BASE COURSE WITH HARD PAVING GRADE AND WEARING COURSE WITH MULTIGRADE BITUMEN: AN INNOVATIVE COUPLE TO FIGHT THE RUTTING AND REDUCE COSTS OF ROAD MAINTENANCE ON THE LONG-TERM. EXPERIMENTS IN FRANCE AND BELGIUM

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SUMMARY

Employed in base courses, the hard paving grades 15/25, 10/20 even 0/10, allow to reach very high levels of asphalt stiffness modulus (12.000 to 22.000 MPa at 15°C and 10 Hz), sometimes close to those of cement-bounded materials. Finalized in the 1980's, the new multigrade bituminous binders became widespread in the 1990's to most of the European producers of bitumen and were the subject of many papers. A lot of road trials of technical demonstration were realised with multigrade bitumen, showing the evidence of the major interest of these products with regard to the normal paving grades, namely a decrease by two of the rut globally registered on courses for the same formulation of bituminous mix, including same aggregates. These bitumens, generally 35/50 graded, sometimes 20/30 even 50/70 became of a common use within the European Union. All these innovations allow to significantly reduce the quantities of materials to be used in the construction and especially to decrease the costs of maintenance, due to an increase of the longevity of both the base and the wearing courses, generally some years. Preliminary results of an experiment realised in the LCPC in France and practical examples of construction sites realised in Belgium on trials with high mechanical constraints such as service stations, and using the innovative couple “base course with hard paving grade and wearing course with multigrade bitumen”, are described in this paper.

KEYWORDS

WEARING COURSE / HARD PAVING GRADES / MULTIGRADE BITUMEN / ANTIRUTTING / SERVICE STATION / BASES

1. BACKGROUND ON HARD PAVING GRADES AND MULTIGRADE BITUMENS

The report of the Technical Committee on Flexible Roads (C8) presented at the PIARC International Seminar on Modified Bitumen of Rome in June 1998, represent a good basis for our knowledge (Corte, 1998). The hard paving grades define as binders of oil origin having a penetration at 25°C lower than 25 1/10mm. Several grades are available in Europe, of which the most common are 10/20 and 15/25 (France, Belgium, Germany). The others, such as 13/22 (Spain) or certain experimental grades (0/10 or 5/10) can be used. The softening points ring and ball are generally between 55 and 76°C. The complex modulus, measured with the viscoelastometer or the dynamic shear rheometer DSR is, as a rough guide, generally beyond 180 MPa (even 250 MPa) at 10°C and 7,8 Hz, knowing that the higher the modulus of the binder the higher the modulus of the bituminous mix for an identical granular skeleton. The main application is indeed that of the High Modulus Mixes (EME), technology of French origin now of common use since 20 years. Interest is the significant reduction of the thickness of bases and so an economy of materials. Increasing the resistance at high temperatures allows furthermore to reduce the risks of permanent deformation by creep. From the European standardization point of view, 2003 could see the publication of the harmonized standard prEN13924 concerning the classes 10/20 and 15/25.

Concerning now the multigrade bitumens, they are mainly intended for use in the wearing and intermediate courses, to which they bring antirutting properties; they can sometimes be used also in bases when they bring a sufficient structural behaviour. The main available class in Europe is 35/50, but it is possible to find a 20/30 or a 25/35, even a 50/70 or a 60/80. Term multigrade (one speaks also in Belgium of bitumen with positive penetration index), today of a common use in the countries of the Western Europe, is the warranty of a wider temperature interval of use than the one of traditional paving grades. They are characterized, for example in the case of 35/50 multigrade bitumen, by:
- A low thermal susceptibility (high penetration index and lower variation of complex modulus with the temperature than for a normal paving 35/50),
- A high Level of consistency at high service temperatures (modulus equivalent to the one of a hard paving grade 10/20) while preserving a good behaviour at low service temperatures (modulus close to the one of a 50/70 normal paving grade).

2 - MULTIGRADE BITUMENS: THE ASFA/LCPC EXPERIMENT ON THE LCPC CIRCULAR TEST TRACK OF NANTES BETWEEN 1992 AND 1998 (FRANCE)

In the 1990's, several experiments studying the rutting phenomena of wearing courses were realized at the Laboratoire Central des Ponts et Chaussées (LCPC) of Nantes in partnership with the Association of French Highways Companies (ASFA) and some French bitumen producers. The aim of all these studies was to evaluate, compared with a classical bituminous mix using a normal paving 50/70, the effect of special binders especially hard paving grades (10/20) and multigrades (first 50/70 then 35/50) face to face with their resistance to rutting.

