New modified binder packed in block for road application

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ABSTRACT

For decades drums have been widely used to transport bitumen in solid form into remote geographic areas where truck delivery in bulk at high temperature (140-160°C) is not possible, because of poor logistic and road infrastructures, or located far from hot bitumen storage facilities.
A new bituminous solution in block form has recently been developed for such geographical areas. This patented technology is based on the addition that holds the bitumen in block. The modified bitumen is then able to sustain load and resist creep up to 75-80 °C. It remains solid and keeps its original shape during transport by containers and storage at ambient temperature during several months.
The bitumen is conditioned in blocks of 20-25kg, which makes it easy to transport by sea, to store, and to dispatch to the end customer. Another advantage is that it does not require the use of drums or other containers, avoiding any concern regarding losses of product, leaks or waste. It is also an energy-efficient solution because no heating is necessary during transport and storage.
This bitumen in block is designed to compete with bitumen in drums on technical, environmental and economical grounds. It shows a significant price and transport advantage on drums any time there are strong logistic or supply issues in a market.
This paper focuses also on various technical studies that have been carried out on the bitumen in block. All results and measurements are in compliance with EN specifications and show that this solution performs equally when compared to reference paving grade bitumen in terms of workability, moisture resistance, rutting resistance, fatigue resistance and thermal cracking resistance.

Keywords: Asphalt, Environment, Low-Temperature, Safety, Storage stability

Bitumen In-Block: a new packaging of bitumen facilating its transport at ambient temperature for long time

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Abstract: Hot bitumen transportation is a major obstacle that prevents the development or progress of infrastructure in the world. Generally, the bitumen road transport is limited to 200-300 km and is very dependant from the state of the infrastructures. To reduce this constraint, different technologies are reviewed across the world. This paper presents a new technology to transport bitumen at room temperature in the form of blocks of 25 kg. Experiments were performed with different bitumen at laboratory scale. This new packaging does not affect the viscosity at high temperature. In addition, there is no dramatic effect of this packaging on the low temperature properties of the binder after aging process. There is also no detrimental effect of the additivation on the mixes characteristics (water resistance, rutting, modulus and fatigue test). Some of these properties are even slightly improved with the technology of In-Block.
Finally, creep measurements show that manufactured blocks can resist to deformation till a high temperature and consequently bitumen transport become distance independent.

Keywords— Bitumen, In-block, transport, hot mixes

1. INTRODUCTION

Bitumen is a viscous black material, coming from crude oil distillation processes. It is one of the most commonly used materials in various applications across the world. From the beginning of the 20^{th} century, important quantities of bitumen material are produced each year in the paving industry as glue binding the aggregates all together.
In paving industry, hot mix asphalt concrete is produced by heating the bitumen binder (around 165°C for pure bitumen and 185°C for polymer modified bitumen), and drying the aggregate to remove moisture prior to mixing [1].
From a rheological point of view, bitumen is considered as a viscoelastic material at room temperature with a very high viscosity, but very sensitive to temperature [2]. Its viscosity varies with temperature following an Arrhenius law with very high activation energy [3, 4].
Bitumen has to be loaded and transported at a temperature up to 200°C. Nowadays, several techniques for transporting hot bitumen exist such as container, tank truck, drums, big-bag and pipeline [5, 6].
In this work, a new packed bituminous solution for road applications adapted to local market conditions and ready to use is proposed. The objective is to use an additive which is able to put the bitumen binder in the form of block. The additivation did not aim at modifying the properties of the bitumen, but only at forming a stable block for transportation at ambient temperature.
The mechanical characterizations have been performed to measure the properties of the new binder obtained and to assess the influence of this additivation on the hot mix characteristics (durability, rutting, modulus, fatigue …). This paper presents also the use of these bitumens in blocks in an experimental jobsite in the south of Algeria.

2. Results and discussion

2.1 Binder characterizations

Experiments were performed on two paving grade bitumen: Bitumen A and B coming from two different TOTAL refineries. These bitumen have then been additivated using a specific additive to obtain blocks, hereafter referred to as "In-block A" and "In-block B". Bitumen In-block is a rectangular block of 25 kg covered by thermoplastic folio. **Figure 1** presents the conditioning of Bitumen In-block on pallet of 1 ton. These blocks can be applied from a temperature of 140°C.

