Bituminous emulsions

High performance termosetting emulsions

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Abstract

Correct tack coating is extremely important, not only in order to seal the existing surface against the entry of water and, but also to bond the wearing course to the base course. Inadequate bonding between layers can result in detachment, followed by longitudinal wheel path cracking, potholes and other distresses, such as rutting that greatly reduce the life of the pavement. The use of conventional emulsions for tack coats can cause problems as they frequently stick to the tires of construction vehicles. Consequently, the bond between the asphalt layers is inadequate. The emulsions usually used for tack coats usually causes problems in the application, since it residual binder have a low consistency that frequently adhere to the tires of the work vehicles and, in consequence, the adherence between the layers of asphalt is reduced. To respond to the need for improvement of these products, for years new types of emulsions (thermo-adherent), made from hard bitumen, have been developed. These emulsions have low tackiness and are therefore resistant to traffic. However, there are still some application conditions, linked to the high summer temperatures, in which even thermoadherents emulsions, have limitations. In this work, the results of the development of high-performance thermosetting emulsions that solve the problems presented by the usual products, with extreme weather conditions, are presented. The advantages are a high adherence to the surface of the pavement and no adhesion to tires, on-site cleaning, fast breakage and greater efficiency even with lower dosage. In order to verify its best performance, results of comparative tests with conventional tack coat emulsions and with normal thermoadherents will be presented

This paper was first published in 2020 in version 1.0 of the proceedings of the 7th E&E Congress. This second edition (version 1.1.) of the proceedings is published in June 2021. The content of this paper has not changed, but the author(s) may have provided additional information in the form of an annex.

1. INTRODUCTION

An asphalt pavement is a structure constituted by one or more layers of bituminous mixture, that are supported on an sub-base course, providing structural features, since it receives directly the traffic loads, and they must be transmitted to the esplanade in the most dissipated possible way. [1].

The top layer also comprises the wearing course of the pavement, providing functional, comfort and road safety features. In order to meet all these expectations, being efficient during the whole service life of the asphalt pavement, it is essential that all the asphalt layers are fully adhered through tack coats with bituminous emulsion.

Inadequate bonding between layers can result in detachment, followed by longitudinal wheel path cracking, potholes and other distresses, such as rutting that greatly reduce the life of the pavement.

The use of conventional emulsions for tack coats usually induces problems as they frequently stick to the tires of construction vehicles. Consequently, the bond between the asphalt layers results inadequate.

To respond to the need for improvement of these products, for years new types of emulsions (called thermo-adherent), made from hard bitumen, have been developed. These tack coat emulsions have lower tackiness and may be, therefore, resistant to traffic. However, there are still some application conditions, linked to the high summer temperatures or hot climates where, even thermo-adherent emulsions have limitations.

In recent years, there has been a great progress in the field of bituminous emulsions and, especially for the application in tack coats, about the development of specific thermo-adherent emulsions. These cationic emulsions upgrade characteristics such as quick breaking index, viscosity, a better consistency of the residual binder and low thermal susceptibility among others; nevertheless its bigger improvement is the lower to none stickiness, even at high pavement temperatures. This guarantees, throughout the whole application of the new bituminous layers, that the dosage of the tack coat corresponds with the projected one, since no binder adheres to the tires of the traffic of work.

Therefore, to achieve an effectiveness in these treatments, it is important to choose the type of emulsion properly, a correct quality control of the product, an adequate selection of the machines, and implementing best practices during application of the tack coat.

In this context, the company CEPSA has carried out an internal research project where the main goal is focused on the development of high performance thermo-adherent emulsions for their application as tack coat between asphalt layers in pavements improving their mechanical behaviour and durability. Similarly, these bituminous emulsions will be evaluated through traditional and innovative laboratory tests in comparison with others bituminous emulsion used for this application.

This paper presents some of the results obtained for these new emulsions to evaluate their performances and main advantages as high adherence to the surface of the pavement and no adhesion to tires, on-site cleaning, rapid setting and greater efficiency even with lower dosage.

2. WHY HIGH PERFORMANCE THERMO-ADHERENT EMULSIONS?

Bituminous emulsions used in tack coating have undergone a clear evolution in recent decades. Thus, traditional tack coating emulsions type C60B3/2 ADH according to European standard EN 13808 [2], gave way to modified tack coating emulsions type C60BP3/2 ADH. The use of these polymers modified bituminous emulsions with meant at the time a remarkable advance for the tack coats to be applied under special wearing courses, since the residual binder from these emulsions is also a polymers/latex modified binder, that guarantees a better adhesion between these surface layers and the intermediate or base layers beneath.

Nonetheless, the biggest challenge in these products was to come because, unfortunately, in hot climates, these tack coats did not guarantee its functionality, after being partially removed by the tires because of the construction traffic, which took an important part of the tack coat. This situation, in addition to smudging the work site and making the road marks to be repainted (Figure 1), means a lower effective dosage of residual binder on the sprayed surface as well as, a lack of uniformity in it, which can cause problems of premature deterioration, since the layers of the firm cannot work in solidarity [3].

