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REPORT. COMPARATIVE ANALYSIS OF BITUMINOUS HOT MIX AND WARM MIX

CLIENT: UNICO GREEN S.L.
FILE: R.P. 117-M and 119-M
WORK: BITUMINOUS MIXTURES FROM ITALY

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1 Background

UNICO ASFALTOS (UNICO GREEN S.L.), requests to Gruppo PLP the present work to analyse the characteristics of a bituminous mix type AC 11 surf PMB 45/80-65 D designed in Italy, when it is manufactured and compacted in hot (180 ºC and 160 ºC), when additive with 0,7% BioRoad Warm mix it is manufactured and compacted in warm (140 ºC and 120 ºC) and, when additive with 2% BioRoad Warm mix it is manufactured and compacted in warm (110 ºC and 80 ºC).

In particular, analysis of the workability and final performance of both bituminous mixes is required.

This mixture is composed of a large proportion of Reclaimed Asphalt, hereinafter RA as indicated in UNE EN 13108-8.

2 Objectives of the work

As indicated in the Background section, the objectives of the work are to determine the characteristics of the hot mix AC 11 surf PMB 45/80-65 D and, with BioRoad Warm mix additives, the warm mix, analysing whether workability or performance is lost when working at lower temperatures.

3 Working formula

The working formula and the manufacturing process of the bituminous mixes have been provided by the applicant.

3.1 Aggregates

The aggregate allocations are as indicated in the following table:

ARID	DOTATION (kg)	
	kg	%
2/6 Basalt gravel	11,30	11,3
6/10 Basalt gravel	18,20	18,2
Filler	0,50	0,5
Reclaimed asphalt (RA)	70,00	70

Image nº1. Aggregate supply of the bituminous mix.

With the proportion of RA used, the bitumen contributed by this material accounts for 3,78% of the mix.

3.2 Binder

The mix and the proportion of new bitumen and bitumen supplied by the RA are as indicated in the following table.

BETUNES	NEW BETÚN. PREPARATION	
	kg	%
CONTRIBUTED BY THE RA	3,78	3,78
NEW (PMB 45/80-65)	1,62	1,62

Figure 3. Amount of bitumen (new + added RA) used in the bituminous mix.

3.3 Hot mix asphalt preparation

3.3.1 Activation of the RA

According to the petitioner, the RA has been activated in the laboratory.

The milling activation is carried out by heating between 120º and 110º, then it is left to stand for a minimum of 15 minutes before being used in the manufacture of the mixture.

3.3.2 Hot mix asphalt manufacture

Once the RA has been activated and the new bitumen has been prepared, the bituminous mix is produced hot with the above-mentioned additions.

The manufacturing temperature was 180 ºC.

The compaction temperature of the test specimens for the laboratory tests was 160 ºC.

3.3.3 Production of the Warm mix asphalt mixture with 0.7% BioRoad

Once the RA has been activated and the new bitumen has been prepared, the bituminous mix is produced in Warm condition with the above mentioned additions.

Subsequently, 0.7 per cent BioRoad Warm mix was added to the asphalt mix, replacing part of the total bitumen in the mix, with the total amount of binder remaining unchanged at 5.4 per cent (RA bitumen + added bitumen + bioroad).

The manufacturing temperature was 140 ºC.

The compaction temperature of the test specimens for the laboratory tests was 120 ºC.

With the BioRoad Warm mix, working temperatures have been lowered by 40°C compared to the standard sample

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3.3.4 Production of the Warm mix asphalt mixture with 2% BioRoad

Once the RA has been activated and the new bitumen has been prepared, the bituminous mix is produced in Warm condition with the above mentioned additions.

Subsequently, 2% BioRoad Warm mix was added to the asphalt mix, replacing part of the total bitumen in the mix, with the total amount of binder remaining unchanged at 5.4 per cent (RA bitumen + added bitumen + bioroad).

The manufacturing temperature was 110 ºC.

The compaction temperature of the test specimens for the laboratory tests was 80 ºC.

With the BioRoad Warm mix, working temperatures have been lowered by 70°C compared to the standard sample.

4 Trials

The tests carried out were those necessary to determine the workability and performance of the two types of bituminous mixes.

4.1 Workability

The workability of a bituminous mix is linked to the viscosity of the binder. It is therefore essential to decide on the manufacturing and compaction temperatures.

The workability of a bituminous mix is closely linked to the density achieved for a typical compaction.

The characteristics of a bituminous mixture, determined on test specimens, will depend on the density of the test specimens.

In summary, the workability of the Warm mix (at the indicated temperatures) will be higher or lower than the hot mix (at the indicated temperatures), based on the density values obtained in the specimens prepared by impact (UNE EN 12697-30) with these mixtures and temperatures.

That is why the tests to determine and analyse the workability have been carried out:

- **UNE-EN 12697-5:2020.** Bituminous mixtures. Test methods. Part 5: Determination of maximum density.
- **UNE-EN 12697-6:2022.** Bituminous mixtures. Test methods. Part 6: Determination of the apparent density of bituminous specimens.
- **UNE-EN 12697-8:2020.** Bituminous mixtures. Test methods. Part 8: Determination of void content in bituminous specimens.