Figure 1: Pallet of Bitumen In-block (1 ton, 40 blocks)

Some characteristics of the paving grade bitumen and additivated bitumen (In-block) are summarized in **Table 1**.

Table 1: Characteristics of pure and additivated bitumen

Test	Standard	Bitumen A	In-block A	Bitumen B	In-block B
Pen ($^{1/10}$mm) at 25°C	EN 1426	35	25	58	31
R&B (°C)	EN 1427	55	109	54	93

It can be noticed that a strong hardening after additivation is obtained (penetration decreases and Ring and Ball temperature (R&B) increases dramatically). However, this effect does not affect the viscosity at high temperature which is unchanged (**Figure 2**). As Figure 2 shows that the effect of additive start to appear at a temperature less than 100°C where the viscosity of In-Block became bigger than the one of conventional bitumen.

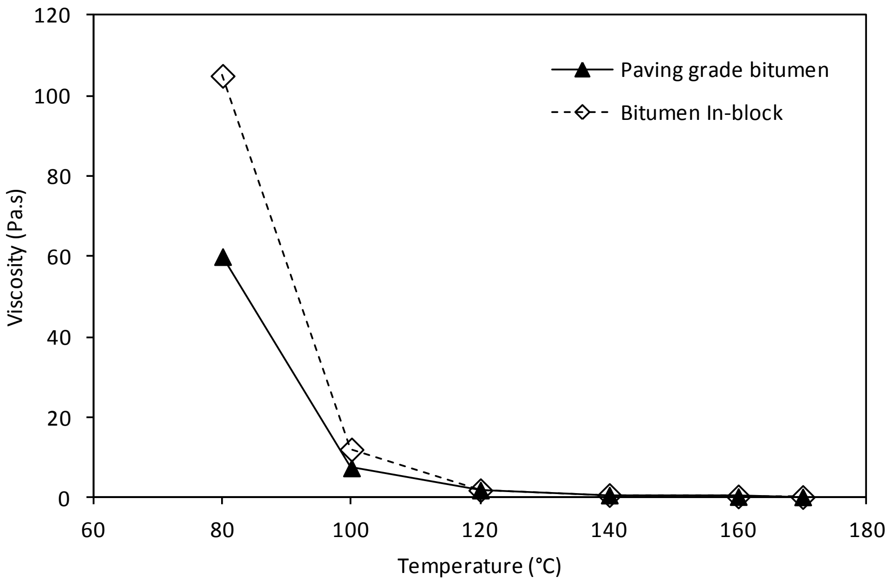

Figure 2: Comparison of the evaluation of viscosity versus temperature between a paving grade bitumen and Bitumen In-block.

As the additive hardens the bitumen base, the properties at low temperature needed to be investigated to ensure no potential degradation (thermal cracking).
In this objective, experiments were performed after aging process such as after RTFOT (Rolling Thin Film Oven Test: standard NF EN 12607-1) and after RTFOT + PAV (Pressure Aging Vessel, standard NF EN 14769) on pure and additivated bitumen [7, 8]. Results show that there is no noticeable effect of the additivation on the low temperature properties evaluated by bending beam rheometer (BBR) [9], whatever the nature of the bitumen base. All results are presented in **Table 2**.

Table 2: Low temperature properties after aging.

	Bitumen A	In-block A	Bitumen B	In-block B
After RTFOT				
Pen ($^{1/10}$mm)	25	21	31	31
Fraass (°C)	-8	-10	-10	-11
η (Pa.s) 160°C	0.34	0.35	0.39	0.38
After RTFOT and PAV				
Pen ($^{1/10}$mm)	18	19	23	21
Fraass (°C)	-2	-3	-4	-1
BBR (Bending Been Rheometer)				
Critical craking temperature (°C) (S =300MPa)	-12.6	-13	-16.1	-15.6
m-value at 300 MPa	0.273	0.266	0.288	0.280
Citical temperature (°C) at m = 0.3 MPa	-8.5	-8.4	-14.2	-13.3

2.2 Mixes characterizations

In order to investigate the effect of the additive on the mixes properties several experiments were performed on mixes made with the bitumen base and the one in block.
All mixes contain approximately 5.4% of binder and the origin of aggregates is from “Le Noubleau” quarry from France. **Figure 3** shows the granular curve used in this study.

