

# A new bituminous binder replacing oxidized bitumen in roofing applications

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Digital Object Identifier (DOI): [dx.doi.org/10.14311/EE.2016.134](https://doi.org/10.14311/EE.2016.134)

## ABSTRACT

*Thanks to its excellent properties of adhesion, the use of the oxidized bitumen as HAC goes back up to decades. However, these oxidized bitumen's stemming from blowing processes possess a high viscosity leading to an application temperature superior of 210°C. In these conditions of applications, smokes are generated and can disturb the operator.*

*In the objective to reduce the application temperature of these HAC, an alternative binder to oxidized bitumen for bonding applications was developed.*

*This new product possesses similar or superior performances to those of the oxidized bitumen. It is characterized by a Ring-Ball temperature close to 100°C and a weak viscosity what allows an important reduction of the application temperature (from 40 to 90°C). This decrease improves on one hand the comfort of the teams of application by a remarkable reduction of smokes and on the other hand allows a substantial energy saving.*

*Besides, peeling experiments showed a bonding property more successful than that observed with oxidized bitumen.*

*Finally, an excellent creep resistance is demonstrated by rheological measurements until a temperature of 75°C under load. Consequently, a stability strengthened by this product in block during its transport and its storage is noted.*

**Keywords:** Adhesion, Bonding, Fumes, Industrial application, Waterproofing

# A new bituminous binder replacing oxidized bitumen in roofing applications

## 1. INTRODUCTION:

Oxidized bitumens are known for their adhesion properties in particular for applications in public works and buildings. They are conventionally used as binder for bonding waterproof membranes or insulation materials on roofs. The recommended application temperature of these oxidized bitumens is generally above 200°C, or even above 250°C to obtain sufficient fluidity and allow their application and the bonding of structures on the floors or walls to be covered. Their use at these temperatures leads to a high energy consumption and requires additional heating time, increasing the duration of the coating process for the implementation of the bonding step.

Bituminous compositions have been proposed to replace oxidized bitumen in bonding applications, in particular non-bituminous compositions such as for example, hydraulic binders based on cement and superplasticizer or bituminous compositions containing elastomers for hot or cold application. There is also a commercial product available on French market and we are going to call it during this study by EAC-SEBS which corresponds to a modified bitumen based on SEBS (polystyrene-b-poly(ethylene-butylene)-b-polystyrene) used for heat welding of thermal insulation or waterproofing sheets for roofing.

The primary purpose of this study was to provide an effective bonding binder that can be used to bond coatings on structures such as floors and walls, with improved tear strength and peel resistance.

Another purpose was to provide a workable bonding binder that is easy to lay in order to shorten the time required for bonding. In particular, this study investigated a bonding binder for hot sealing (coating) that makes it possible to lower the application temperature of bituminous bonding binders while being sufficiently workable at this temperature (less than or equal to 160°C).

A final objective of the study was to provide a bituminous binder that can withstand its transport and storage conditions.

## 2. SAMPLES AND TESTING CONDITIONS

Five bonding binders were evaluated in this research. They were:

Oxidized bitumens marketed by a petroleum company and called Box1, Box2 and Box3. These three oxidized bitumens are obtained by blowing bitumen.

A new product developed and marketed since February 2014 by a petroleum company and called in this study bitumen B.

A product presents on the market and we are going to call it by EAC-SEBS. The characteristics of these products are listed in **Table 1**.

**Table 1: Results of characterizations carried out on different types of bonding binder.**

Bonding binder	<b>B<sub>ox1</sub></b>	<b>B<sub>ox2</sub></b>	<b>B<sub>ox3</sub></b>	<b>C<sub>1</sub></b>	<b>C<sub>2</sub></b>
Type of bitumen	Oxidized 1	Oxidized 2	Oxidized 3	Bitumen B	EAC-SEBS
P25 ( <sup>1/10</sup> mm)	25	28	40	29	42
R&B (°C)	113	85	100	115	76.5
Brookfield viscosity at 150°C (mPa.s)	7480	1058	2246	170	776

## 3. RESULTS AND DISCUSSION

According to the present study, composition C<sub>1</sub> has a lower viscosity at 150°C than oxidized bitumens **B<sub>ox1</sub>**, **B<sub>ox2</sub>** and **B<sub>ox3</sub>** and composition C<sub>2</sub>. Therefore, compared to existing hot binders on the market, the compositions are

sufficiently workable at low temperature to be applied at temperatures of about 160°C, thereby reducing energy consumption and application times of the bonding binder and therefore the length of the coating process. Moreover composition C<sub>1</sub> was found to have an equivalent R&B and penetrability P25 to those of the oxidized base B<sub>ox1</sub>.

