WHICH GRADE OF BITUMEN FOR COLD ASPHALT CONCRETE ?

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ABSTRACT

The renewed interest in emulsion mixes and in particular for cold asphalt concrete is reinforced because of the distinct advantages in respect of the environment and the strong emphasis recently placed on sustainable development.

French standard P 98-139 of January 1994 defines the wearing course emulsion asphalt concrete for road surfaces supporting low to medium traffic and especially recommends a 70/100 or 160/220 as the base bitumen of the emulsion.

To assess the effect of the bitumen grade on the behaviour of mixes in July 2005 EIFFAGE TRAVAUX PUBLICS completed two adjoining sections of cold bitumen concrete with these two grades of bitumen and the same formula, in terms of aggregate and binder content, on a local road of the Correze in the Massif Central (France).

It was monitored for four years: it showed that the use of 160/220 bitumen is entirely suited to this type of mix.

Keywords: emulsion, bitumen, cold asphalt concrete, wearing course

1. INTRODUCTION

Bitumen emulsion asphalt offers undeniable advantages for the environment: its characteristic energy-saving capacity and reduced greenhouse gas emissions make it all the more appealing in a context where sustainable development is now systematically taken into account in the road construction industry.

Recent research carried out by the USIRF (Union des Syndicats de l'Industrie Routière Française – *Union of French road construction industry syndicates*) has lately shed light on the specific features of emulsion asphalts whose behaviour is different from hot asphalt mixes because of their evolving nature. ([1], [2] and [3])
In particular, the characteristics of bitumen-based emulsion are amongst the parameters playing an important role in this development.

This article describes the creation and monitoring over four years of two adjacent sections of emulsion asphalt concrete (EAC) applied as the wearing course of a secondary road (RD) in the Massif Central region. The composition of these two coatings differs solely in the bitumen-based emulsion, being 70/100 for the one and 160/220 for the other.

2. CONTEXT

In the context of a maintenance contract for low-use secondary roads in the Corrèze department, a section measuring 1.8 km long and 6.5 m wide, well exposed (no shade) and low-lying (300 m), was recoated in July 2005 with a 3 to 5 cm thick layer of EAC 0/6 made using bitumen emulsion of grade 70/100 for one section and 160/220 for the other section.

The French standard P 98-139 of January 1994 [4] regarding 0/10 or 0/14 EAC for use in wearing courses of a thickness of 6 cm to 8 cm on highways of low or medium traffic use (annual average daily traffic on the busiest lane of 300 lorries maximum, vehicles with a payload over 5 tonnes) recommends for pure bitumen-based emulsion either 70/100 bitumen or 180/220 bitumen (grade broadened to 160/220 from 1999 – NF EN 12591 [5]).
Even if this standard has to be revised bearing in mind the change in particular towards lower thicknesses and grading, it was beneficial to test the effect of the bitumen-based compound on the behaviour and development of the two bituminous concrete coatings.

The pavement base was made up of old surface dressing on an untreated foundation layer.
The traffic was estimated to be an annual average daily traffic (AADT) of 50 lorries on the most heavily used lane (class $T3^-$: 50 to 85 lorries per day – AADT). Deflection measurements were taken using the Benkelman beam under the twinning of 6.5 tonnes of a 13 tonne axle: they were found to be between 70 and 126 hundredths of a millimetre with an average of 87 and a characteristic value (average + two standard deviation) of 115, corresponding to a rather low road structure (deflection class C4: 100 to 150), which is often the case on low traffic frequency secondary roads.

3. MATERIALS

3-1 Formulation

The aggregate comes from a quarry of metamorphic rock (leptynite gneiss).
The aggregate composition of EAC is as follows:
- gravel 4/6 40% in weight
- sand 0/4 60 % in weight

The percentage of passing accumulated in the different sieves is shown in table 1. The grading curve is continuous, close to the standard for the sand part.

The emulsions are slow breaking cationic formulae with 60% bitumen (class C60B6 under standard NF EN 13808 [6]). Their aqueous phase is the same and helps to obtain full coating of the aggregates, satisfactory workability for good application and satisfactory water sensitivity.

The emulsion content of the EAC is 9.5 parts per hundred (ppc) in relation to the dry aggregates, or a residual 70/100 or 160/220 bitumen content of 5.7 ppc.

Table 1: grading

Sieve (mm)	0.063	0.08	0.315	0.5	2	4	6	10
Passing	6.9 %	8 %	18 %	22 %	47 %	73 %	99 %	100 %

The total water content is 7.1 ppc in relation to the dry aggregates + residual bitumen.

3-2 Performance

The Duriez test (NF P98-251-4 [3]) was carried out on the two laboratory-made EACs using aggregates and site samples of the two emulsions. It regularly gives a good estimate of the voids content obtained in situ on the one hand upon completion of the work and on the other hand in the longer term, depending on the force of the static compression moulding of the asphalt test specimens (60 kN for the long term and 20 kN for the short term). The results are shown in table 2.

