STUDY TO OPTIMISE THE APPLICATION OF PREVENTIVE TREATMENTS ON ICE FORMATION AS A MEASURE TO DECREASE THE ECONOMICAL COST AND THE ENVIRONMENT IMPACT, USING A SYSTEM OF SALINITY CONTROL ON DRY ROADS TRATAMIENTOS

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ABSTRACT

Among winter period, the climatic conditions in the state of Lleida, where L4 sector is located, cause an important number of days with northern or north-western wind which maintains a very low temperatures with a dry road.

Our experience allows estimate that the permanence of the salt on the road is higher in dry than in wet road conditions, especially when we use brine for anti-icing treatments. But, the consequence of a hypothetic accident, where the driver denounces ice on the road when we have not realize the pertinent treatment, promotes us to carry out anti-icing treatments to defend ourselves against possible claims and not because they were necessary. These unnecessary treatments became an important increase of the economic cost of the infrastructure's conservation and a higher impact on the environment.

This paper expects to provide the trends about the taken salinity measurements reveal, under various conditions (e.g. traffic, different pavements types and different treatment types). Decision makers might use these trends as a tool for understanding the connection between the different factors that are involved about the amount of residual salt on the dry road. In future seasons, we could get better relationship between the residual salt and the traffic conditions.

1. BRIEF DESCRIPTION OF THE SECTOR

Sector L-4 is located in the northeast of the Iberian Peninsula, in the province of Lleida, as you can see in Figure 1. Roads maintained include the highway A-2, main connecting track between the cities of Barcelona and Madrid and the traffic of goods between the two populations. It generates a large amount of traffic to be one of the pillars of Spanish roads, with an annual average daily traffic (AADT) that is currently around 33,000 vehicles per day and a percentage of 32% heavy. It runs through relatively flat areas, with prolonged and gentle slopes, except at surroundings of the Panadella (highest of the road, reaching almost 700 m), where it limits with the province of Barcelona.

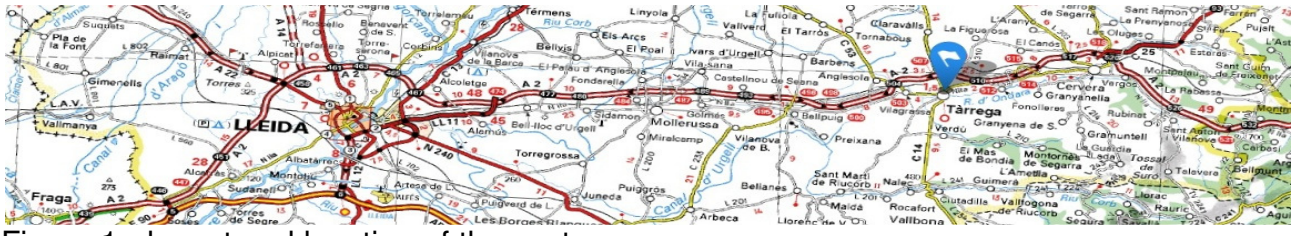

Figure 1 - layout and location of the sector

1.1. Climatology

Most relevant sector L-4 climatologically values, referred to Lleida City, are the following [3]:

- Average annual temperature: 14.7ºC. Monthly average January temperature: 5.3ºC, while for the month of August is 24.7ºC
- Average annual rainfall: 369 mm
- Average annual number of days of greater than or equal to 1 mm rainfall: 46. Wettest month: may; less rainy month: July.
- Annual average number of snow days: 1 (January)
- Annual average number of foggy days: 53
- Average annual number of days of glazed frost: 37

The sector is located on a plateau slightly downward toward the West, so the previous values, especially those related to days of glazed frost and snow, increasing eastward.

During the winter season, the climatic conditions in the area where is located the sector L-4 in the province of Lleida, allow that we have a significant number of days when the North or Northwest wind blows and it maintains very low temperatures but the dry road surface.

1.1.1 *Winter season 2012-13*

Last winter season, road surface required the application of preventive treatment for ice formation in 61 nights. The month with the largest number of treatments was January, when there were 22 interventions.

These preventive treatments were applied at 5,053 km of roads. For doing these treatments, snowplough trucks, according to GPS equipments that shipped, should travel a total of 34.621,12 km

In the application of these preventive treatments, were used a total of 604 t of ClNa and 1.300.836 l ClNa brine.

Has also been necessary the application of curative treatments in three short snow storm, occurred on dates 23rd February, 13th March and 29th April, when we could take measurements of salinity in continuous, using a salinity meter fitted on an all-terrain, as well as taking readings of ambient temperature and road surface temperature also in continuous, getting their registration through a web application, as shown in Figure 2.

Although this system of measurement deviates from the procedure detailed in this study, it has been possible to extract a number of trends that will be showcased at the conclusions section.

