Self Ice Melting Winter Pavements

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Synopsis

Thanks to important developments in draining pavements the disadvantages of driving in the rain have been strongly reduced, and the virtual elimination of the risk of aquaplaning has notably enhanced driving safety.
Moreover, the great versatility of porous materials includes protection for the environment on which a road is built. Such protection includes the noise-absorbing effects of these materials, which, today, thanks to SIRUUS studies, can handle a vast range of sound frequencies and abate them as they are generated.
Having overcome the problems represented by the formulation and reliability of materials as well as the question of reducing costs, the remaining question concerns winter management because in relation to closed pavements, draining pavements require greater attention and immediate action as regards de-icing and snow clearance.
This question has delayed the application of functional draining pavements on mountainous sections where, despite their very poor draining properties, ***semigrenu*** pavements are frequently used.

At present winter management requires a special type of salt mix - viscous salts (a sodium chloride and calcium chloride mix) – which while remaining longer on the ground needs double storage facilities and special salt sprinklers.
The results are excellent from the point of view of road use but their deployment is susceptible to delays in maintenance action, while operating errors are always possible.
On the other hand, the new technologies to be discussed in this paper produce a considerable reduction in the temperature necessary for the formation of ice (normal ice, verglas or snow), thanks to the addition of proactive fillers in the mixtures that constitute the drainants. Their benefits are:

- the non-necessity of external treatment in cases of verglas or simple ice
- the tolerance of one or two hours' delay in de-icing work with salt-sprinklers in the event of snow.

The use of self ice melting materials guarantee maximum safety because all their actions take place within the body of the draining layer, without extruding onto the road surface. In the past their use with closed mixtures was a cause of concern because, during spring and winter rainfalls, liquids with a potentially slippery effect seeped out onto the road surface.
In addition, the new products behave differently with respect to the past, and therefore the adverse behaviour indicated above no longer applies, and not even in closed mixtures; other investigations on this question are at present underway.

The following research programme was undertaken:

Mixture tests with active fillers to identify mechanical resistance variations
De-icing tests (in a climatic test chamber - tests on normal bituminous mixes/ tests with additive)
Adherence tests on draining surfaces (repetition of tests on normal bituminous mixes.)
Experimental layer on the A1 near Rome
Validation for experimental use on critical areas (A7 Genoa)
Continuation of validation tests for environmental aspects with the development of more durable active agents that do not corrode road structures

The first experimental applications were made in mild climatic conditions in areas near Rome to test environmental behaviour. However, applications for the real verification of winter operations - involving the Apennine section of the A7 Genoa - Milan motorway - where in the context of icing and snow of January valid behaviour is being obtained, which will be duly reported in the final presentation of this paper, which will also add the details on the evaluation tests and the formulations of the foregoing de-icing products.
In future these products may have applications for pedestrian areas and normal mountain roads.

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I Winter road management

Winter maintenance has a major impact upon motorway users, who are also able to cast immediate judgments on its effectiveness. However, maintenance also has a big impact on the organisation of the section managements and on the operating costs that road administrations must bear.

The various reasons for wanting to improve the systems at present in use regard the following aspects :

- the probable effectiveness of the service and the consequent loss of image when motorway sections must be closed due to snow. This is a general consideration but of particular importance when the sections involved are of primary importance for the links within the country[1];
- the costs borne for carrying out a service that actually might not produce the effects needed in a continuous manner and give adequate results in terms of image.

The improvements made in recent years as regards equipment and meteorological monitoring systems can improve winter management but they may not be fully understood or under-used on account of:

- the unreliable nature of the weather forecasts provided
- higher levels of traffic than in the past;
- the behaviour of some truck drivers;
- lack of precise information on the operations in course.

To these facts, must be added the added problem of the large-scale use made of draining, anti-noise, bituminous conglomerates, CDF, which on the Autostrade network alone have exceeded 33 million square metres and whose use is still expanding in all climatic sites of the network. And this tendency could present some problems, even given the present organisation.

II The winter management of draining pavements

The CDFs have an unjustly poor reputation as regards winter management. There are no technical grounds for this attitude and what criticism that can be made only refers to certain organisational weaknesses.

It is true that they call for a different form of treatment with respect to normal pavements, but if such management actions are conducted properly, the draining surfaces will be safe and comfortable even in winter conditions and on mountain roads. This is shown by the results obtained in Italy and also in Japan (see Rassegna del Bitume 45/2003 and the acts of Asfaltica 2004).