The values of the R&B and penetrability P25 are used to assess the consistency of bitumen and bituminous compositions as well as their resistance to deformation. Thus, the higher the R&B and the lower the penetrability, the better the consistency of the bituminous composition and its resistance to deformation. The bituminous compositions studied in this research had a similar consistency to that of currently marketed oxidized bitumens while allowing application at a lower temperature than that of oxidized bitumens.

### 3.1 Creep test

The creep test was carried out as follows. A 0.5 kg mass of each sample of bonding binder was hot cast in a scrap metal mould and then unmoulded when cold. The resulting blocks were placed in ovens at different temperatures under a load of 3.65 kg (+/- 50 g) to simulate the stacking of the blocks one on top of the other, during transport.



**Figure 1: Diagram of the test for evaluating the resistance to deformation.**

Six blocks are in fact generally stacked vertically on a pallet during transportation of bitumen blocks. Blocks were first placed in an oven at a temperature of 40°C. If no creep was observed after a certain time of not more than 15 days, new blocks were moulded and placed at a higher oven temperature. This operation was repeated until a substantial creep of the blocks was observed. This creep leads to a deformation of the blocks and a flow of the bituminous composition. Blocks deformed in this way are unusable as bonding binder. The evaluation of creep was performed qualitatively by visual inspection.

**Table 2** below shows the creep test results obtained for the different samples.

**Table 2: Summary of creep test results obtained with the different bonding binders analysed.**

Bonding binder		B <sub>ox1</sub>	B <sub>ox2</sub>	B <sub>ox3</sub>	C <sub>1</sub>	C <sub>2</sub>
Oven temperature (°C)	40	slight creep after 3 days	slight creep after 3 days	slight creep after 3 days	no creep*	slight creep in 4h
	50	creep in 24h	considerable creep in 24h	creep in 24h	no creep*	creep in 24h
	60	NR**	NR**	NR**	no creep*	NR**
	70	NR**	NR**	NR**	no creep	NR**
	80	NR**	NR**	NR**	no creep	NR**
	85	NR**	NR**	NR**	slight creep after 6 days	NR**

\*: No creep observed after 15 days at the temperature.

\*\* NR: not relevant; the bonding binder was not tested as creep was observed at lower temperatures. Only the bituminous composition C1 packaged in the form of blocks does not creep under usual storage and transport conditions.