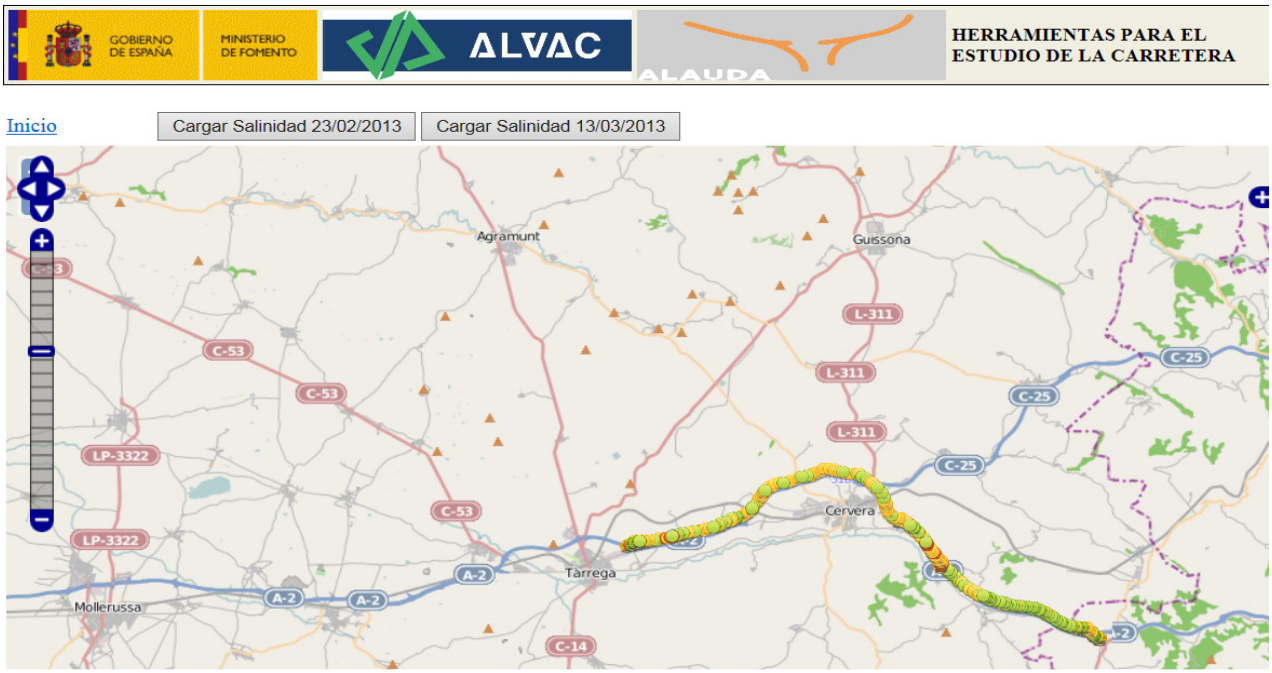

Figure 2 - map of salinity obtained through web application with data from continuous salinity meter.

2. BACKGROUND RELATING TO THE TREATMENT OF ROAD IN WINTER.

Sector L-4 has comprehensive contracted maintenance since year 1994. Initially work related to winter maintenance were implemented with two axle trucks equipped with salt spreader and V-blade or angle blade, leaving the application areas and the anti-icing treatment dose to the experience and judgement of the driver.

These early machines were imprecise as to dosage and application width and had to be operated by the driver manually, having to handle the spreader. Proportionally to the advance of technology in the accuracy of dosing and widths and the management thereof from the cockpit, the daily traffic on the roads in the sector were increasing, especially in relation to heavy vehicles, intensities reaching its greatest exponent with the implementation in service of the stretch of the A-2 Highway between Cervera and Jorba, so continuity was given to the Barcelona - Madrid route throughout the province, in the year 2006.

In addition, the regulations for the application of this type of treatment was becoming more restrictive and demanding, in implementation of the “Nota de Servicio sobre la Actuación de los Servicios de Conservación en las Campañas de Vialidad Invernal”, on date 2nd October 2006 [2], for highways case with level of service 1 (NS-1), it could not occur any restriction by the presence of ice, it meant, since that moment, the presence of ice on the road could not be happened, as you can see in table 1

Table 1 - desirable disturbances to traffic due to snow and ice, on roads with level of service 1 (NS-1)

NIVEL DE SERVICIO	CONCEPTO	FENOMENO METEOROLOGICO	PERTURBACIONES AL TRÁFICO DESEABLES DEBIDAS A LA NIEVE Y AL HIELO								
			CORTE DE LA CIRCULACIÓN A VEHÍCULOS PESADOS		CIRCULACIÓN CON CADENAS PARA VEHÍCULOS LIGEROS		CORTE DE LA CIRCULACIÓN A TODOS LOS VEHÍCULOS		BLOQUEO DE LA CALZADA		LIMPIEZA MARGENES
			NÚMERO	DURACIÓN	NÚMERO	DURACIÓN	NÚMERO	DURACIÓN	NÚMERO	DURACIÓN	TIEMPO MÁXIMO DESDE QUE TERMINA DE NEVAR
NS-1	En este nivel no se admitirán situaciones de bloqueo de la calzada ni corte de la circulación a todos los vehículos. Con este fin se aplicará la medida de cortar la circulación de vehículos pesados y restringir el paso a ligeros con cadenas siempre que sea preciso, procurando reducir al mínimo el tiempo de restricción.	NIEVE	INDETERMINADO	t + 2 h.	INDETERMINADO	t + 2 h.	0	-	0	-	6 HORAS
		HIELO	0	-	0	-	0	-	0	-	

Another factor to consider when it is high humidity weather, with fog and low temperatures, the application of anti-icing treatments on road surface, facilitates the accumulation of moisture on it, causing the pavement to be more sliding. In these circumstances, the event of an accident could occur the user, with the lack of knowledge by the traffic authority assists to the accident, claim about main cause of the crash was the presence of ice. That fact may compromise the performance of the contract with the Administration, in the event that the contractor is not able to prove the application of necessary anti-icing treatment, in the hours before.

We think that is the reason why still now, the possible amounts of residual salt existing on the surface are not taken into account in the operational plans, when establishing the criteria to apply new anti-icing treatments.

Also anti-icing treatments have experienced a major evolution. Initially, ClNa treatments were applied in our country, only. Years later, the development of pre-wetted treatments, increased the stay and effectiveness of the residual salt on the road. Currently, the use of brine in the application of this type of treatment is becoming more common, because it is more effective and efficient on dry road.

Experience allows us to estimate that residual salt on dry road stays longer time than the case of wet road, especially when brine is used in the implementation of anti-icing treatments. But, the consequence of a hypothetic accident, where the driver denounces ice on the road when we have not apply the pertinent treatment, promotes us to carry out anti-icing treatments to defend ourselves against possible claims and not because they were necessary. In addition, continuous improvement in equipment and types of treatments applied, contrast with the maintenance of the criteria for its application in the protocols of action every year.

These unnecessary treatments became an important increase of the economic cost of the infrastructure's conservation and a higher impact on the environment. This is the reason why we consider that the possibility to estimate the residual salt over a dry road, could optimized the application of preventive treatments on ice formation, reaching a decrease on economics costs and damages on the pavement, as well as the environmental impact they posed.