Figure 1: Problems presented with conventional tack coat emulsions.

To solve this problem, the bitumen emulsion sector undertook 15 years ago the development of new tack coat emulsions that sought to guarantee the solidarity operation of the asphalt mix package during the entire service life of the firm. These new emulsions were called thermo-adherent and are characterized by having a good adhesion to the support but minimal to the vehicles of the work traffic. Its specifications are currently included in the Spanish regulations in the national annex of the UNE EN 13808 / 1M: 2014 [4] and in art. 214 of PG-3 [5].

The particularity of these emulsions is that, once the breakage occurs, they leave a high consistency residual binder film on the asphalt mixture that does not have stickiness to the tires of the work, so that the coating remains adhered to the support and does not get up attached to these. However, the application of the next layer of hot bituminous mixture causes that, because of the temperature, that residual binder layer is activated and adhered to it, which is the objective sought.

To date, millions of m^2 of roadways have already been treated with these thermo-adherent emulsions in the tack coats between layers and, except in very critical conditions, they are working properly. However, we must know their limitations in order to solve them with a new generation of high performance thermo-adherent emulsions.

Thermo-adherent emulsions are rapid cationic emulsions made of hard, modified or not, bitumen, without flux oils and with a medium binder content (60%). This composition makes thermo-adherent emulsions difficult to formulate. In general, emulsions with an average particle size greater than 5 microns and a high polydispersity are obtained. All these factors translate into a high tendency to sedimentation, which means that these emulsions are not very stable at prolonged storage times. They are manufactured with the conventional system, using high power shear colloid mills where the binder phase must have temperatures between 130-150 ° C, and a viscosity between 200 and 300 mPa.s, in turbulent regime, with stirring rate around 3000 to 5000 rpm, and a temperature for the aqueous phase of 40-60 ° C. This manufacturing system limits some final characteristics of the emulsion, such as viscosity or binder content.

As an alternative, some manufacturers [6] propose a system that differs from the conventional one, since it works with bitumen at lower temperatures, around 100 °C, and therefore with higher viscosity (above 4000 mPa.s for a 50/70 penetration bitumen), and with very low stirring speed. In this way, they obtain homogeneous emulsions, with very little average particle sizes, even less than 1 micron, and with low polydispersity, which means high viscosity and as a consequence, excellent storage stability of the emulsion. The main drawback of this system of manufacturing thermo-adherent emulsions is that the production is very low and therefore, they still do not allow their production and supply for large works.

Since most of the emulsion factories are based on the use of colloid mills, what this work addresses are the necessary improvements in the design and manufacture of the new emulsions, thanks to the selection of raw materials and the use of additives that allow to enhance the performance of the current thermo-adherent emulsions, especially in those most critical application conditions.

Currently, in these situations, complementary measures [7] can be considered, such as the use of non-stick treatments on truck wheels and material transference vehicles (MTV), these being a particularly aggressive type of vehicle for tack coats due to the large unit load that support their tires (see Figure 2).

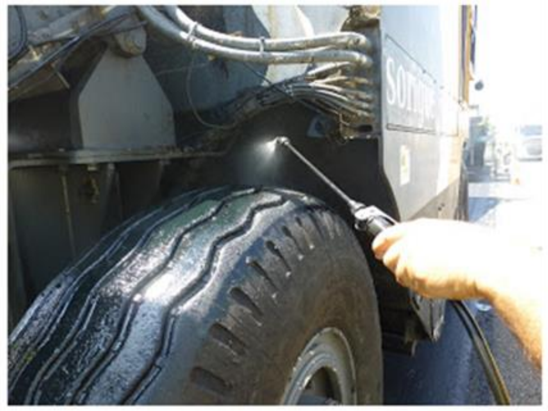


Figure 2: Detail of the application of a non-stick treatment on the wheels of a MTV. (Source: Motores y carreteras)

In very hot periods the tack coat absorbs heat and that makes the residual bitumen softer, thus increasing its stickiness. In these cases, it may be advisable to apply the coating shortly before the spread of the asphalt mixture, now that simply with the heat of the support the emulsion breakage is almost immediate, releasing small amount water, what helps to control the rise in bitumen temperature and reduces its stickiness. However, this practice must be very controlled because, as a general rule, the works traffic cannot circulate above the tack coat until the emulsion has broken and this aspect has to be verified. In small pavement maintenance works, the coordination between milling works, tack coat application and the laying of the asphalt mixture can be especially complex due to the lack of physical space and the need to minimize cutting time of the lanes affected by conservation labours.

For these critical situations, in recent years some manufacturers have been investigating the development of high performance emulsions for this application.