The possibility of realizing in situ tests on the LCPC circular fatigue test track, as a supplement to the laboratory investigations (Corte, 1998), had allowed obtaining from the first experiments of 1992-94 numerous results:
- A very important effect of the type of binder on the improvement to rutting resistance, notably in the experimental case of a formulation of asphalt given unstable (i.e. high rutting level) by the use of more than 30 % of crushed sand,

- A sharply improvement in the rutting resistance of such unstable asphalts (reduction of the rut by a factor of 2 or 3 after 30.000 cycles) by the use of a hard bitumen 10/20 or a 50/70 multigrade binder;
- Evidence of the more aggressive character of tridem axles of heavy trucks with regard to tandem axles, this behaviour conducting to an increase from 20 to 40% of the rut for a reference asphalt, effect being all the more important as the asphalt contained a bigger proportion of crushed sand.

A second series of experiments (Gramsammer, 1999) was realized in the years 1996-1998 to complete these works, and notably experiment known ad "Rutting 5" realized during the summer 1998 which aimed to estimate the rutting behavior under axle of type tridem (three wheels, so very aggressive) of three typical bituminous mixes BBSG 0/14 using 35/50 multigrade binders and a reference asphalt using a normal paving 35/50 from the standard EN12591, more representative of bitumen types actually used in France for wearing courses, than the 50/70 was. This test allowed to show the efficiency of multigrade binders. The tested BBSG had been formulated to lead in laboratory to a rut of 13% after only 3.000 loads during a test with the LPC rutting machine at 60°C. The thickness of BBSG courses was 9 cm for the four tested binders. The number of realized loads was 150.000. At the end of test, one notes that ruts are between 2.5 and 3.3 times lower on the asphalts using the multigrade binders that on the asphalt using the normal paving bitumen. The improvement of performance seems moreover all the more pronounced as temperature is high. On the other hand between the three tested multigrade binders, differences are very low.

As a supplement to this experiment, an additional laboratory testing program on materials was realized in 1999-2002, collectively between the LCPC and the three participating bitumen producers. Objective was to highlight performance related properties between tested mixes and multigrade binders used, especially at low service temperatures (resistance to cracking) and intermediate temperatures (resistance to fatigue). The first tendencies of this study show:
- By comparison with the normal paving grades, the temperatures of isomodulus at 300 MPa measured with the Bending Beam Rheometer (BBR, XPT 66-062) are significantly lower, even after ageing tests RTFOT+PAV (20 hrs), what is favorable to a better resistance at low temperatures; the more empirical Fraass breaking point test conducts to the same tendency,
- In the intermediate temperatures of service, and due to a level of complex modulus of multigrade binders at 15°C / 10 Hz twice lower than for normal paving 35/50, one can expect no cracking to occur; this can also be explained by lower modulus in the mixes with an average level of 8.000 MPa at 15°C / 10 Hz instead of 11.000 for the 35/50 normal paving grade for the same granular skeleton. The lower level of the complex modulus does not however constitute an obstacle to a good design of the road structure, because the structural character is essentially devoted to and brought by the base.
-In the high temperatures of service, the level of complex modulus measured with the DSR are sharply higher, before and after RTFOT, than for a normal paving 35/50 (about 10 to 12°C more for the temperature to which the modulus G* = 10 kPa at 7,8 Hz). The best resistance to permanent deformations is confirmed by the test on the circular track.

The complete results of this study should be published during in year 2004.

3 - COUPLE HARD PAVING GRADE AND MULTIGRADE BITUMEN: CONSTRUCTION SITES FOR TECHNICAL DEMONSTRATION (BELGIUM)

3.1 Road trial of the service station of Nivelles on the highway E19-Bruxelles/Mons (Belgium, 2000)

On the occasion of a project of construction of a new service station on both sides of the highway E19 between Brussels and Mons at "Orival" near Nivelles, an innovative road trial using hard and special bitumen was proposed to the technical teams of the Wallon Ministry of Equipment and Transport (MET) (Jamois, 2001). From the very beginning of the project, a voluntarily partnership approach had been privileged**,** various stakeholders testing to find a common language. Actually and as an example, if in France reference test is the LCPC rutting test, practised at 60°C until 30.000 cycles, Belgium is used to manage the test at 35°C and until 100.000 cycles. In term of formulation, difficulty was to respect the Wallon rule (technical requirements CCT RW 99) while playing with the space of freedom in the granular composition and binder content to optimise the final performances of asphalts applied.