3. PROCEDURE FOR DETERMINING THE AMOUNT OF RESIDUAL SALT ON DRY ROAD.

For this purpose, several points of salinity control have been situated all along L4 roads. They have been located close to our meteorological and gauging stations to be able to determinate climatologically conditions and traffic affluence. Using a salinity gauge manual we take three measurements in each point of control: one on the external lane, a second one on the internal lane and finally on the wheel tracks of the external lane. These measurements were initiated at the end of the last winter season, but in the current season when they have become extensive, obtaining on 9th January 2013, the data supplied in the enclosed plan (Figure 3). It should be noted on that day, the sector was thick fog in the traces, with maximum temperatures of 3° C and minimum of - 4° C, with very wet road and close to 100% humidity

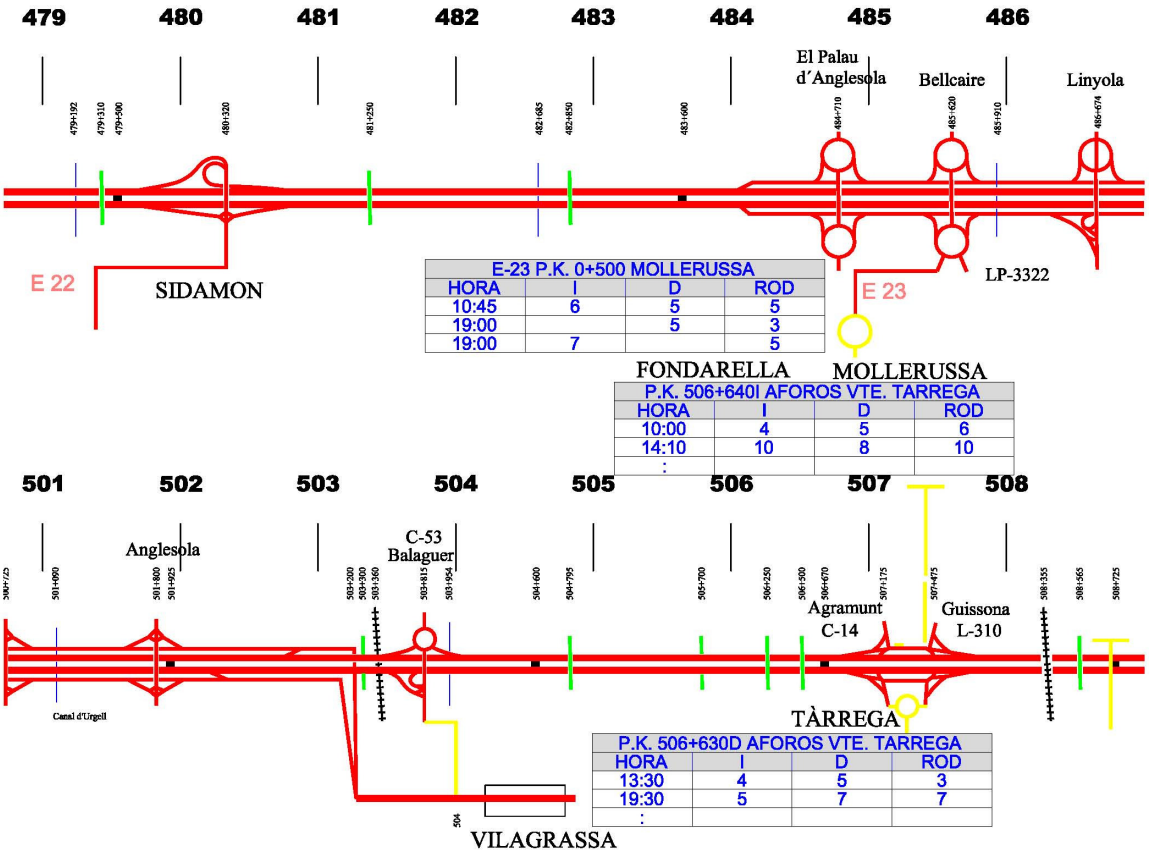

Figure 3 – fragment of plane with the data reported for January 9th, 2013

4. ANALYSIS OF EXISTING DATA.

Last season, more than 7,000 measurements, were taken on road stretches with different types of pavement (porous asphalt or asphalt concrete), with different type of anti-icing treatment (dry salt or brine), at different times of day and different existing traffic.

Given the amount of data taken and the number of variables involved in the process of determination of the amount of residual salt, at the moment only general trends have been found, nonetheless this paper is not devoid of interest.

It would be necessary to have more resources and time in order to establish a more detailed in the relationship between residual salt, the characteristics of the traffic and the existing meteorology [1].

To facilitate the display of data, we have limited the maximum amount of residual salt to 15 g/m2. Note that there is not data for all shifts or for all points of control, so many of the existing graphics discontinuities may be attributable to this circumstance. This lack of data is justified by damage to the salinity meter or because the monitoring roads services responsible for them, have had more urgent requirements that have prevented taking measurements.

Charts the y-axis corresponds to the amount of residual salt registered on the pavement in g/m2, while the x-axis includes dates of measurements.

4.1. Analysis of the data for a single check point.

4.1.1. Records of residual salt depending on measuring shifts.

Analyzing the data obtained for a single point of control, measurements vary substantially depending on the temperature and humidity conditions at the time of the measurement. As can be observed, the highest values were taken in the measurements performed in the evening shift ("turno tarde", between the 14 and 22 hours), when these registers are the most distant in time from the previous preventive treatment was applied.

This trend is repeated in different checkpoints, regardless of the type of pavement or traffic, as you can see in figures 4, 5 and 6.