The work presented is divided into two parts. The first is based on an evaluation of the physicochemical characteristics of different emulsions for tack coating, where the evolution in their performance of these emulsions can be appreciated until the optimization with the high performance emulsion was achieved. The second part is based on a comparative laboratory study of the evolution during storage presented by some of these formulations. This study is based on assessing the storage stability of the selected emulsions for 2 months. For this, two formulations have been selected (one standard formula and another plus an additive to enhance its performance). As bituminous emulsions are dispersions of bitumen in water, a critical factor in the storage of these products is temperature. Therefore, it is planned to store them in extreme temperature conditions that the lowest could be 5ºC and the highest 65ºC.

3. PHYSICOCHEMICAL CHARACTERISTICS OF DIFFERENT EMULSIONS FOR TACK COATS

First, the typical composition of emulsion formulations for tack coating considered in this work is presented in Table 2.

Table 2: Typical dosage percentages for the preparation of tack coat emulsions

COMPONENT	C60B3 ADH	C60B3 TER	C60BP3 ADH	C60BP3 TER	C60BP3 TER HP
Bitumen 160/220	58-60		40-60		--
Bitumen 15/25		30-60		30-60	0-40
Bitumen 35/50*		30-60		30-60	0-40
PMB 45/80-65**	--	--	0-20	0-20	0-20
Flux oil	0-2	--	0-2	--	--
Additive	0,0-0,3	0,0-0,3	0,0-0,3	0,0-0,3	0,0-0,3
Surfactant	0,15-0,25	0,15-0,25	0,15-0,25	0,15-0,25	0,15-0,25

Additive 2	--	0,0-0,15	--	0,0-0,15	0,05-0,15
Acid	1,0-1,5	1,0-1,5	1,0-1,5	1,0-1,5	1,0-1,5
Cationic latex	--	--	0-2,5	0-2,5	0-2,5
Water	38-42	38-42	38-42	38-42	38-42

Bitumen 50/70 could be used for warm climates
** Another PMB from EN 14023 could be used too

Subsequently, the typical characteristics of the emulsions used in Spain for the application of tack coats are collected in table 3. In the first two columns, the typical values for conventional emulsions are collected. In the next two columns, values for modified emulsions, (PMB or latex). The last column on the right shows the values obtained for the high performance emulsion developed.

Table 3: Main physical and mechanical properties.

PROPERTY		C60B3 ADH	C60B3 TER	C60BP3 ADH	C60BP3 TER	C60BP3 TER HP
Sieve residue (%)		0,01	0,02	0,01	0,0	0,01
pH		3	1,5	3,4	1,7	4,6
Water content (%)		41	40,5	41	39,5	39,6
Oil distillate content (%)		1,6	0	1,6	0	0
Binder content (%)		59	59,5	59	60,5	60,4
Breaking value		90	167	88	159	120
Efflux time, 2mm at 40ºC(s)		38	66	33	50	85
Settling tendency (7 days storage) (%)		5,5	2,1	8,2	1,3	5,5
Method of Recovery: by distillation	Softening point ,°C Penetration at 25ºC,dmm Elastic rec. at 25ºC, % Coh. by pendulum, J/cm^2	43,3 124 -- --	64 30 - -	45,3 125 25 0,85	58,7 43 43 0,91	69,4 24 65 0,91
Method of Recovery: by evaporation	Softening point ,°C Penetration at 25ºC,dmm Elastic rec. at 25ºC, % Coh. by pendulum, J/cm^2	40,1 162 - -	68,7 28 - -	44,5 153 41 0,91	61,9 39 46 0,98	66,8 33 56 0,98
Method of Recovery: by stabilisation	Softening point ,°C Penetration at 25ºC,dmm Elastic rec. at 25ºC, % Coh. by pendulum, J/cm^2	50,4 68 - -	76,5 21 - -	53,1 69 51 0,87	73,3 28 41 0,91	72,8 24 45 0,95
Adhesivity with reference aggregate (%)		95	90	100	75	90
Particle size (µm)		7,21	8,92	4,12	5,98	3,50

Figure 3, 4 and 5 displays the results of properties for the different types of tack coat emulsions. In Figure 3 are presented the comparative results for each essential property of the five tack coat emulsions. One of the most important indicators to expect a good anti-stick performance is the softening point of the binder after distillation or after evaporation, much higher than those of the conventionally used emulsions. Also other characteristics are improved: figure 4 presents the results of the Cohesion Pendulum test, displaying the value of cohesion energy obtained for modified bituminous emulsions. It is seen that the cohesion of the thermo-adherent emulsions (C60BP3TER and C60BP3 TER HP) are higher than the ones for conventional tack coat (C60BP3 ADH) and, especially in the case of the high-performance thermo-adherent emulsions (C60BP3 TER HP), an increase in the cohesion energy of the residual binder after stabilisation is reached, which is representative of the state of binder from the tack coat that will be finally on the road.