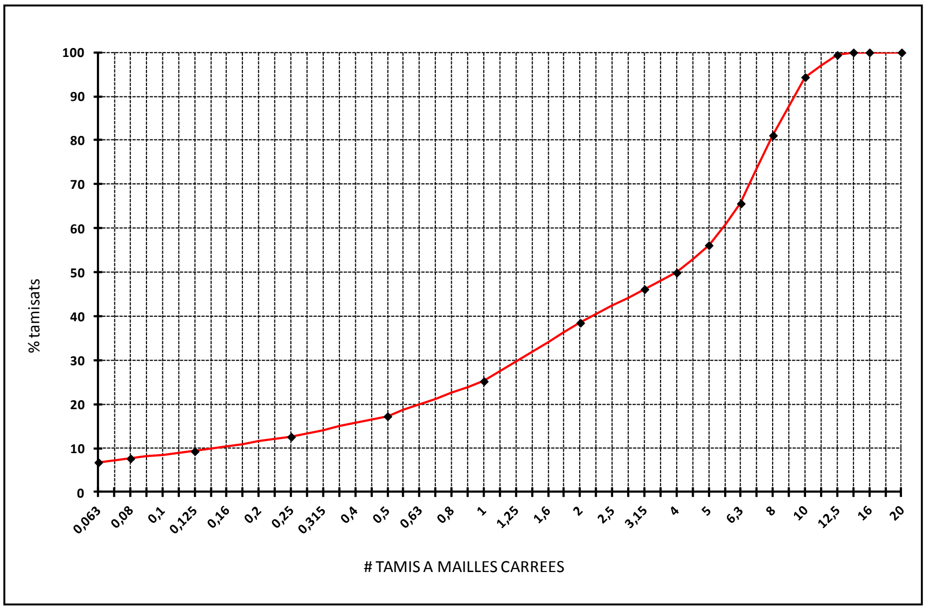

Figure 3: The granular curve used in this study with all binders.

- *TSRST experiments*

Experiments were performed using the Thermal Stress Restrained Specimen Test (TSRST) in order to determine the tensile strength and temperature at fracture of compacted bituminous asphalt mixtures by measuring the tensile load in a specimen according to EN 12697-46 [10]. Resulting failure temperature and failure stress obtained from the tests are presented in **Table 3**.

Table I: Failure temperature (T_F) and failure stress (σ_F) obtained by TSRST test on all analyzed binders.

	Bitumen A	In-block A	Bitumen B	In-block B
T_F (°C)	-24.6	-23	-27	-26.7
σ_F (MPa)	4.38	4.2	4.55	4.4

Whatever the nature of bitumen (A or B), it is clearly observed that the properties of mixes are identical for bitumen and bitumen in block.

- *Moisture sensitivity*

The test allows the determination of the water sensitivity of the bituminous mix. The compression resistances after and before soaking of the slabs in a bath of thermostatic water are measured. Experiments were realized basing on the standard EN 12697-12-B at 18°C [11]. All results for Bitumen In-block and conventional paving grade bitumen are presented in **Table 4**. *R* is the compression resistance at air and *r* is the compression resistance in water. Higher the ratio r/R better the water resistance of the mix.
It is observable that both compression resistances in water and at air are improved with Bitumen In-block A and B comparing to the conventional grade bitumen A and B.

- *Resistance to rutting*

Rutting refers to permanent deformation of mixtures of bitumen and aggregates. It is a complex phenomenon where the overall performance is dependent on the properties of the aggregates, bitumen, contact of aggregates and bitumen, etc. It is primarily the result of repeated traffic loading cycles.
These properties change through time due to excessive permanent deformation or cracking. The performance of the asphalt mixtures depends on the load frequency and temperature, and also, there is a strong dependency in terms of the voids content.
Experiments were performed according to the standard EN 12697-22 at 60°C and 30000 cycles [12] and are presented in **Table 4**.

Table 4: Duriez and rutting resistance results for conventional and In-block Bitumen

	Bitumen A	**In-block A**	**Bitumen B**	**In-block B**
Duriez experiment (Mositure sensitivity)				
r (MPa)	8.7	10.9	7.6	9.0
R (MPa)	10.5	12.8	8.8	10.4
r/R	0.83	0.85	0.86	0.87
Resistance to rutting				
Void %	6.6	6.8	7.0	6.8
Depth at 3000 cycles (%)	3.5	3.6	6.0	3.7

First of all, the voids content is similar in any cases, conveying a similar workability for all the bituminous mixes.
The depth at 60°C after 30000 cycles is much lower for Bitumen In-block than the one obtained with conventional bitumen. For example, a better resistance to the permanent deformation is observed with In-block B (3.7 % of depth) comparing to Bitumen B where the percentage of dept reaches 6%. This result confirms the hardening of the mix that was measured in the moisture sensitivity test.