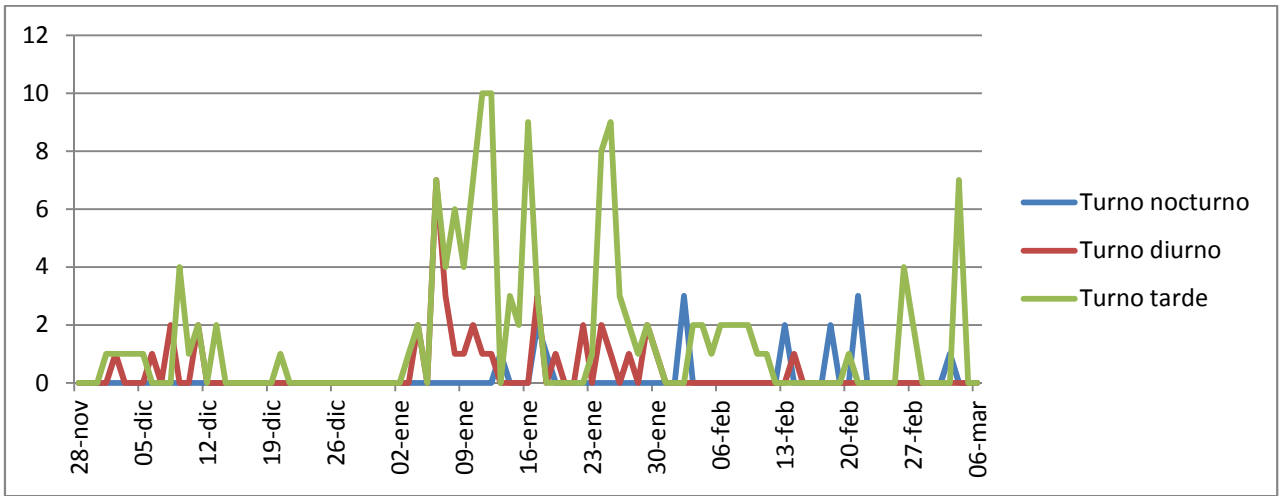

Figure 4 - data analysis by shift in porous asphalt when use of brine, left lane, p.k. 528+230 - D

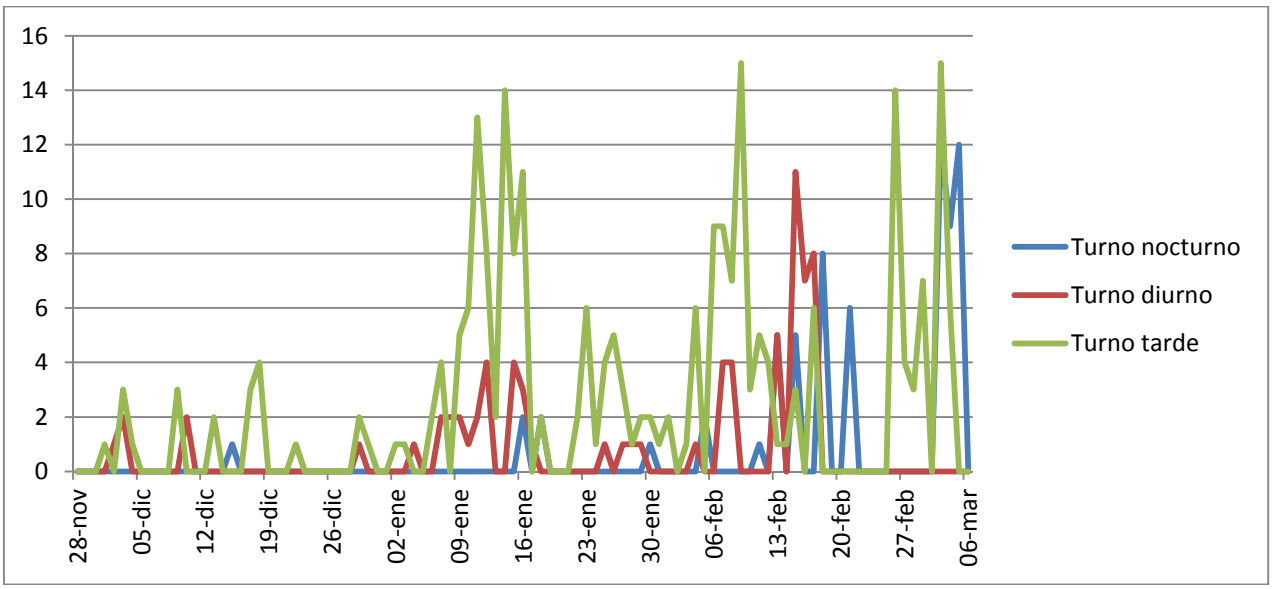

Figure 5 - data analysis by shift in porous pavement when use of dry salt, left lane, p.k. 466 + 250 – I

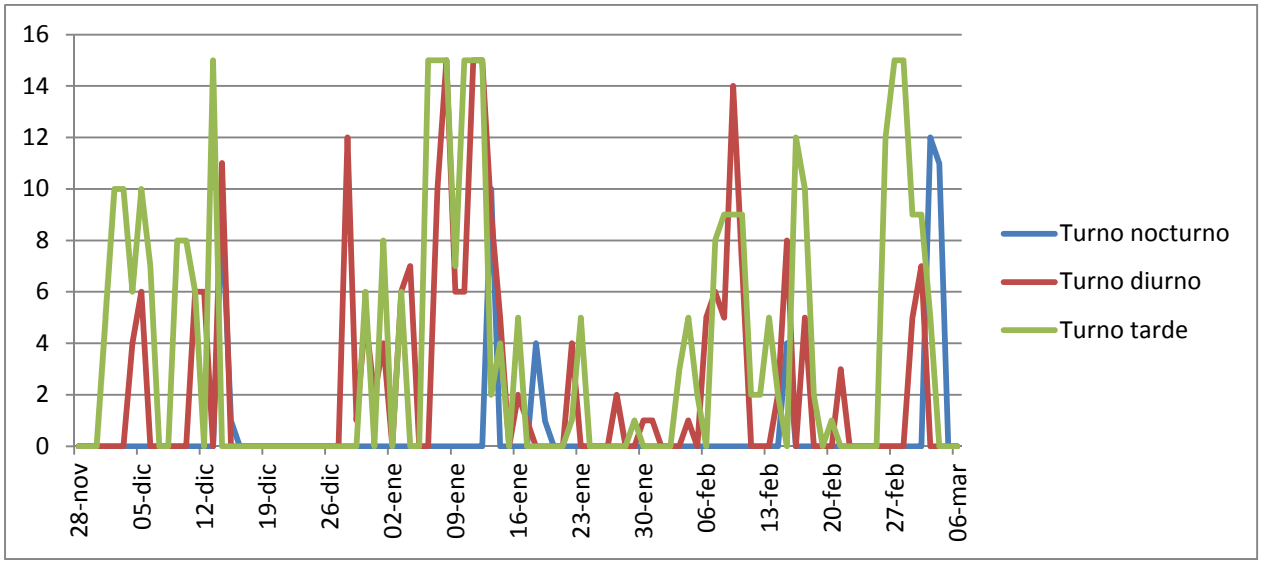

Figure 6 - data analysis by shift in asphalt concrete, when use of brine, left lane, E-23, km 0 + 500

4.1.2. Records of residual salt on the basis of the area of the lane where perform the measurement.

Hereinafter, for the analysis of the data records, the afternoon (14 to 22 hours) shift, will be used by estimating the more in line with reality, because the solubility in laboratory tests are usually drawn up to ambient temperatures of 20 ° C, that circumstances are more assimilated to those recorded on this shift than the rest, although these temperatures are not reached.