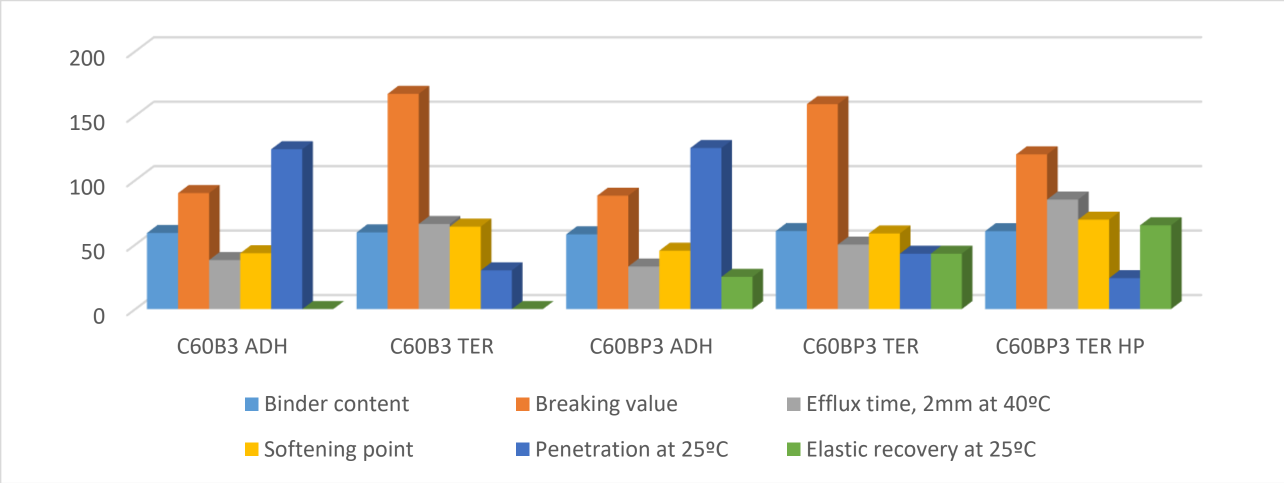


Figure 3: Results of essential properties of tack coat emulsions

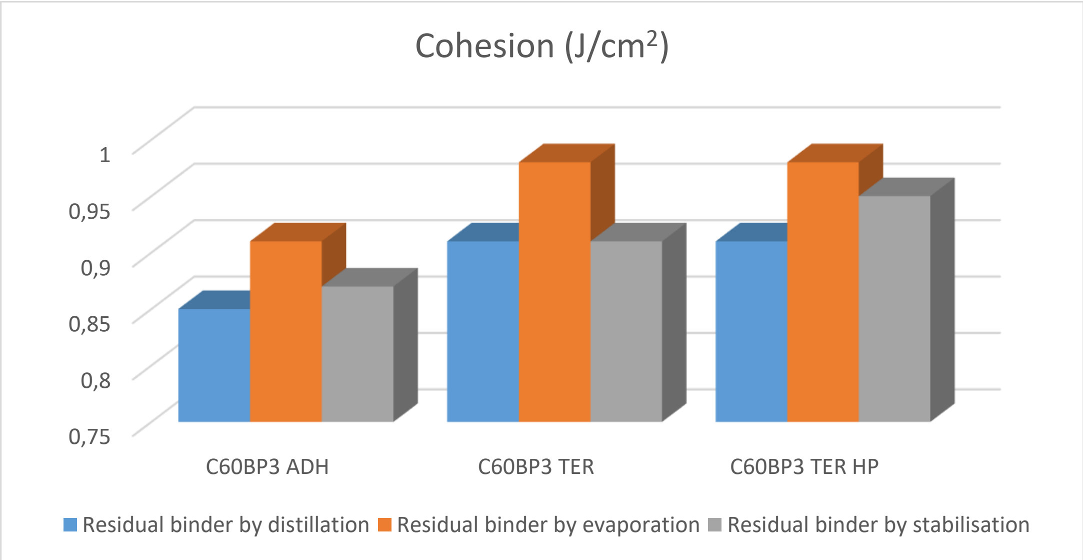


Figure 4: Results of cohesion of residual binders from tack coat modified bituminous emulsions