- *Modulus and fatigue measurements*

In order to deeper the comparison between Bitumen In-block and conventional bitumen, modulus and fatigue measurements on hot mixes were performed basing on the standard EN 12697-26 and EN 12697-24 respectively [13, 14].
A small improvement on modulus and fatigue experiments is observed with Bitumen In-bock comparing to mixes with conventional Bitumen. **Table 5** presents all the results obtained for the four mixes at same voids content.

Table 5: Modulus and fatigues results obtained

	Bitumen A	**In-block A**	**Bitumen B**	**In-block B**
Modulus at 15°C, 10 Hz, trapezoidal specimens				
Void %	3.7	3.6	3.8	3.9
Modulus (MPa)	11700	11700	8800	9300
Fatigue at 10°C,				
Void %	4	3.8	3.7	3.9
$\varepsilon 6$ µdef	124	135	140	130

In general, using Bitumen In-block does not raise problem on the manufacturing of mixes and all characteristics and performances are unchanged or even better (rutting and water sensitivity).

2.3 Assessment of the creep resistance of the block

In order to evaluate the resistance of block during the transport and the storage phases, a new in-house essay was implanted at lab scale. This test consists in measuring the strength and the stress supplied by the block under a load and at a given temperature. Experiments were performed at 50°C under a load 3.65 kg (7 times the mass of the block) and results are presented by **Table 6**.

Table 6: Force and Stress supplied by bitumen at 50°C

	Bitumen A	In-block A	Bitumen B	In-block B
Force max (N)	4.7	43.6	3.6	40.4
Stress at force max (N/mm^2)	0.032	0.14	0.011	0.13

According to this table, creep resistance for the formulation of bitumen In-block compounds is at least ten times more than the one of conventional bitumen In-block at 50°C.
On the other side, experiments were performed at lab scale with the objective to determine the temperature from which a deformation appears on these blocks. These blocks were placed on an oven under a load equivalent to the one undergoes by the block of a real palette of 1 ton.
Under a load seven times the mass of the block, Bitumen A and B deform completely at a temperature of 25°C. However, In-block A and B support a temperature of 70°C with any deformation. From 75°C, In-block deforms at start to flow (**Figure 4**).

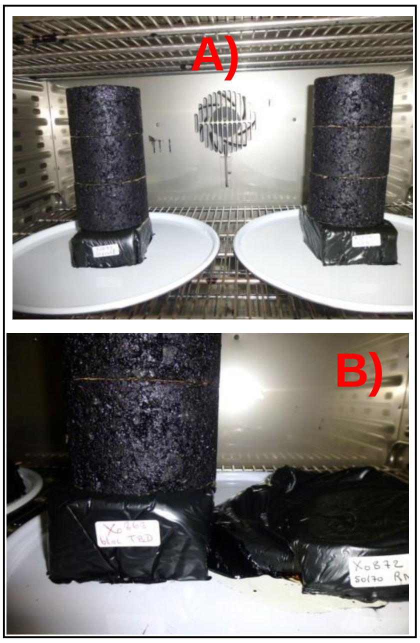

Figure 4: Creep resistance test, A) Bitumen In-Block (left) and conventional bitumen (right) at the beginning of the test at 50°C, B) after 1 hour conventional block completely deformed and Bitumen In-block resists to more than 30 days at 50°C

2.4 Bitumen In-block industrial production and transport to Algeria

In the aim of verifying the resistance of the Bitumen In-block during both transport and storage phases, a production of 25 tons of Bitumen In-block was conducted on December 17th, 2014 at Total plant in Brunsbüttel - Germany. 40 blocks of Bitumen In-block were conditionning in a pallet of 1 ton and all pallets were placed in a container as **Figure 5** shows.