Analyzing the recorded data, the area of the lane where the measurement is made is not so significant, in the sections where anti-icing treatment is carried out with brine, because the salt distribution is more uniform. In the case of Figure 7, it is observed that measurements in wheel-tracks are in general lower than the rest of the lane, but this claim is not confirmed in Figure 8.
On areas treated with dry salt, there is a lesser stay time of residual salt on the lane and a greater divergence depending on the area where the measurement is taken, obtaining

measurements in the area with more traffic (right lane and wheel-track), as you can see in Figure 9.

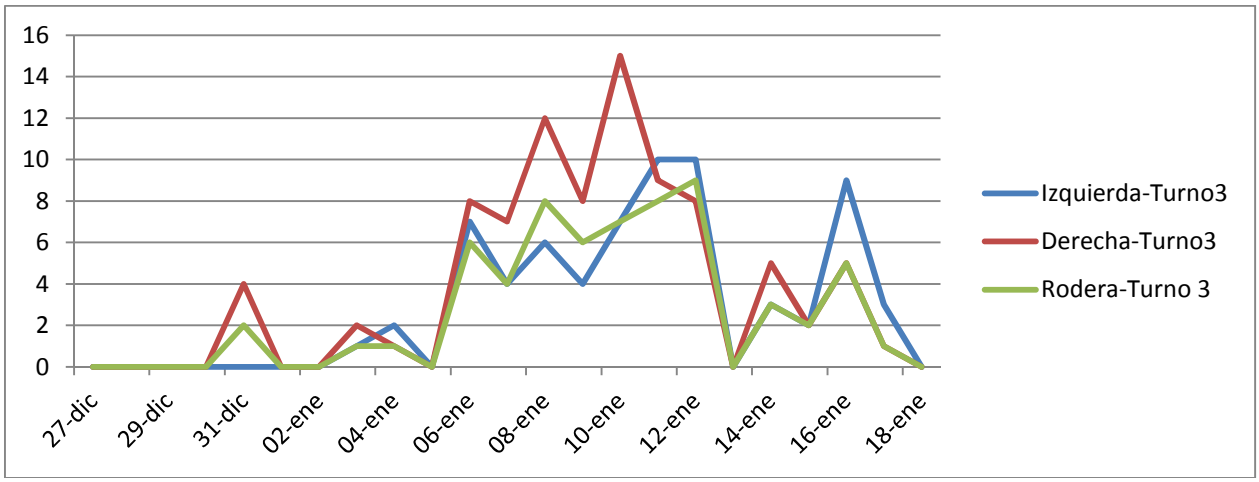

Figure 7 - data analysis by area with porous pavement where use of brine, p.k. 528 + 230 - D. At this point of control were carried out anti-icing treatments daily from December 27th to January 16th, with the exception of the days of December 28th and January 1st. Between December 29th and January 1st, were significant moisture mists, therefore measurements were practically nil. January 5th there was a malfunction on the salinity meter. Days 11th and 12th January occurred again mists, and on 13th, 18th and 19th January, intense rainfalls.

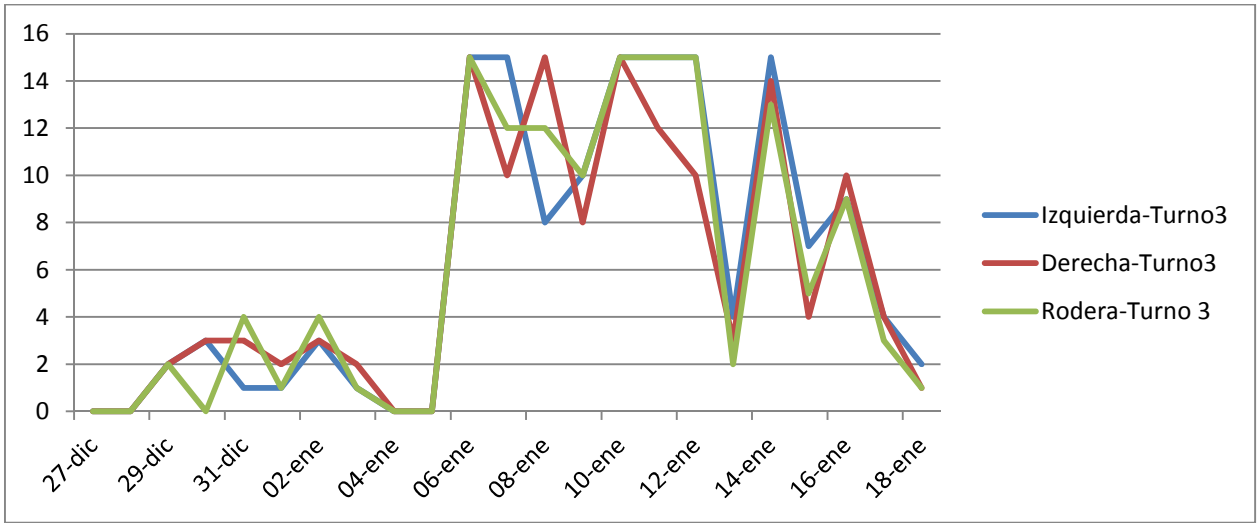

Figure 8 - data analysis by area with porous pavement where use of brine, p.k. 506 + 640 - I. At this control point could be considered the same data of treatment and meteorology.