Given their permeability, C.D.Fs tend to discharge liquids more rapidly than ordinary surfaces, which could indicate that also anti-freeze salts, intrinsically soluble, will be rapidly drained away. However, this is not true, especially if the salts used are rendered more ***"viscous"*** by the combining sodium chloride with calcium chloride brine. This mix, in addition to operating at temperatures of minus 5 degrees, tends to "cling to" bitumen-coated aggregates. And this behaviour explains the reason why salts remain longer on CDF pavements with respect to normal pavements.

The specific problem of CDFs refers to the penetration of snow inside the pervious surface. If there is not sufficient brine inside the surface to melt it, the snow tends to accumulate and turns the road surface white.

In order to prevent this happening, in addition to making use of viscous salts, it is also necessary to take action ***ahead of*** the formation of ice and the settling of snow by using slightly higher amounts of salts with respect to closed pavements. These salts will not be lost because they remain longer inside the permeable surface and hence impede the formation of the "white" layer.

In the event that these precautions are not carried out correctly, or when the snow has already formed, or the snowfall is particularly strong, brine calcium chloride solution sprinklers must be used. These cannot, however, be used in the absence of snow because an excess film could be left on the road surfaces and could produce opposite and unwanted conditions of slipperiness

In brief, permeable pavements require:

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[1] Although such events are usually the fault of users' conduct, especially on mountainous sections - where the blockage is almost always the result of the non observance of prohibitions on overtaking by heavy vehicles - they do not alter the administrator responsibility for improving the effectiveness of the road operations by avoiding blocks, even given the foregoing conduct, or for lessening their effects when they do occur.

- Viscous salts (mix of NaCl and $CaCl_2$) in large quantities;
- Immediate salting;
- Availability of sprinklers.

The foregoing calls for a special organisation, but this is not a peculiarity of CDF pavements alone. For example, the first two characteristics are identical to the winter salting needs of bridges. As is known, bridges are subject to the rapid icing or the rapid accumulation and icing up of snow on account of their limited thermal insulation in comparison with roads, whose insulation is provided by their "natural" support. The difference in insulation means that if de-icing is not performed promptly roads, with or without CDF, will be blocked as the bridges become inaccessible to traffic in transit.

Naturally draining pavements that do not ice up immediately and/or prevent snow from settling would play a more important role in winter management, especially in sectors rendered critical by climate and traffic.
These were the research results obtained hitherto on anti-icing compounds incorporated into the porous conglomerates (single or bi-layer)[2]. Compounds that work in this manner, containing de-icing chlorides inside them, were used in Switzerland in the 1990s, but abandoned because they produced slippery surfaces during the period of spring rainfalls (i.e. when temperatures exceeded 0°C).
Recently similar compounds, but supplemented by controlling substances have reappeared on the market and exhibit greater reliability than their Swiss predecessors. They led to the opinion that their use in draining pavements could achieve the dual purpose of acting promptly when the snow is flattened by traffic and in preventing snow from settling, without giving rise to slipperiness. In the absence of regular controls they would have acted within the porous mix, which, as known, has a very extensive bitumen film within the communicating voids that constitute the draining and sound-absorbing structure of these materials.
This solution would have been able to give the green light to the massive application of draining surfaces on motorways and mountain roads.

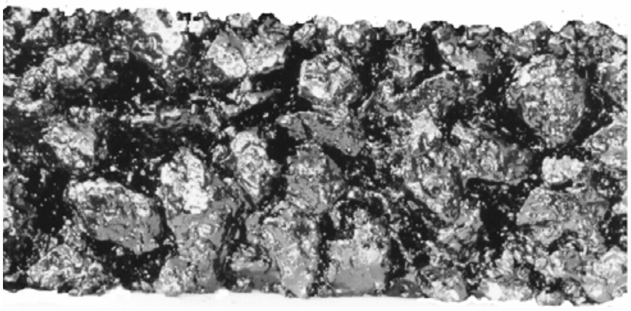


Figure 1 – Cross-section of a draining pavement. The de-icing agents are included in the bitumen film: In the draining pavement the film coming into contact with water has an extension >> with respect to that of normal bituminous mixes.