3.1.1. Study of laboratory

To support during 30 years (duration of the concession) an estimated traffic of 4.000 vehicles per day, of which 15% of heavy lorries, the design chosen by the MET was:
5 cm SMA B1 0/14 (wearing course) + 12 cm BB3A 0/20 (base) + 20 cm of thin cement mix + 25 cm of sand draining on muddy able to freeze ground (foundation course).

To limit the risks of rutting on the heavy vehicles way, study consisted in looking for an innovative solution bringing in a special hard bitumen 15/25 for the base and a multigrade 35/50 bitumen for the wearing course.

After granular analysis of various cuts of materials, tests consisted in optimising formulations with the Giratory Shear Press (PCG) and according to the Marshall test method. The rutting being a damage able to affect as far the base as the wearing course, the resistance of asphalts to permanent deformations was tested on the LPC traffic simulator and by determination of the Marshall creep. Finally, resistance of mixes to water degradations was checked by practising tests in water with Duriez samples. The basic structure of the road having been established, with a BB3A formulated with a 50/70 normal paving grade, passage to a hard paving grade going to the direction of an increase of the base stiffness and the preservation of thickness of the layers, led to avoid the determination of the complex modulus at 15°C/10 Hz for this asphalt.

Base course:

A Belgian formulation type BB3A 0/20 was realized with 5.3 ppc of a hard paving grade 15/25 by watching to respect the requirements of granular composition and of binder content of the RW99 technical requirements. Another formulation based on the French concept of high modulus asphalt (EME 0/14) was studied with 5.1 ppc of hard bitumen (class 1 of the standard AFNOR NFP 98-140, traffic beyond 8.000 heavy vehicles per day). Experience from the last fifteen years in France confirmed the necessity of reaching high compacity levels in place as well as a sufficient binder content to guarantee a good resistance against the mechanical fatigue. These requirements are a function of the level of constraints to which is submitted the layer in the road structure. Considering the low level of deformation by traction at the bottom of the base, estimated during the design calculations, in situ compaction levels of at least 90% were considered sufficient for this

trial. For the EME, the stiffness modulus at 15°C-10Hz used in the design calculations have to reach at least 14.000 MPa.

As described in table 1, this hard grade presents a moderate thermal susceptibility favourable to the preservation of viscoelastic properties at low temperatures, indispensable for the relaxation of constraints and a high level of consistency at high temperatures to limit the risk of creep. The implementation of the base material being foreseen in two passes of 6 cm, the estimation of void contents on construction site made from compaction measurement at 60 gyrations was 4.2% for the BB3A 0/20 and 6.8% for the EME 0/14.

Table 1 - Characteristics of the hard paving grade 15/25

CHARACTERISTICS		METHOD	
Penetration @ 25°C	(1/10 mm)	EN 1426	18
Temperature softening point	(°C)	EN 1427	65.0
IP Pfeiffer		EN 1426	-0,2
Fraass breaking point	(°C)	EN 12593	-8
Test of Bending Beam Rheometer (BBR):		XPT 66062	
• θ 300 MPa	(°C)		-12
• θ M = 0,3	(°C)		-14
Complex Modulus @ 7,8 Hz :		NFT 66065	
• θ For G* = 4/3 10^8 Pa	(°C)		7
• θ For G* = 10^4 Pa	(°C)		78
• θ isodéphasage	(°C)		25
After RTFOT (1. 15 in 163°C):		EN12607-1	
• Penetration @ 25°C	(1/10 mm)		15
• Temperature softening point	(°C)		72.0
• Fraass breaking point	(°C)		-6

At the conclusion of the rutting tests on the LPC traffic simulator, the EME 0/14 showed to be the most successful with an average rut depth of 4.2% after 30.000 cycles at 60°C, estimated at the compaction level of C_{100} (most severe level). These results were also confirmed by the Belgian rutting test practised at 35°C which indicated 1.4 mm of average rut after 100.000 cycles.

The table 2 below, recapitulates the characteristics of the EME 0/14 laid as a base on the low way for heavy traffic.