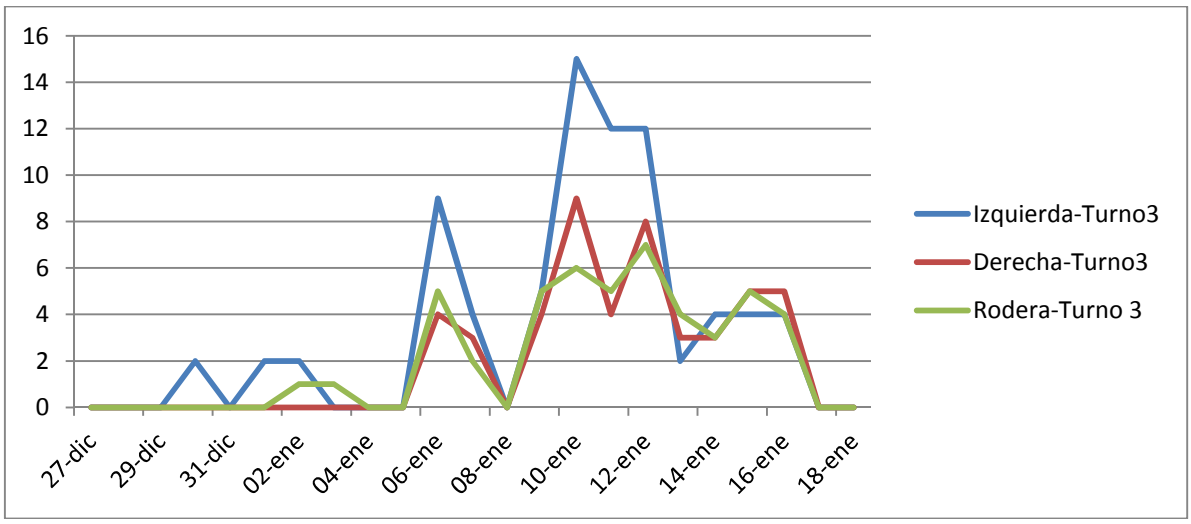

Figure 9 - data analysis by area with porous pavement where use dry salt, p.k. 446 + 100 - I. At this control point could be considered the same data of treatment and meteorology, with the exception of the treatment on 15th and 16th January evenings.

4.2. Analysis of the data between different check points

4.2.1. Records of residual salt depending on the type of pavement.

It is observed in analyzed records that, in general, measurements made in porous asphalts show very lower values than those obtained on asphalt concrete. That can be justified because part of the fluid solution used by the salinity meter is lost between the porosity of the pavement (figures 10 and 11).

Measurements carried out in the next few points, where could be considered the existing traffic is the same, as shown in Figure 12, gets the most common relationship between measurements in porous asphalt, with respect to measurements taken over asphalt concretes, it would be 1:4. Anyway, this relationship should be contrasted in future seasons, because if it was true, it would mean that residual salt values considered in this paper, would be much higher in reality onto porous asphalts.

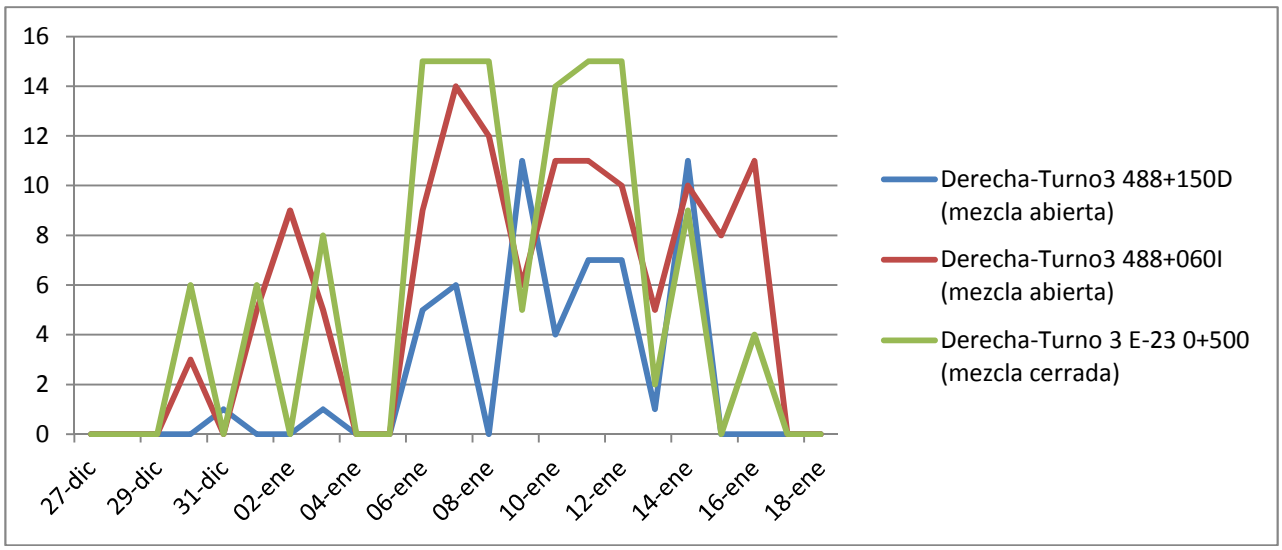

Figure 10 – data analysis by check control points on right lane with different types of pavements, when use brine.