4.2 Performance of bituminous mixes

The performances taken into account to analyse the two types of mixes were water sensitivity.

The tests carried out were as follows:

- **UNE-EN 12697-12:2019.** Bituminous mixtures. Test methods. Part 12: Determination of the water sensitivity of bituminous mixture test specimens.

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5 Results obtained

The laboratory reports of the results of the above tests are attached in the annex.

5.1 Workability

5.1.1 Results obtained

The following table summarises the results obtained

PARAMETERS		RESULTS		
		HOT MIXING	WARM MIX 0,7%	WARM MIX 2%
Maximum density ($^{kg/m3}$)		2.367	2.366	2.366
Breaking load P (KN)		14.412	14.261	14.313
Gaps (%)	Air	4,68	4,70	4,67

Figure 4. Workability of bituminous mixes

5.1.2 Analysis of the results obtained

As you can see, the three mixes show very similar results.

The workability of the mix without BioRoad Warm, made at 180 ºC and compacted at 160 ºC, is practically the same as the mix with 0.7% added BioRoad Warm, made at 140 ºC and compacted at 120 ºC and the mix with 2% added BioRoad Warm, made at 110 ºC and compacted at 80 ºC.

By reducing the working and compaction temperatures to 110°C and 80°C, it can be seen that the workability is not altered.

5.2 Services

5.2.1 Results obtained

The following table summarises the results obtained

PARAMETERS		RESULTS		
		HOT MIXING	WARM MIX 0,7%	WARM MIX 2%
Water sensitivity	Indirect tensile strength wet $(ITS)_d$	1,38	1,36	1,37
	Indirect tensile strength dry $(ITS)_w$	1,43	1,41	1,41
	Relationship between resistances to indirect traction (ITSR %)	97	96	97

Figure 5. Characteristics of the bituminous mix in Working Formula

5.2.2 Analysis of the results obtained

As you can see, the performance of the three types of mixtures in terms of workability is very similar.

The ITSR values are higher than the minimum of 85% required by European road standards for this type of mixture used in wearing courses; for base and intermediate courses, the ITSR must be higher than 80%.

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6 Conclusions

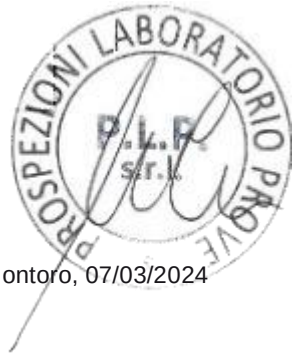
Based on the tests carried out, it can be concluded that:

With bioroad warm mix, at a dosage of 0.7% of total biding material similar or better results were achieved vs. Our specimen mixture where 70% of Rap is accounted for and composed of a PMB type bitumen, produced at 140ºC and compactated at 120ºC. Tests were further extended to production temperatures of 110ºC and compactation at 80ºC, with 2% of Bioroad warm mix, where similar positive results were measured vs specimen.

The Warm mix has the same workability and performance as the hot bituminous mix.

7 Date and signatures

This report consists of a cover page, table of contents, five pages and three annexes.



Montoro, 07/03/2024

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ANNEX 1

Test report.
Hot bituminous mixture

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DETERMINATION OF THE WATER SENSITIVITY OF BITUMINOUS SPECIMENS

Normative reference: UNI EN 12697-12

Client : UNICO ASFALTOS — **Prot.:** R.P.117-M

Bituminous mixture : Milled at 70% - compaction temperature 160°C — **Data:** 22/02/2024

Specimens	Specimen characteristics			Breaking load P (KN)	Indirect tensile strength ratio ITS (MPa)	Deformation diametric at break (mm)	Indirect traction coefficient CTI (N/mm^2)	% Void (UNI EN 12697-8)	Type of specimen failure	Type of aggregate failure
	Diameter D (mm)	Height H (mm)	Density mass (Kg/m^3)							
1	100	65,1	2364	14,599	**1,428**	1,45	**155**	4,8	a	e
2	100	65,4	2370	14,475	**1,410**	1,48	**150**	4,6	a	e
3	100	65,2	2369	14,769	**1,443**	1,40	**162**	4,6	a	e
Test temperature: 25°C on dry samples (UNI 12697-23)										

Specimens	Specimen characteristics			Breaking load P (KN)	Indirect tensile strength ratio ITS (MPa)	Deformation diametric at break (mm)	Indirect traction coefficient CTI (N/mm^2)	% Void (UNI EN 12697-8)	Type of specimen failure	Type of aggregate failure
	Diameter D (mm)	Height H (mm)	Density mass (Kg/m^3)							
1	100	65,7	2368	13,969	**1,354**	1,70	**125**	4,6	a	e
2	100	65,6	2361	14,420	**1,400**	1,60	**137**	4,9	a	e
3	100	65,0	2370	14,245	**1,396**	1,73	**127**	4,6	a	e
Test temperature: 25°C on wet samples (conditioned in water at 40°C for 72 hours) (UNI 12697-23)										

Compaction method: Impact compaction 2 x 50 strokes (UNI EN 12697-30)

Type of specimen failure: a) clear tensile failure; b) deformation; c) combination.