Table 2 - Characteristics of the EME 0/14 asphalt

EME 0/14		RESULTS	SPECS.
Composition:			
Hard bitumen 15/25 content	(ppc)	5,1	
Richness Modulus		3,11	> 2,5
Characteristics of the asphalt:			
• PCG Test (NF P98-252)			
- Compacity at 10 gyrations		85,6	
- Compacity at 60 gyrations		93,2	
- Compacity at 100 gyrations		95,4	≥ 94
• Marshal Test (CME 54.14)			
- Stability	(KN)	23,7	≥ 10
- Creep	(mm)	2,6	≤ 3,5
• Duriez Test (NF P98251-1)			
- Compacity	(%)	92,6	
- Resistance to crushing	(MPa)	18,2	
- Report Immersion/Compression		0,87	≥ 0,75
• LPC Rutting Test (NF P98253-1)			
- Average rut at 60°C and 30.000 cycles	(%)	4,2	≤ 8
- Compacity	(%)	95,4	
• Belgian Rutting Test (CME 54.18) @35°C:			
- 3.000 cycles	(mm)	0,65	
- 10.000 cycles	(mm)	0,91	
- 30.000 cycles	(mm)	1,22	
- 100.000 cycles	(mm)	1,41	≤ 2,10

Wearing Course:

In the study of formulation, two objectives were aimed:
- To reach a strong macrotexture to assure the adhesion of vehicles by rainy time,
- To offer a good resistance to the rutting.

The main characteristics of the multigrade binder used, collected in the table 3, confirm a high level of consistency at high temperatures to limit the creep associated to viscoelastic properties at low and intermediate temperatures, allowing to support the mechanical and thermal constraints. These values answer the specifications of the Belgian standard NBN T54-105.

Table 3 - Characteristics of the multigrade bitumen 35/50

CHARACTERISTICS		METHODS	RESULTS
Penetration @ 25°C	(1/10 mm)	EN 1426	35
Ring & Ball softening point	(°C)	EN 1427	62,0
IP Pfeiffer		EN 1426	0,6
Fraass breaking point	(°C)	EN 12593	-19
Complex modulus @ 7,8 Hz		NF T 66-065	
Temperature at which:			
$\lvert G^* \rvert = 4/3.10^8$ Pa	(°C)		-7
$\lvert G^* \rvert = 10^4$ Pa	(°C)		75
θ isodéphasage	(°C)		30
After RTFOT Test (1hr15 @ 163°C):		EN 12607-1	
- Penetration @ 25°C	(1/10 mm)		29
- Ring & Ball softening point	(°C)		70,5
- Increase of R&B	(°C)		7,5
- Remaining penetration	(%)		72,5
Complex modulus @ 7,8 Hz after RTFOT:		NF T 66-065	
Temperature at which:			
$\lvert G^* \rvert = 4/3.10^8$ Pa	(°C)		-6
$\lvert G^* \rvert = 10^4$ Pa	(°C)		80
θ isodéphasage	(°C)		32

On the basis of a compromise between the rutting resistance and the macrotexture estimated by the test of height of sand, the Belgian formulation type SMA B1 0/14 was chosen for the 5 cm wearing course. This asphalt answers to characteristics described in the table 4.

Table 4 - Characteristics of asphalt SMA B1 0/14

SMA B1 0/14		RESULTS	SPECIFICATIONS.
Composition:			
Multigrade bitumen 35/50 content	(ppc)	7,0	
Modulus of richness		4,1	
Characteristics of the asphalt:			
• PCG Test (NF P98-252)			
- Compacity at 10 gyrations	(%)	87,2	$\leq$ 91
- Compacity at 40 gyrations	(%)	93,4	88 - 94
- Compacity at 50 gyrations	(%)	94,9	
• Duriez Test (NF P98251-1)			
- Compacity (%)		96,0	
- Resistance in the destruction	(MPa)	8,0	
- Report Immersion/Compression		0,92	$\geq$ 0,8
• LPC rutting Test (NF P98253-1)			
- Average rut @ 60°C and 3.000 cycles	(mm)	7,5	$\leq$ 15
- Average rut @ 60°C and 10.000 cycles		9,3	
- Compacity	(%)	94,9	
• Belgian rutting Test (CME 54.18)			
- Average rut @ 35°C and:			
3.000 Cycles	(mm)	0,73	
10.000 Cycles	(mm)	1,29	
30.000 Cycles	(mm)	1,48	
100.000 Cycles	(mm)	1,82	$\leq$ 1,95
• Macrotexture HSv (NF P98216-1)	(mm)	1,8	

3.1.2 Realisation of the trial and follow-up after 3 years of traffic

Manufactured between 170 and 180°C, the EME and SMA asphalts were laid without any trouble. Compared with the theoretical formulations, the average binders contents recovered from the trial were in agreement with the theoretical formulations. Carrots taken by core sampling showed that the use of a 15/25 hard bitumen in base course allowed to significantly increase the criteria of the Marshall Test imposed by the Belgian specifications. The SMA asphalt presents a high level of macrotexture, due to the use of 60% of aggregates 7/14, what is in agreement with the study of laboratory.