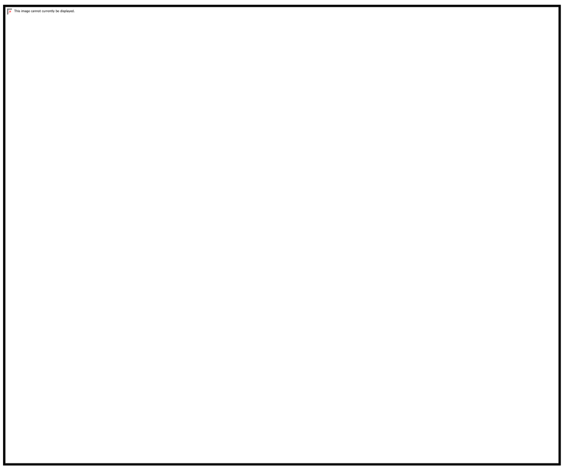

Figure 5: Conditioning of In-block pallets and preparing the container of 25 tons of Bitumen In-block to travelling to Algeria by ship.

This container was then shipped to Algeria on December 20th, 2014 and it was arrived on destination on January 19th, 2015. After, this container was stored on the port of Alger waiting logistic procedures.
On March 22th 2015 the container containning blocks leaves Alger to the its destination on the south-east of Algeria (Ouargla).
Under a temperature of 40°C blocks present a very good aspect and no deformation was noticed after more than 12 weeks after their production as we can see on the **Figure 6**.

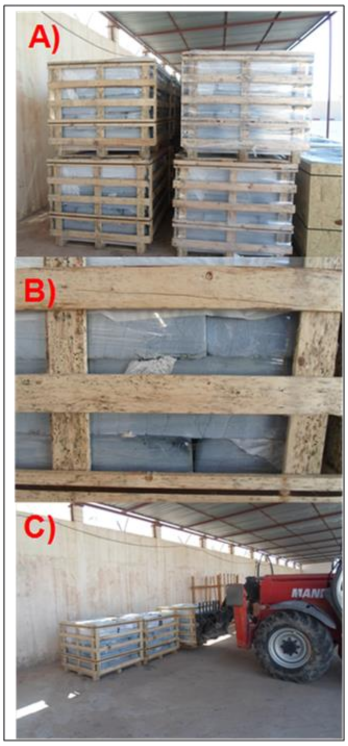

Figure 6: Quality of pallet (A) and blocks (B) arriving at Ouargla on the south of Algeria on March 22th after more than 3 months of production.

Finally, a road construction test will be done on the mid of April with Bitumen In-block in the city of Ouargla (800 km in the south of Alger) in order to validate this new technology.

2.5 Road construction at Ouargla

At Ouargla, Bitumen In-block was stored outside under sunlight to evaluate the deformation of blocks during time at a outside temperature between 38 and 45°C. The product behaves well and only a small deformation of blocks is observed after a few days of exposure. They remain acceptable in a whole (**Figure 7**).

Figure 7: State of blocks after a storage in the sun during 7 days. A collapse of 6 cm is observed.

The first step of the wellsite was realized with a mixture of a conventional bitumen 50/70 and Bitumen In-block (approximative proportion 50/50). The second step was realized with 100 % Bitumen In-block. No difference between the two steps of the trial was noticed and the blocks melt rapidly in the kettle and do not lead to any difficulty during the production of bitumen hot mixes. **Figure 8** presents some pictures during the construction of road in Ouargla on April 13th, 2015. With the aim of following the state of the wellsite, samples will regularly be taken and assessed.

Figure 8: Road construction at Ouargla with Bitumen In-block on April 13th, 2015.

3. CONCLUSIONS

Using an innovative technology; conventional paving grade bitumen can be transported in the form of blocks without external packaging.

Firstly, a strong hardening of In-block bitumen is noticed, but this hardness has neither a negative effect on the viscosity at high temperature nor on the low temperature properties of the binder.

Besides, there is no detrimental effect of this new technology on all the mixes characteristics (TSRST, water resistance, rutting test, modulus and fatigue). Some of these properties are even slightly improved with the technology of In-Block.

Finally, by using this technology conventional bitumen can be transported in form of blocks of 25 kg at room temperature without any deformation till a temperature of 75°C. A container containing 25 tons of Bitumen In-block was transported from the north of Germany to the south of Algeria. No problem was observed in the 12 weeks between the production of these blocks and their storage. With Bitumen In-block a road was constructed in Ouargla in the south of Algeria and no difficultites were noticed during construction.

4. NEXT

With the aim of following the state of the worksite, samples will regularly be taken and assessed. Others roads contructions are in preparation in different African countries (e.g. Congo, South Africa, …).

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