III The first application of de-icing compounds

The product in question is called T, based on stabilised chlorides, and was tested in the laboratory to determine its de-icing behaviour.
For this purpose standard draining conglomerates were prepared with a 5% dosage by weight with respect to the aggregates and frozen under a film of water (see figure 2).
At 18 degrees below zero the treated material was still covered with water and unhardened ice, while the normal sample had iced up completely with hard, adherent ice.
Subsequently, a research programme was commenced which can be summarised as follows:

2004 research programme

- De-icing tests (in a climatic test chamber - tests on normal bitumen conglomerate/ tests with additive)

[2] Naturally the compound solution is also valid for normal conglomerates that might even not require other traditional treatment.

- Tests on mixes with T compound to identify variations in mechanical resistance
- Tests of draining surface adherence with skid tester (repetition of tests on normal bituminous mixes)
- Laying tests on A1 motorway in “warm” areas to determine pavement behaviour in spring rain conditions (July 2004)
- Validation of experimental use on “critical ” areas (A7 Genoa Serravalle) October 2004

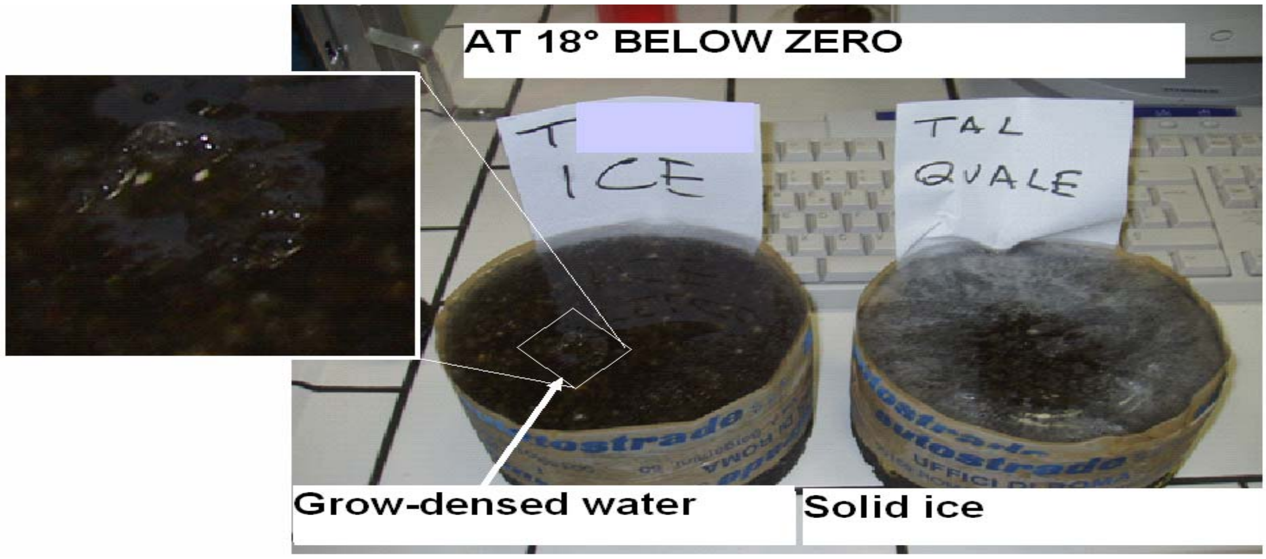


Figure 2 -Tests after freezing action18° below zero. Note the type of ice found: only grow- densed water, with proactive fillers (left) ; solid ice, with pure bitumen (right)

All operations returned satisfactory results:

- spring rain did not affect road adherence and this was verified with repeated SCRIM (Coefficient of Transversal Adherence CAT) measurements as the experimental area was near the Fiano Centre - the measuring equipment centre.
- The experiment on the A7 was kept under control by telecameras on the route which ascertained that the snow did not settle (see figure 3)

Figure 3 - on 25, 26 and 27 October 2004, across the northern carriageway of the motorway GE-Serravalle A/7, a bitumen conglomerate as an eco-draining wearing course was laid from the mouth of the tunnel CAMPORA.
For about 1,400 m from Km 116+360 to Km 114+960 the conglomerate was supplemented with T, to an extent of (about) 5 %. A telecamera ascertained the successful outcome of the experiment.

At this point it was necessary to evaluate the **duration over time** of these measures in order to determine the real costs of the operation and the need to take action in the event of the loss of de-icing action, which ideally should coincide with the useful life of the course either in terms of adherence or wear.
Initially the system shown in figure 4 was applied, but no significant variations were found.