After 3 years, the visual aspect of the state of surface noted:
- No longitudinal crack either transverse or opening of joint,
- No ravelling or presence of free aggregate on the low sides,
- No rut or noticed collapse.

The statements of rutting with the ultrasonic transversoprofilometer device on roadways for accessing the service station in the direction of Brussels on one hand and of Mons on the other hand, end in an average rut between 4 and 5 mm, what is considered as unimportant compared to previous trials realized on service-stations in Belgium where ruts until 20 mm after 3 years were sometimes noted.

3.2 Other trials realised in Belgium (2000-2003)

Following the success of the first construction site of technical demonstration on the service station of Nivelles, several other trials were realised for 3 years in Belgium with the couple asphalts using a hard paving bitumen in base course and a multigrade bitumen in wearing course. The table 5 below collects these references of construction sites.

Table 5 - Examples of trials realised in asphalt using the couple hard paving grades in base course and multigrade binders in wearing course

YEARS	TRIALS	BITUMEN
1999	Antwerp / Schoten - Parking factory of lubricants (6700 m²)	Base: 8 cm AB-3A 0/20 with 4,5% hard bitumen 10/20 (60 T, 6700 m ²) Wearing course: 4 cm AB-4C 0/10 with 6% multigrade bitumen 35/50 (40 T, 6.700 m ²)
1999	Quays of Zeebrugge's port (zones of storage and containers handling)	Base course: 8 cm EME 0/14 with 4,6% hard bitumen 20/30 (9.500 m ²) Wearing course : 6 cm BBSG 0/10 with 5,7% asphalts multigrade 35/50 (9.500 m ²)
2002-2003	Jabbeke's area - road Station on the highway E40 Bruxelles-Ostende in two senses(directions)	Base course: 6 cm AB-3B 0/14 with hard bitumen 10/20 (280 T, 37200 m ²) wearing course: 5 cm SMA C1 0/14 with multigrade bitumen 35/50 (350 T, 41200 m ²)
2003	Minderhout's area - road Station on the highway E19 Anvers-Breda	Base course: 6 cm AB-3A 0/20 (1st part with 2,6% hard bitumen 10/20 and 40% of recycling then 2nd part with 4,5 % hard bitumen 10/20) (11 T, 2200 m²) Wearing course: 5 cm SMA C1 7/10 with 7% multigrade bitumen 35/50 (45 T, 3800 m ²)

3.3 Economic earning due to the couple hard paving grade / multigrade bitumen

For the concessionaire of gas station, traditional types of mixes used led to have to realize the first operation of maintenance on the access roads of stations in the three years following construction, what generated a relatively high cost of maintenance. The innovation which constitutes the use of a complex of hard paving grade in base course and multigrade bitumen in wearing course allows, while preserving all the advantages of asphalts, namely comfort, flexibility and safety, to hope reasonably to push away the first operation of maintenance in 7 or 10 years after the construction, or the earning from 4 to 7 years. Today the concessionaire does not hesitate any more to appeal to this innovative

concept as give evidence of it the construction sites realized in 2002 and 2003 on the other service stations.

4 - CONCLUSION

It has been shown through examples presented in this paper, whether it is during experiments on the LCPC circular test track in France or the construction sites of service stations in Belgium, that the composite of high modulus asphalt in base course using a hard paving grade 10/20 or 15/25 and a wearing course asphalt using a multigrade bitumen 35/50 allows to reach particularly high levels of performances. The stiffness at high service temperatures allows this type of bituminous mixes to reduce by a factor 2 or 3 the rut depth which would be normally observed on a road formulated with normal paving grades, while preserving a sufficient flexibility at low service temperatures in order to avoid a too premature appearance of a cracking phenomenon. Concessionaire, responsible for the maintenance, will win at it in elongation of the life cycle of his road of some years and so in economy in the costs of maintenance.

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REFERENCE

(1) Corte, J-F. (1998) Use of modified bituminous binders, special bitumen and bitumen with additive in road techniques. International Seminar on Modified Bitumen PIARC, Rome 17-19/06/1998. Final Report.

(2) Corte, J-F. et al. (1998) Study of the rutting of the wearing courses with the LCPC circular track test. Bull. Liaison P&C N°217, ref. 4214 , pp.13-30

(3) Gramsammer, J-C. et al. (1999) Rutting of asphalts using special binders under the effect of simple wheels and of a tridem. RGRA N°777 , PP.65-68

(4) Jamois, D.; Berger, J.; Legreve, A. (2001) Experiment of high performance bituminous mixes for base and wearing courses in new construction on the site of a service station (E19-Nivelles). XIXè Belgian Congress of Road, Genval 12-14/09/2001