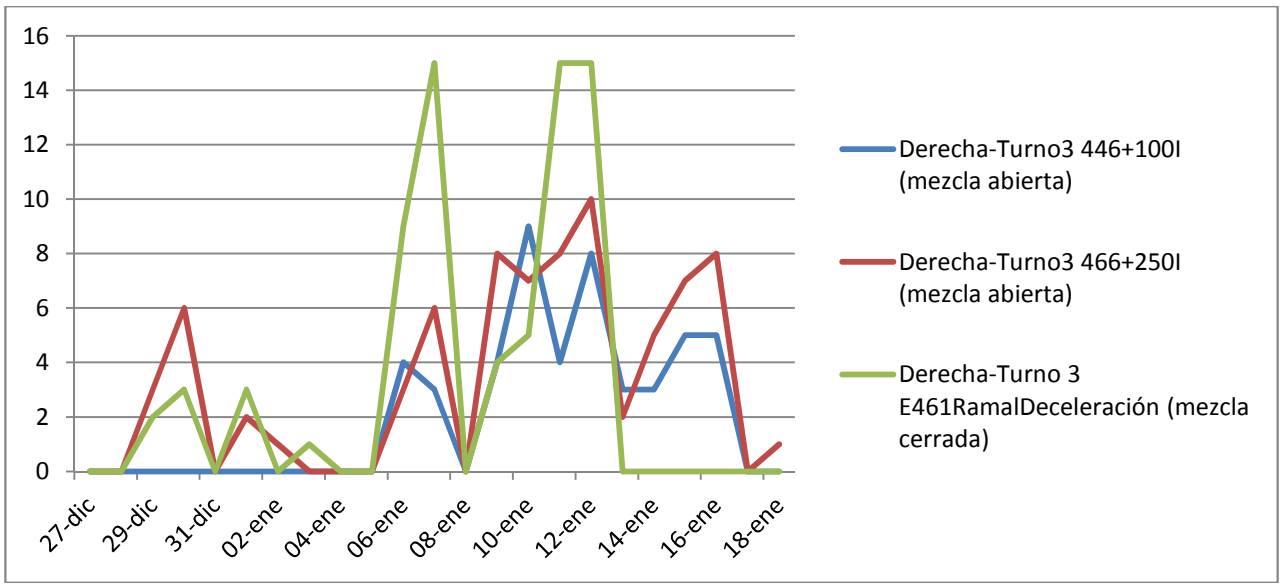

Figure 11 - analysis of the data by check control points on right lane with different types of pavements, when use dry salt.

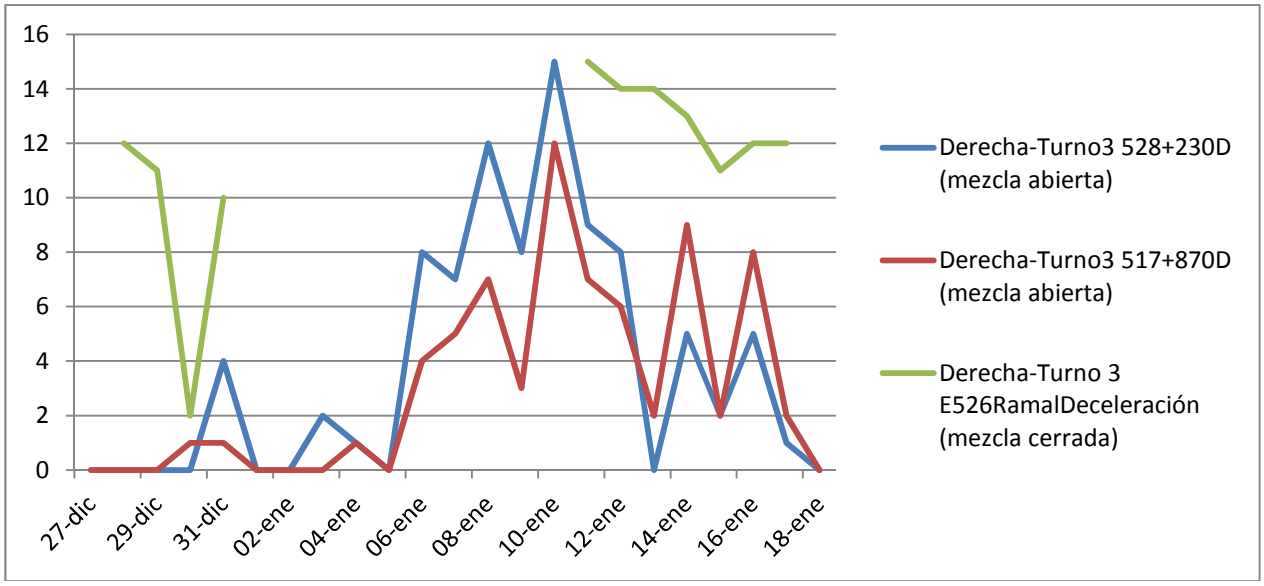

Figure 12 – data analysis by check control points on right lane with different types of pavements, when use brine.

4.2.2. Records of residual depending on the type of anti-icing treatment

Observation of the data reported in figures 13, 14 and 15, it could be concluded permanence of residual salt is higher when anti-icing treatments are made with brine, respect to those made with dry salt, regardless of the type pavement on apply.

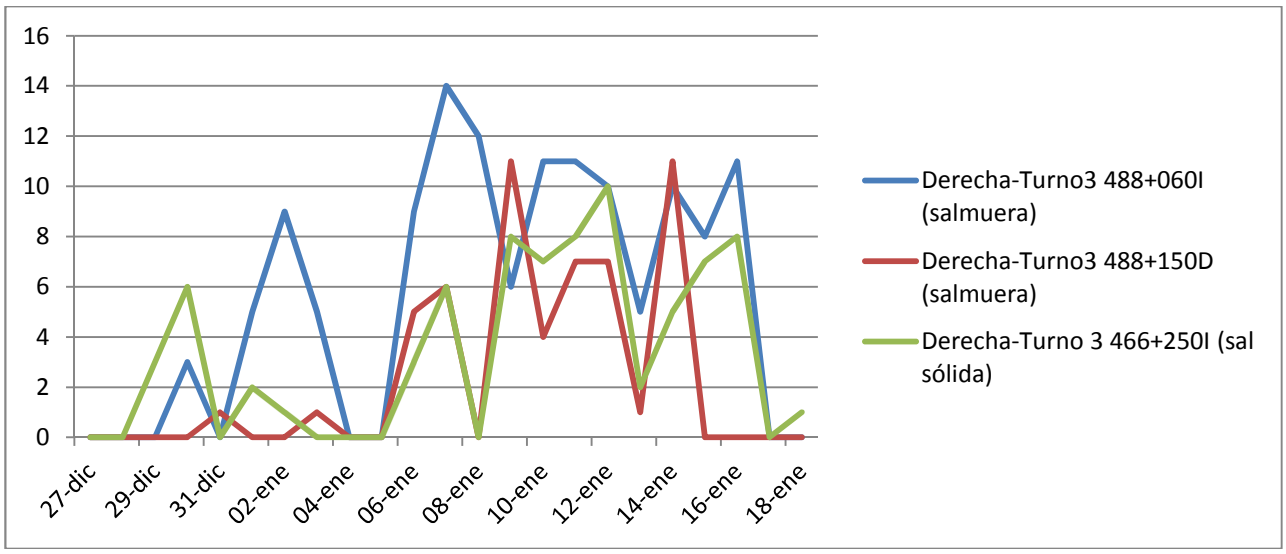

Figure 13 - data analysis by check points on right lane with different types of treatment, on porous asphalt pavements.