Figure 4
Adherence tests in a laboratory with a skid tester and tests with continuous applications of distilled water for 1000 hours without evidence of variations

Consequently, a new research programme was designed which also took into account the new de-icing products with even more advanced features which, in the meantime, had become available.

IV The new de-icing compounds

The new compounds act in such a way as to prevent or delay the formation of ice on the pavement when the temperature of the air is below zero or, otherwise, to prevent ice forming from "sub-zero" rain or prevent snow from settling. They comprise a series of appropriate reducing, tackiness-inducing, water repelling and dispersing compounds that in addition to preventing the accumulation of water to stop it condensing into ice are also:

- totally free of chlorides which, in addition to becoming potentially slippery if the air temperature is relatively high, could also attack the cementitious and steel parts of reinforced concrete structures;
- completely integrated in the bitumen film so that they can provide an effective anti-icing action both as concerns the external surfaces of conglomerates in contact with tyres, and the internal surfaces, of the small channels that constitute the walls of the voids of the draining pavements;
- released gradually in order to perform their action and move from the inside of the pavements (in contact with the conglomerate aggregates) to the outside (in contact with the air inside or outside the conglomerate) of the bitumen film in order to continually present new active and effective elements for self de-icing action;
- not able to alter the resistant structure of the conglomerates that contain them, which would otherwise reduce the adhesion of the bitumen film on the aggregates, lower the self-repairing capacity of the latter when wearing cracks appear as a result of traffic, or increase their visco-plastic deformability.

These compounds, that always operate “troubling” ice crystal rising, therefore, contain a mix of at least three substances, which, in addition to the primary activities mentioned earlier, facilitate initial dispersion, allow good adherence to the aggregate stones of the conglomerate and are protected against the disaggregating action of rainwater and thawing.

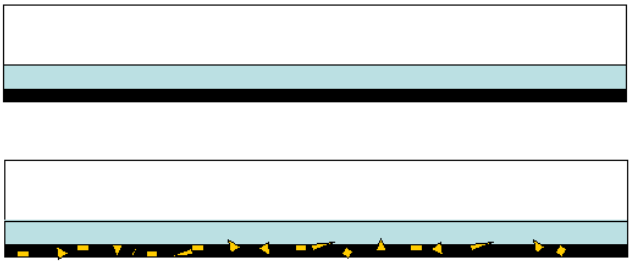
The final form of the foregoing mixes enables them to be added to the normal fabrication processes of the conglomerates. They may take at least two types of form:

- solid in the form of granules or powder;
- liquid in the form of low viscosity, sprayable solution;

The compounds made be introduced as they are or combined with a different kind of fibre (vegetable, vitreous or synthetic) so that the finished product can offer other functions in addition to the specific functions described hitherto and/or enhance the dispersion functions of the product in the conglomerate.

IV a) Test methodology

The test programme was thus recommenced with the introduction of a new methodology to speed up the tests: the testing moved from tests on the conglomerates to tests on the prepared bitumen films with various types of substances in a 50% proportion with respect to the bitumen (figure 5). The preceding products (type T) were also tested as well as a range of products similar to the type discussed above.



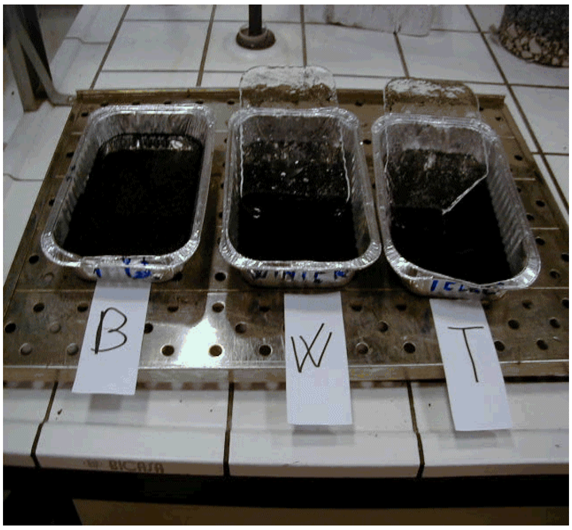


Figure 5 – Untreated bitumen film on the bottom of a container with a film of water and a film of bitumen previously mixed with anti-freezing products, also on the bottom of a container with a film of water, both to be placed in a freezer. In the photograph the new products W, with ordinary bitumen B and the first additive T.