### 3.2 Peel test

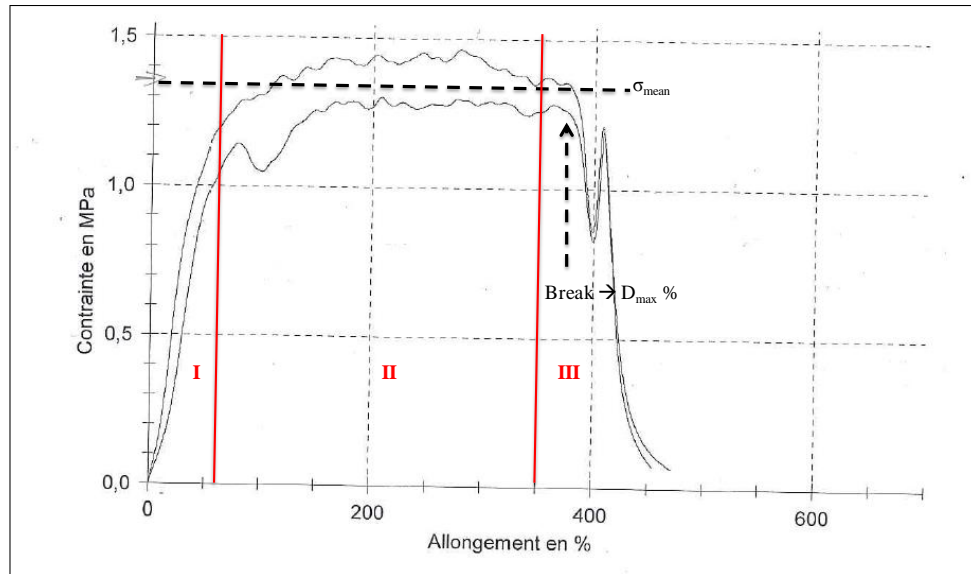
The principle of this test is to apply traction on a sample consisting of two strips of an identical sealing membrane bonded together by the adhesive binder to be tested. Each strip had an initial length of 15 cm. The two strips were bonded by pouring at 160°C a layer of the bonding binder 1 to 2 mm thick on one side of one of the membrane strips. The two strips were then joined and held together until the bonding binder had cooled to form the test sample. One of the two ends of the two sample strips was not bonded for a length of about 4 cm. When the sample had cooled to ambient temperature, the peel test was performed using a commercially available Zwick tensile strength testing machine equipped with a thermal chamber for carrying out the test at 23°C. Each unbonded end of the sample was held by a grip of the tensile testing machine. The initial distance between the two grips was 50 mm. The angle of traction between the two membranes of the sample, initially at 90° was progressively opened during traction which was performed at a speed of 10 mm / min. Under stress, the membranes of the sample lengthened until the bonding binder yielded and the membranes came apart or until at least one of the membranes tore (**Figure 2**).



**Figure 2: Picture of peel test made by tensile testing machine.**

The tensile testing machine measures the mean stress applied to the sample ( $\tau_{\text{mean}}$ ), the maximum distance between the two grips before separation of the two membranes as a percentage of the initial distance between the two grips ( $D_{\text{max}}$ ), and the energy provided to achieve this maximum distance ( $E_{\text{max}}$ ). The results are given in the Table 3 and a typical curve of the peeling test obtained with bitumen B is in **Graph 1**, the trial was repeated two times. 3 regions (I, II and III) can be identified in this graph:

- The first region at  $D < 50\%$  of elongation corresponds to the separation of two ends of the two sample strips (not bonded for a length of about 4 cm).
- The intermediate region corresponds to the separation of the two samples bonded by bonding binder (Bitumen B in this case). In this part, the stress is constant due to a resistance of the bonding binder. From this part the mean stress applied to the sample  $\tau_{\text{mean}}$  can be calculated and it is equal to 1.3 MPa in the case of Bitumen B.
- Beyond 375 %, the two samples are completely separated or broken. From this part the maximum distance ( $D_{\text{max}}$ ) is calculated and it is equal to 380% as reported in Table 3.



**Graph 1: Typical curve of the peeling test obtained with bitumen B.**

The bituminous composition **C<sub>1</sub>** was a particularly effective bonding binder compared to oxidized bitumens. This is shown by the results of the peel test where the mean stress  $\tau_{\text{mean}}$ , distance  $D_{\text{max}}$  and energy  $E_{\text{max}}$  were significantly higher than those of bonding binders **B<sub>ox2</sub>** and **B<sub>ox3</sub>**.

**Table 3: Results of the peel test with different bonding binders.**

Bonding binder	<b>B<sub>ox2</sub></b> *	<b>B<sub>ox3</sub></b> *	<b>C<sub>1</sub></b>	<b>C<sub>2</sub></b> *
$\tau_{\text{mean}}$ (MPa)	0.9	0.35	1.3	0.6
$D_{\text{max}}$ (%)	150	120	380	350
$E_{\text{max}}$ (J)	2.5	1.1	8.7	3.5

\* Implementation required a temperature of 190°C instead of 160°C.

Compared to the bituminous composition **C<sub>2</sub>** comprising a polystyrene-b-poly(ethylene-butylene)-b-polystyrene polymer (SEBS), the bituminous composition **C<sub>1</sub>** clearly had higher maximum stress  $\tau_{\text{max}}$  and energy  $E_{\text{max}}$  values for an equivalent  $D_{\text{max}}$  value.