Table 2: results of the Duriez test on the voids contents and compressive strengths obtained

Moulding force Applied for 5 min [7]	**60 kN**		**20 kN**	
	EAC base 160/220	**EAC base 70/100**	**EAC base 160/220**	**EAC base 70/100**
% voids (geometric measurements)	13.3 %	14 %	19.5 %	20.6 %
Compressive strength at 18°C:				
- R at 14 days maintained in air at 18°C and 50% relative humidity (RH) MPa	3.1	4.9	1.6	2.5
- r at 7 days in air at 18°C and 50% RH + 7 days in water at 18°C MPa	2.7	4.2	1.3	1.8
- Water sensitivity: r/R	0.87	0.86	0.82	0.72

The voids contents at the same moulding force are of similar size with a slightly lower value for the 160/220. This may be explained by the lower consistency of this grade of bitumen in comparison with the 70/100 at the same temperature, prompting the densification of the EAC.
It may be noted that the water sensitivity of the EAC with 160/220 bitumen is hardly affected by the increased voids content whereas a slight fall could be observed with the 70/100 bitumen.
Most of the emulsion asphalt concrete is applied in a thin layer (3 - 5 cm), sometimes in a very thin layer (2 - 5 cm).
Therefore the present French standard [4] has to be rewrited for taking into account this development.
Nevertheless the compressive strengths (R and r) and the water sensibility (r/R) meet the technical requirements of this standard:
- R ≥ 3 MPa with 160/220 bitumen
- r ≥ 4 MPa with 70/100 bitumen
- r/R ≥ 0,7

4. MANUFACTURE - LAYING

Both EACs were made by continuous mixing in a traditional mobile coating plant for cold asphalt mixes installed within the quarry itself situated at approximately 10 km from the jobsite.

They were applied in a thickness between 3 and 5 cm in hot, sunny weather (air temperature: morning +24°C, afternoon 30°C) using a finisher in half-carriageway widths over a tack coat laid as the work progressed.

The compaction plant consisted of a VTO vibratory tandem roller at the front (forward and reverse vibration) and a 3t/wheel pneumatic-tyred roller (10 to 12 passes).

As the lack of depth made it difficult to take density measurements using a nuclear density gauge, the voids contents were not measured at the end of the compaction stage.

Neither EACs presented any significant differences once it had been laid.

Only the pavement surface macrotexture depths [8] measured using sand testing differed slightly 3 months after laying:

- 0.4 mm for the 160/220 bitumen EAC
- 0.5 mm for the 70/100 bitumen EAC.

They show a tighter appearance in the EAC base using 160/220 bitumen as the post-compaction caused by traffic over the summer helped the surface to close, with the 160/220 bitumen consistency being less dense than that of the 70/100 at the same temperature.

5. MONITORING THE DEVELOPMENT OF THE BINDER AND ASPHALTS

5-1 Binders

Several binders have been identified for their penetrability at 25°C (Pen 25°C) and softening point (SP):
- the two bitumen grades, 70/100 and 160/220, taken in the factory
- the bitumen dissolved in perchloroethylene to quantify the impact of the binder recovery operation through distillation using a vacuum rotary evaporator (NF EN 12697-3) [9]
- the stabilised binders of the two corresponding emulsions (24 h at ambient temperature + 24 h at 50°C + 24 h at 85°C according to NF EN 14895 in force in 2005 [10]
- the binders from the Duriez test samples, 14 days exposed to the air either at 18°C – 50% RH or at 35°C – 20% RH for both EACs.
- the binders from both manufacturing sources, laboratory and jobsite
- finally, the binders from the EAC plugs sampled on a number of occasions (16 months, 44 months and 51 months)

All the binders were extracted from the asphalt mixes according to the recovery method of standard NF EN 12697-3 [9]

The results are shown in tables 3 and 4

Table 3: characteristics of binders and asphalt mixes with 70/100 bitumen

Binder	Pure-based bitumen	Bitumen recovered after being dissolved in perchloro-ethylene	Stabilised binder of the factory-made emulsion	Binder from the laboratory manu-factured EAC 24 h after manufacture	Binder from jobsite manu-factured EAC 42 days after manufacture*	Binder from Duriez test samples moulded at 20 kN and maintained	
						14 days 18°C 50% RH	14 days 35°C 20 % RH
Pen 25°C (0.1 mm)	83	65	68	60	49	53	45
SP (°C)	46	47.8	48.8	50.4	52.4	51	52.8

Binder	extracted from asphalt mix core-samples taken at:		
	16 months (3 cores of 4 cm average thickness)	44 months (3 cores of 2 cm average thickness)	51 months (3 cores of 3.5 cm average thickness)
Pen 25°C (0.1 mm)	49	20	30
SP (°C)	52.2	59.6	57.2

* Stored in leak tight bucket after manufacture.