The containers thus prepared were then cooled down to minus 20° C for 45 minutes, in order to be certain that the film of water iced up completely. The containers were then removed and placed in an over at 30°C and the parts of the water that melted were weighed every 5 minutes to obtain the curves set forth in the following figures.

The de-icing compounds lost water more rapidly than the others, as shown in table 1 and figure 6 below. The letters indicate the various types of compounds evaluated. The first class comprises salts containing chloride ions and siliceous compounds **(W1, W2, W3).**

The second class is made up salts not containing chloride ions and siliceous compounds (**W8, W9, W10)**. These mixes, plus one reference to just bitumen: "**B**"; one of bitumen +T and one of bitumen+Wr: all have a ratio of 1/1 by weight with bitumen.

Time/min	B	T	W1	W2	W3
	% dissolved water				
0	0.00	0.00	0.00	0.00	0.00
10	8	8	48	20	32
20	45	46	74	39	63
30	65	74	94	67	89
40	83	100	100	91	100
50	94			100	
60	100				

Table 1

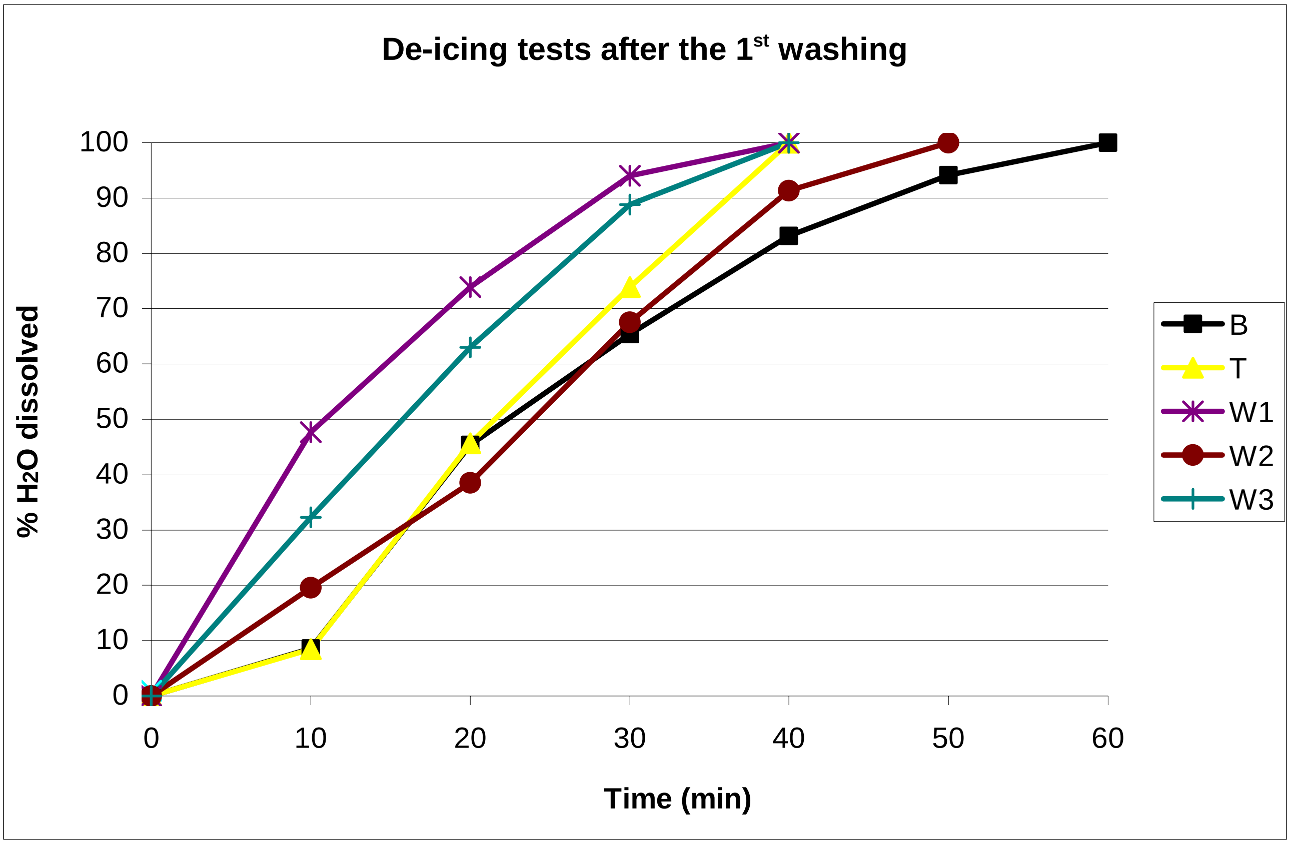


Figure 6

The superiority of compound W1 is immediately apparent if the first loss is evaluated, which supposes the presence of free water produced by the compound under the ice.
The same tests were carried out for other compounds with the following results