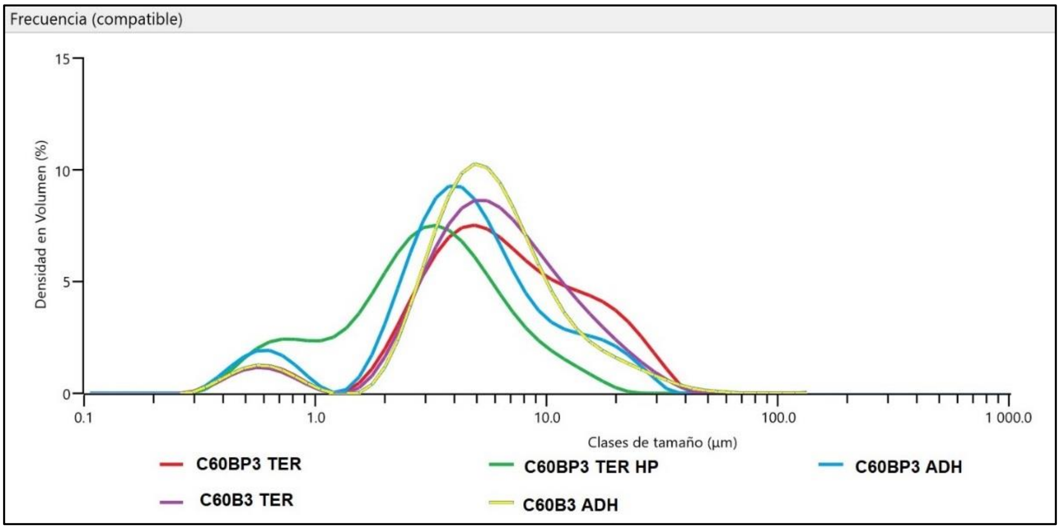


Figure 5: Results of particle size distribution of tack coat emulsions

Figure 5 shows the particle size distribution for bitumen micelles on the different emulsions. None of them are monodispersed. Emulsions with an average particle size greater than 5 microns are obtained in three of the emulsions studied and a high polydispersity in all of them, even for C60BP3 TER HP whose particle size is 3.5 microns

4. HIGH PERFORMANCE TERMO-ADHERENT EMULSIONS.COMPARATIVE STUDY OF STORAGE STABILITY

In terms of use and handling, storage stability is key feature for thermo-adherent emulsions too. That's why the improvement of this characteristic is considered also very important.

The study is based on assess the behavior during storage of two of the emulsions selected from the previous section (C60BP3TER and C60BP3 TER HP) for a period of two (2) months.

16 identical samples of each type of emulsion were prepared in the laboratory and stored in climatic chambers for 8 weeks. Half of each type (8 packages) were introduced into a chamber at 5 ° C and the other half were introduced into a chamber at 65 ° C. For this study, two formulations of thermo-adherent emulsions were selected: the first was a C60BP3 TER formulated without a stabilizing additive (Additive 2 in Table 2), while the second was a C60BP3 TER HP, formulated with a stabilizing additive. Since asphalt emulsions are dispersions of bitumen in water, a critical factor in the storage of these products is temperature. Therefore, its storage is planned at the lowest and highest recommended storage temperature for these types of emulsions.

During the study, each week a sample of each emulsion was removed from the cold chamber and the same from the hot chamber and they were tested using the tests indicated in Table 4 below.

Table 4: Test program for storage stability of emulsions at cold (blue) and hot (red) temperatures

CARACTERÍSTICAS	Standard	C60BP3TER		C60BP3 TER HP	
		5ºC	65ºC	5ºC	65ºC
Sieve residue (%)	EN 1429 [8]	X	X	X	X
Efflux time, 2mm at 40ºC(s)	EN 12846-1[9]	X	X	X	X
Settling tendency (7 days storage) (%)	EN 12847[10]	X	X	X	X

The results are shown in Table 5 and the following graphs (Figures 6, 7 and 8). Colors have been assigned for better visualization of the results, with the red color corresponding to the samples maintained at 65 ° C and the blue color corresponding to the samples maintained at 5 ° C

Table 5: Results for storage stability of emulsions at cold (blue) and hot (red) temperatures

WEEK	SIEVE RESIDUE (%)		SETTLING TENDENCY (%)		EFFLUX TIME AT 40ºC (s)	
	C60BP3TER	**C60BP3 TER HP**	**C60BP3TER**	**C60BP3 TER HP**	**C60BP3TER**	**C60BP3 TER HP**
1	1,53	0,02	10,3	0,8	36	68
2	1,04	0,01	8,4	0,3	35	72
3	0,34	0,02	12	0,3	35	75
4	0,2	0	14	0,6	36	82
5	0,05	0	11	0,8	36	84
6	0,13	0	16,4	0,82	33	75
7	1,03	0	15,2	0,7	32	76
8	0,09	0,01	14,3	0,71	31	77
1	0,02	0,04	15,5	1,6	37	78
2	0,21	0,05	14	4,3	35	77
3	0,04	0,01	16	2	36	76
4	0,02	0,03	17	2,5	37	73
5	0,01	0,02	23	1,7	36	75
6	0,01	0,02	12,1	5,2	35	74
7	0,02	0,03	10,3	2,4	35	74
8						