The bituminous composition Bitumen B was outstanding and more effective as a bonding binder than existing bonding binders on the market, particularly compared with oxidized bitumens and bitumens modified with polymers. It also has an excellent workability. It has a very good fluidity at a temperature of 150°C, which makes it suitable as a bonding binder at an application temperature of below 160°C. On the contrary, the recommended application temperature for oxidized bitumens is generally about 220°C to 250°C to obtain sufficient fluidity to allow their use as a binder. At this temperature, there is a high energy consumption and a long heating time. The recommended application temperature of bonding binder **C<sub>2</sub>** is from 190°C to 200°C. At this temperature, power consumption and heating times are still excessive.

### 3.3 Workside trials

#### a- Bonding with Oxidized Bitumen **B<sub>ox1</sub>**

Initially, foam glass was bonded with oxidized bitumen of type **B<sub>ox1</sub>** on the vapour barrier layer already in place (**Figure 3**). Considerable smoke emissions were observed both above the melter, the temperature of which was measured at 265°C, and during the bonding of expanded glass blocks by employees (equipped with protective masks).





**Figure 3: Bonding of foam glass blocks with B<sub>ox1</sub>: significant smoke emissions were noted.**

The B<sub>ox1</sub> oxidized bitumen blocks used on this site were blocks made at Brunsbüttel (TBD). The melter temperature was reduced (burner valve on minimum) in order to use the Bitumen B binder after completely emptying the tank of B<sub>ox1</sub>.

**b- Tests with Bitumen B**

The temperature readings then indicated 170°C in the tank and 160°C in the bitumen watering can before application. A temperature of about 100°C lower is observed with Bitumen B compared to the oxidized block B<sub>ox1</sub>.

Several tests were carried out to check the bonding behaviour of Bitumen B according to several techniques:

**a- Bonding foam glass blocks:** each block of foam glass was bonded by a thin layer of binder with an estimated thickness of about 1 mm, poured with the watering can. The temperature of Bitumen B on the ground was between 150 and 155°C. Bitumen B had a very good fluidity at a temperature of 150°C with more or less no smoke emission (**Figure 4**).



**Figure 4: No smoke was emitted during bonding of foam glass with Bitumen B at 160°C.**

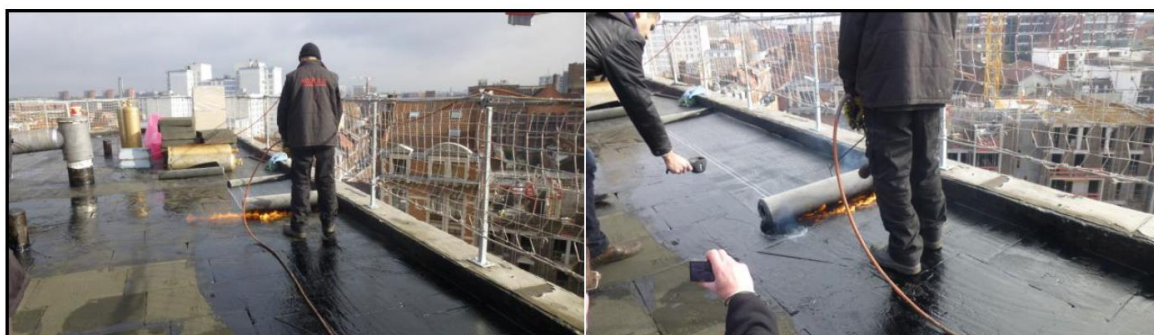
**b- Low temperature bonding of a membrane:** The same operation was repeated for bonding a vapour barrier in order to test adhesiveness. The roof temperature was about 9°C and Bitumen B was poured at a temperature of about 155°C. For this type of test, the binder temperature must be well above 130°C, temperature at which the vapour barrier membrane begins to soften.

After cooling of the assembly in approximately ¼ hour (T = 15 ° C), a traction was performed and the internal structure of the membrane (glass fibre mat) was found to tear and it was almost impossible to tear the Bitumen B (**Figure 5**).



**Figure 5: Bonding membrane by Bitumen B, tearing of the membrane after a tensile test.**

**c- Bonding with a torch:** A 3<sup>rd</sup> and final test was performed by bonding a membrane with the torch (another technique that can be used) on foam glass blocks previously coated with a thin layer of Bitumen B “glaze”. The appearance of the bonding was very good and no problems were encountered.