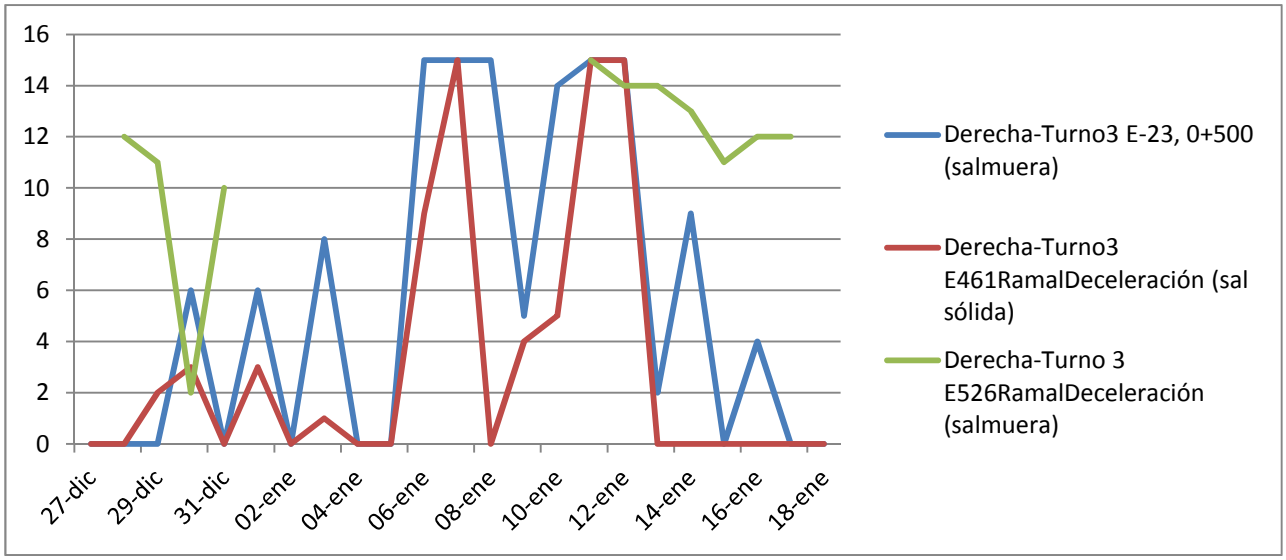

Figure 14 - data analysis by check points on right lane with different types of treatment, on asphalt concrete pavements.

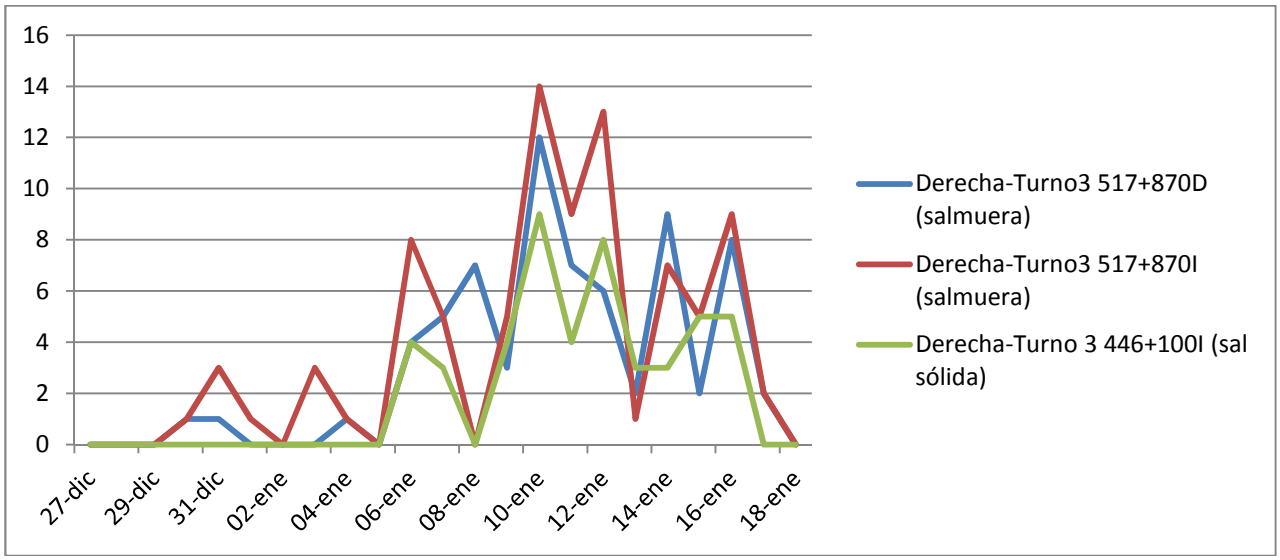

Figure 15 - data analysis by check points on right lane with different types of treatment, on porous asphalt pavements.

5. CONCLUSIONS

It is considered that an optimization in the application of anti-icing treatments, could be achieved by taking into account the existing carriageway residual salt.

Through this paper has attempted to elucidate the relationship between the permanence of the residual salt on the carriageway and factors involved therein, as the type and quantity of existing traffic, temperature and humidity, type of pavement and type of treatment applied.

It would be useful to continue with the registration of these measurements and entering a more detailed analysis where integrate data traffic, humidity and temperature, in order to determine in greater detail their direct relationship in the permanence of the residual salt on the road.

Meanwhile, the trends discussed in the previous paragraphs are provided:

- The measurements provided by the salinity meter have a great dependency with the environmental conditions of temperature and humidity.
- Measurements made on porous asphalt pavements should be corrected by a conversion factor, because a part of the solution is lost through the interstices of the mixture.
- The recordings made in areas treated with brine, confirm an overstay of remnants salt and better homogeneity in its distribution on the carriageway, than the case of treatment carried out with dry salt.
- Although on the asphalt concrete pavements, residual salt measurements are higher, estimated that its tenure on carriageway is less.
- According to measurements of salinity and temperature in continuous during the snow storms, the free-flow heavy traffic on the outside lane allows have higher temperatures more than 1 ° C, to the rest lane, that can be a great help in the road cleaning works.
- Measurements of salinity in continuous during the storm, as % of salinity upon the sample taken, are not significant, because in those moments the road is completely wet.

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