	0,03	0,01	11,5	3,2	34	74

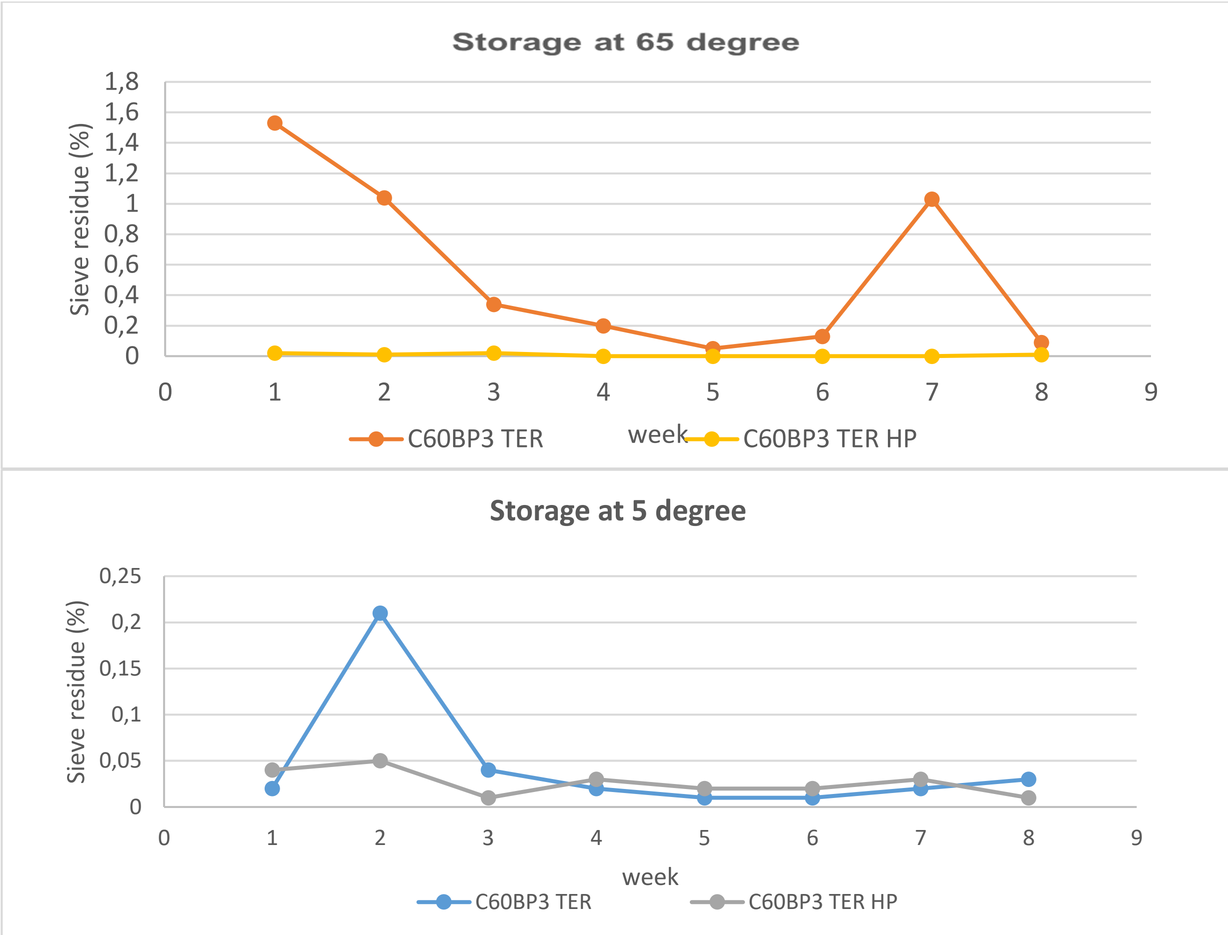
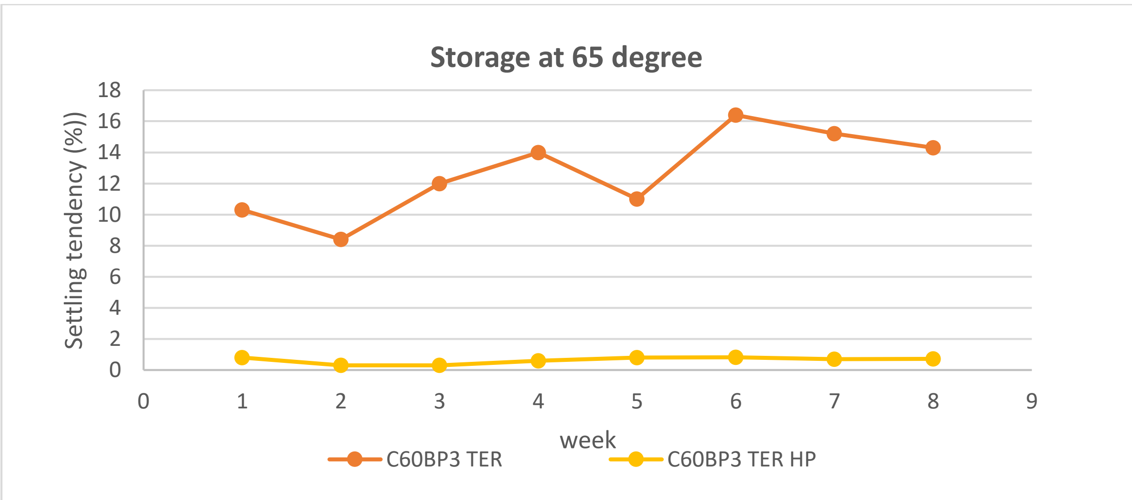