**Figure 6 : Bonding of a membrane with Bitumen B using a torch.**

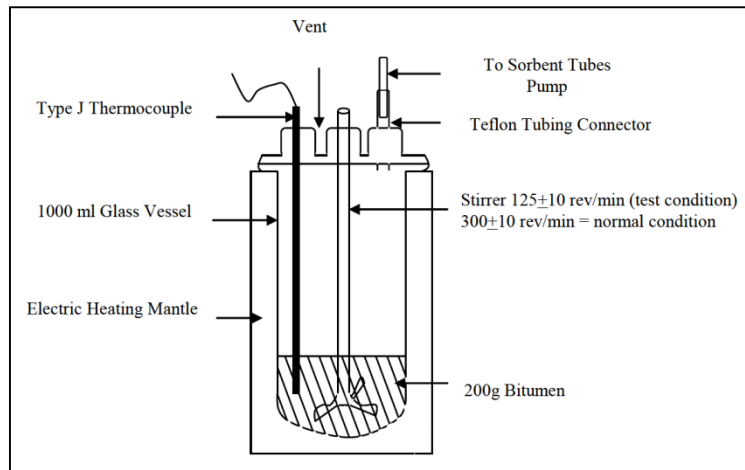
### 3.4 VOC measurements:

In order to assess the toxicity of Bitumen B during its application, measurements of VOC (volatile organic compounds) were made in collaboration with the laboratory of the Heritage Research Group in Indianapolis. Comparative measurements for several binders including Bitumen B and oxidized bitumen B<sub>ox1</sub> were made using a method similar to that of the Environmental Agency (EPA), SW-846 8260B.

#### a- Operating Protocol:

The bitumen pre-heated in a thermostated chamber at the desired VOC measurement temperature was transferred into a reactor below in order to generate smoke under controlled stirring. The smoke emissions were absorbed by a specific cartridge, as shown diagrammatically in **Figure 7**.

The VOCs were then extracted from the cartridge by desorption with a vacuum pump, and recovered in a solvent such as dichloromethane and analysed by GC-MS (gas chromatography-mass spectrometry).



**Figure 7: Diagram of the smoke generation system.**

**b- Analysis results:**

The VOC results are summarized in **Table 4**. This table shows the results obtained with Bitumen B at an application temperature of 160°C, bitumen RA used in the sealing application at 180°C produced by the same petroleum company and oxidized bitumen studied at two different temperatures, 200 and 230°C.

**Table 4: Summary of VOC results obtained on the different bitumens.**

	Temperature	VOC (mg/kg)
Bitumen B	160°C	16.3
Bitumen RA	180°C	72.5
Oxidized bitumen B <sub>ox1</sub>	170°C	135
Oxidized bitumen B <sub>ox1</sub>	200°C	407
Oxidized bitumen B <sub>ox1</sub>	230°C	2023

Bitumen B emitted 10 times less VOC at 160°C than an oxidized bitumen used at a similar temperature (difference ≤ 10°C) (16.3 vs. 135 ppm), and in particular about 100 times less than an oxidized bitumen at a “standard” application temperature (230°C).

**4. CONCLUSION**

Bitumen B was evaluated in this study as a bonding binder. Laboratory tests showed its high performance compared to standard bonding binders such as oxidized bitumen or polymer modified bitumen. Its low viscosity is a great advantage as the application temperature can be lowered by several tens of degrees compared to an oxidized bitumen. This allows a reduction in energy consumption of about 30% and almost non-existent smoke emissions with Bitumen B at 160°C. This reduction in emissions was validated by a study of volatile organic compounds which showed that Bitumen B emits 10 times less smoke than oxidized bitumen at an application temperature of about 160°C.

The different tests performed on building sites confirmed the results obtained at laboratory scale and clearly demonstrated the different advantages of Bitumen B compared to other bonding binders.

**ACKNOWLEDGMENTS**



We thank the companies MEPLÉ and FOAMGLAS (France and Belgium) for their contributions during the preparation and execution of the different sites to validate the product. We also thank Heritage laboratory (US) for its contribution when performing toxicity tests on the different bonding binders.