Type of failure of the aggregates: d) broken; e) intact.

Is the average indirect tensile strength of the dry group	ITS_d	1,43
Is the average indirect tensile strength of the wet group	ITS_w	1,38
Is the indirect tensile strength ratio (%)	ITSR	97

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ANNEX 2

Test report.
warm mix asphalt 0,7%

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DETERMINATION OF THE WATER SENSITIVITY OF BITUMINOUS SPECIMENS

Normative reference: UNI EN 12697-12

Client : UNICO ASFALTOS **Prot.:** R.P.117-M

Bituminous mixture : Milled at 70% - 0.70% Additive Warm mix - compaction temperature 120°C **Data:** 22/02/2024

Specimens	Specimen characteristics			Breaking load P (KN)	Indirect tensile strength ratio ITS (MPa)	Deformation diametric at break (mm)	Indirect traction coefficient CTI (N/mm^2)	% Void (UNI EN 12697-8)	Type of specimen failure	Type of aggregate failure
	Diameter D (mm)	Height H (mm)	Density mass (Kg/m^3)							
1	100	65,3	2368	14,425	**1,407**	1,48	**149**	4,6	a	e
2	100	65,1	2365	14,568	**1,425**	1,51	**148**	4,8	a	e
3	100	65,6	2366	14,501	**1,408**	1,45	**153**	4,7	a	e
Test temperature: 25°C on dry samples (UNI 12697-23)										

Specimens	Specimen characteristics			Breaking load P (KN)	Indirect tensile strength ratio ITS (MPa)	Deformation diametric at break (mm)	Indirect traction coefficient CTI (N/mm^2)	% Void (UNI EN 12697-8)	Type of specimen failure	Type of aggregate failure
	Diameter D (mm)	Height H (mm)	Density mass (Kg/m^3)							
1	100	66,0	2368	14,206	**1,371**	1,75	**123**	4,6	a	e
2	100	65,8	2366	14,010	**1,356**	1,73	**123**	4,7	a	e
3	100	65,5	2363	13,856	**1,347**	1,77	**120**	4,8	a	e
Test temperature: 25°C on wet samples (conditioned in water at 40°C for 72 hours) (UNI 12697-23)										

Compaction method: Impact compaction 2 x 50 strokes (UNI EN 12697-30)

Type of specimen failure: a) clear tensile failure; b) deformation; c) combination.

Type of failure of the aggregates: d) broken; e) intact.

Is the average indirect tensile strength of the dry group	ITS_d	1,41
Is the average indirect tensile strength of the wet group	ITS_w	1,36
Is the indirect tensile strength ratio (%)	ITSR	96

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ANNEX 3

Test report.
warm mix asphalt 2%

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DETERMINATION OF THE WATER SENSITIVITY OF BITUMINOUS SPECIMENS

Normative reference: UNI EN 12697-12

Client : UNICO ASFALTOS

Bituminous mixture : Milled at 70% - 2% Additive Warm mix - compaction temperature 80°C

Specimens	Specimen characteristics			Breaking load P (KN)	Indirect tensile strength ratio ITS (MPa)	Deformation diametric at break (mm)	Indirect traction coefficient CTI (N/mm^2)	% Void (UNI EN 12697-8)	Type of specimen failure	Type of aggregate failure
	Diameter D (mm)	Height H (mm)	Density mass (Kg/m^3)							
1	100	65,3	2360	14,448	**1,403**	1,49	**149**	4,5	a	e
2	100	65,1	2355	14,526	**1,428**	1,50	**148**	4,9	a	e
3	100	65,6	2358	14,518	**1,401**	1,47	**153**	4,6	a	e
Test temperature: 25°C on dry samples (UNI 12697-23)										

Specimens	Specimen characteristics			Breaking load P (KN)	Indirect tensile strength ratio ITS (MPa)	Deformation diametric at break (mm)	Indirect traction coefficient CTI (N/mm^2)	% Void (UNI EN 12697-8)	Type of specimen failure	Type of aggregate failure
	Diameter D (mm)	Height H (mm)	Density mass (Kg/m^3)							
1	100	66,0	2358	14,245	**1,378**	1,76	**123**	4,8	a	e
2	100	65,8	2356	14,190	**1,353**	1,74	**126**	4,5	a	e
3	100	65,5	2359	13,954	**1,382**	1,75	**123**	4,7	a	e
Test temperature: 25°C on wet samples (conditioned in water at 40°C for 72 hours) (UNI 12697-23)										

Compaction method: Impact compaction 2 x 50 strokes (UNI EN 12697-30)

Type of specimen failure: a) clear tensile failure; b) deformation; c) combination.

Type of failure of the aggregates: d) broken; e) intact.

Is the average indirect tensile strength of the dry group	ITS_d	1,41
Is the average indirect tensile strength of the wet group	ITS_w	1,37
Is the indirect tensile strength ratio (%)	ITSR	97

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