Figure 6: Sieve evolution during storage at 5/65°C



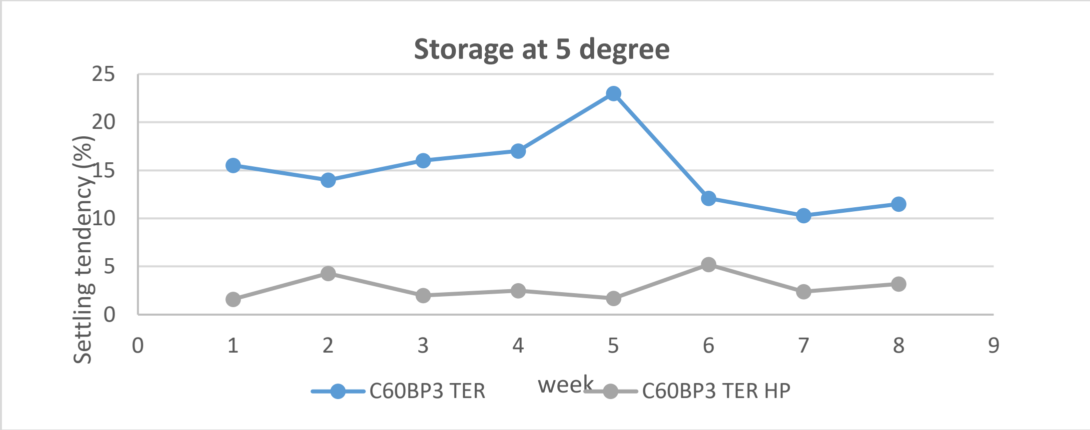


Figure 7: Settling tendency (7 days storage) evolution during storage at 5/65ºC

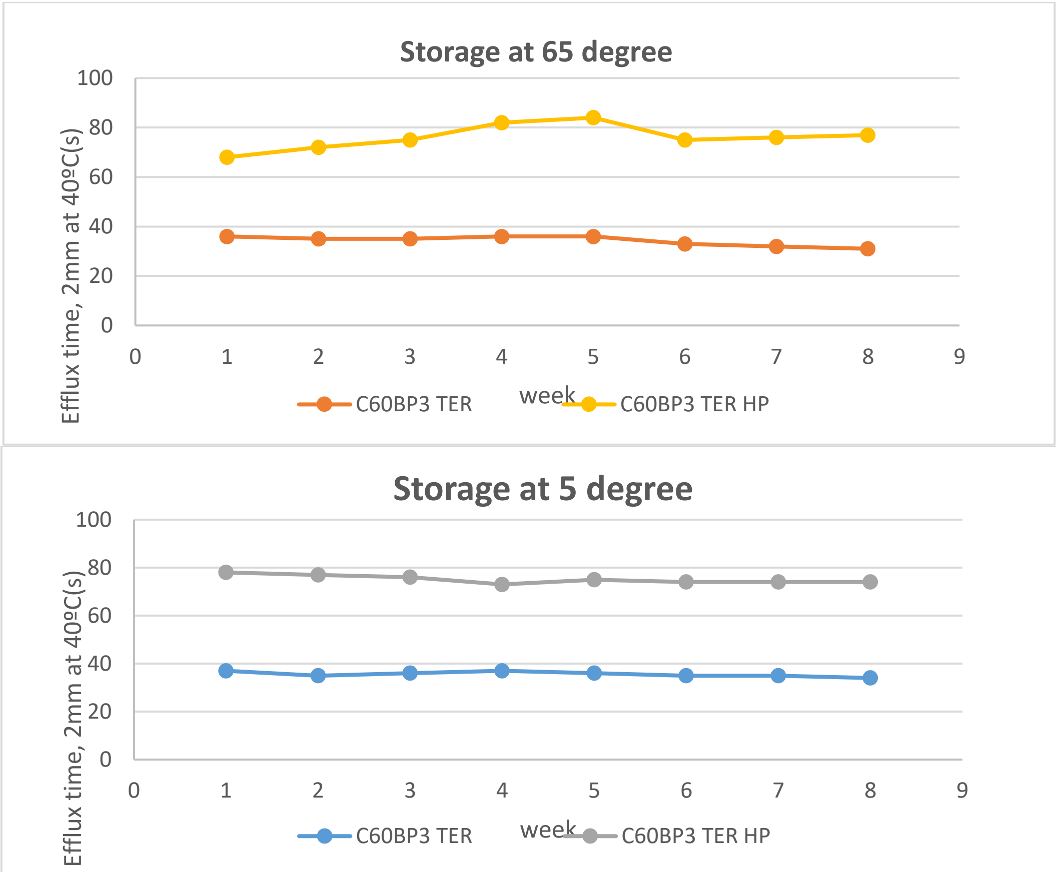


Figure 8: Viscosity evolution during storage at 5/65ºC

The results in Table 4 display a better performance during both low and high temperature storage of the modified high performance C60BP3 TER HP emulsion.