Table 4: characteristics of binders and asphalt mixes with 160/220 bitumen

Binder	Pure-based bitumen	Bitumen recovered after being dissolved in perchloro-ethylene	Stabilised binder of the factory-made emulsion	Binder from the laboratory-manufactured EAC 24 h after manufacture	Binder from jobsite manu-factured EAC 42 days after manufacture*	Binder from Duriez test samples moulded at 20 kN and maintained 14 days 18°C 50% RH	Binder from Duriez test samples moulded at 20 kN and maintained 14 days 35°C 20% RH
Pen 25°C (0.1 mm)	184	154	150	113	95	105	95
SP (°C)	40.2	41	41.8	45.4	46.8	46.4	46.4

Binder	Extracted from EAC core-samples taken at: 16 months (3 cores of 4 cm average thickness)	Extracted from EAC core-samples taken at: 44 months (3 cores of 2 cm average thickness)	Extracted from EAC core-samples taken at: 51 months (3 cores of 3.5 cm average thickness)
Pen 25°C (0.1 mm)	48	24	37
SP (°C)	52.4	57.4	54.6

* Stored in leak tight bucket after manufacture.

Significant hardening may be observed of the residual bitumen as soon as the EAC is made whether in the laboratory or at the plant.
Binders from the EAC made at the plant are a little harder, which could be explained by the delay of 42 days between their sampling and their analysis (laboratory workload problem), even though the EAC samples were kept in leak tight cases.

With regard to the changes to the softening point, which is a weaker indicator of penetrability, being easier to replicate, a bitumen grade loss may be observed (NF EN 12591) [5] as is the case for the hot asphalt mixes.

Still with regard to the softening point, the binder extracted at 16 months from the 70/100 bitumen-based jobsite EAC shows a consistency similar to that of the binder from the Duriez test samples kept for 14 days at 35°C and 20% RH. For the 160/220 bitumen EAC, this is not the case: the consistency of the binder changed more on the jobsite, becoming equivalent to that of the 70/100 EAC at 16 months.

At a little over four years on the jobsite (51 months), the binders continued to harden, reaching the consistency of 20/30 for the 70/100 and 35/50 for the 160/220 [5].

The thickness of the asphalt also plays a major role in the changes in hardening of the binder. Indeed, the binders from plugs taken at 44 months in a localised area where the average thickness is lower (2 cm) because of the distortion of the road surface, present a greater degree of hardening: the characteristics of 20/30 bitumen are obtained in both cases.

5-2 Asphalt mixes

Measurements of voids content and indirect tensile stiffness modulus at 10°C and 124 ms (NF EN 12697-26) [11] were carried out on EAC cores -samples taken at 16 months and 51 months from the jobsite (table 5).

Table 5: voids content and indirect tensile stiffness modulus at 10°C 124 ms (Sm)

Period	16 months					51 months					
EAC	70/100 base			160/220 base		70/100 base			160/220 base		
Voids content	19.2 %	21.1 %	19.4 %	16 %	12.3 %	17.6 %	12.2 %	18.5 %	17.1 %	16 %	15.2 %
Sm (MPa)	3900	3300	3200	4400	4900	3150	4250	3000	4100	3600	4700
Thickness of plugs tested	3.5 cm			3.5 cm		3 cm	4 cm	6 cm	3.5 cm		

At 16 months, an overall level of rigidity is reached that is satisfactory for a cold asphalt mix, confirming the good general condition of both EACs on the site after 4 years.
Even though the results are dispersed, the highest module values are those obtained with the 160/220 bitumen.
The only difference noted is in the surface aspect at 51 months, being more open with the 70/100 base EAC.
There was indeed slight ravelling (chippings breaking away) that now appears to have stabilised on both EACs; it is more serious with the 70/100 bitumen EAC, revealed by an greater average pavement surface macrotexture depth measured using sand testing: this was 1.2 mm as compared with the value of 0.8 mm for the 160/220 base EAC.

6. CONCLUSIONS

These results confirm the good performance of bitumen emulsion asphalt concretes in spite of the fact that the voids contents remain high especially with a 0/6 grading.
The use of 160/220 bitumen is absolutely plausible and even desirable for EAC on low structured road with low traffic use.
Indeed, because of its consistency, it enables better coalescence of the asphalt particles to be obtained when coming into contact with the aggregates, helping to form a binder film and consequently densification of the mixture.
Moreover, even though the hardness of the binder over time is more marked in relative value than that of the 70/100 and gets closer to it, the material nonetheless remains flexible and adapts perfectly to the distortion of the base layer without showing signs of rutting.
Finally, the EAC cohesion appears stronger with this grade of bitumen, as is shown by the smaller change over time of the macrotexture.

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