400
Air void content	%	6,2	6,2	6,2
WTS_{air}	$mm/10^3$ cycles	0,01	0,012	0,011
RD_{air}	mm	0,05	0,05	0,05
PRD_{air}	%	0,1	0,1	0,1

Results obtained were similar of those obtained in Laboratory, except in the case the Wheel Tracking Test. The WTS, RD and PRD and much more lower than those obtained in the previous laboratory studies. These values would pass the Spanish requirements for surface layers.

The bitumen content of the plant produced asphalt mix, was determined by means of a solvent extraction, according to EN 12697-3, also a comparison in terms of viscosity, needle penetration, and softening point was made with respect to the original bitumen used in the emulsion (Table 10).

Table 10 : Binder extraction

Test	Unit	Original	Recovered
Bitumen content	%	4,5	4,7
Penetration	0,1 mm	57	55
Ring & Ball	ºC	50,5	51,5
Viscosity 135ºC	cp	385	415

The recovered bitumen has very similar physical properties to the original one, which means that the WMA carried out with bituminous emulsions do not oxidized the bitumen in the same way as the HMA does, the lower temperature and the thin water film present during the mixing with aggregates, reduce the oxidative hardening, which can provide benefits in the long term aging [1], and can explain some limited values in the mechanical tests results.

8. CONCLUSIONS

The methodology carried out to design in laboratory a WMA based on emulsion has been successful, and the later field trial has also obtained suitable characteristics. No control HMA has been needed for a comparison of the performance .

Comparing the test results for the laboratory and plant produced WMA, there is a significant difference in the Wheel tracking test WTS value, being the plant produced mix more resistant to rutting effects.

REFERENCES

[1] Newcomb, D. "An Introduction to Warm-Mix Asphalt." National Asphalt Pavement Association. Accessed from http://fs1.hotmix.org/mbc/Introduction_to_Warm-mix_Asphalt.pdf August 8, 2007.