The effect on the stability of emulsions during cold storage (5 ° C) is greater than during hot storage (65 ° C). Hence it is observed that the sieving values in Figure 6 are, in general, higher at 5 ° C, although, in the case of the modified high performance thermo-adherent emulsion (C60BP3 TER HP) the obtained values are always below the maximum allowed (0.1%), regardless of storage temperature and until the end of 8 weeks.

The graphs in Figure 7 also show a lower tendency to sedimentation of the modified high performance thermo-adherent emulsion (C60BP3 TER HP) for which low sedimentation results and less than 10% are always obtained.

As for the evolution of viscosity with storage time, the graphs in Figure 8 show that there is no effect on this characteristic should the product is stored cold or hot, although throughout the entire test time a higher viscosity of the high performance modified thermo-adherent emulsion (C60BP3 TER HP) had been mantained as a result of the incorporation of a stabilizing additive in the formulation.

5. CONCLUSIONS

The purpose of this work is to study the optimization of high performance modified bitumen emulsions for application in tack coats to improve their behaviour and ensure the long lasting service life of the pavement. This paper reviews the importance of tack coat performance and the role of this type of bituminous emulsions.

The results presented in this work anticipate a good behaviour during the application and a very good stability of these emulsions during storage at critical temperatures.

The results obtained for these new emulsions support their advantages such as high adherence to the pavement surface and non-stickiness to tires, on-site cleaning, quick setting and greater efficiency on tack coats application. Final test trial on field is expected to confirm this in the future.

From this study, the main conclusions are the following:

-The development of high-performance thermo-adherent emulsions represents an improvement in the characteristics of the emulsions type C60BP3 TER currently used and they meet the specifications set for these emulsions in the national annex of the European standard EN 13808 for application in tack coats.

-The use high-performance thermo-adherent emulsions (C60BP3 TER HP) allows a higher consistency of residual binder. This would allow an increased resistance to be adhered to trucks tyres and other work vehicles while applying de next layer of asphalt on the road.

-Polymer thermo-adherent emulsions (C60BP3TER and C60BP3 TER HP) present higher cohesion than the type C60BP3 ADH, produced with softener bitumen and this is expected to play an essential role on the mechanical response and durability of the pavement. These type of emulsions are specially recommended under the wearing course as it is usually produced with polymer modified bitumen.

-The results of the laboratory study conducted to evaluate the behaviour during storage of polymer thermo-adherent emulsions for 2 months, have shown a better performance during storage, at both low and high temperature, of the modified high performance emulsion C60BP3 TER HP. Particularly, it was improved the resistance to settling based on its higher viscosity and lower particle sizes obtained for this new emulsion.

-Similarly, this study demonstrated that the modified high performance emulsion C60BP3 TER HP could be considered storage stable for long periods of time at temperatures between 5 and 65ºC.

- Results are expected to be confirmed on site in the next future.

6. BIBLIOGRAPHY

[1] Andaluz, D et al., Buenas prácticas en la ejecución de los riegos de adherencia. SNF2018 – En ruta hacia una economía circular.

[2] EN 13808:2013 Framework for specifying cationic bituminous emulsions.

[3] Soto, J.A. Innovaciones en tecnología en frío. Capítulo 3. ATEB 2009.

[4] UNE EN 13808/1M:2014 Cationic bituminous emulsions specification. National annex. AENOR, 2014.

[5] PG-3 Pliego de Prescripciones Técnicas Generales para Obras de Carreteras y Puentes. Artículo 531. Riegos de adherencia, Enero 2015

[6] Querol, N. Nueva generación de termoadherentes: termoadherentes termoestables. V Jornada Nacional de ASEFMA, 2010.

[7] Guía de buenas prácticas en la ejecución de Riegos de Adherencia. ATC. GT6 Madrid, Spain, 2018.

[8] AENOR – Asociación Española de Normalización y Certificación, EN 1429:2013. Bitumen and bituminous binders - Determination of residue on sieving of bituminous emulsions, and determination of storage stability by sieving

[9] AENOR – Asociación Española de Normalización y Certificación, EN 12846-1:2011. Bitumen and bituminous binders - Determination of efflux time by the efflux viscometer - Part 1: Bituminous emulsions

[10] AENOR – Asociación Española de Normalización y Certificación, EN 12847:2009. Bitumen and bituminous binders - Determination of settling tendency of bituminous emulsions