Time/min	B1	WR	W8	W9	W10
	%dissolved water				
0	0	0	0.00	0	0
10	10	36	13	12	27
20	58	66	55	61	63
30	82	100	78	89	91
40	95		100	100	100
50	100				

Table 2

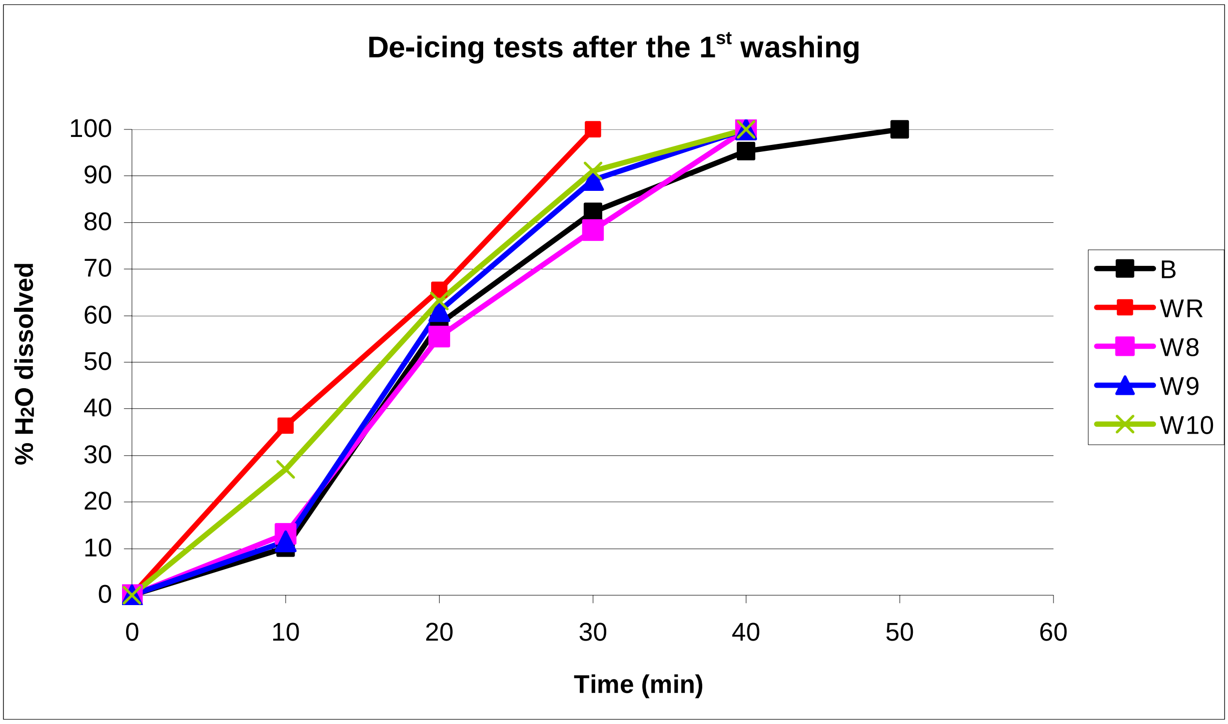


Figure 7

In order to study the loss of effectiveness over time the tests were repeated after 35 washings with a resulting loss of performance by the salts of about 5 - 10%, while the principal characteristic of the film of water bitumen -ice remained intact.

In conclusion as a further verification of the operation of the best W type mixes (without chloride) the time needed for the total **freezing** of non-treated samples (compact ice)was recorded at various temperatures :
It is to naturally remember that the processes of de-icing are stronger in the film of water to contact with the bitumen and that the thickness of the film used on the tests (5 mm) makes harder the de-icing of the parts "distant" from the same bitumen; in the reality the films of water that freeze him have thicknes less than 1 mm.
The times of congelation are measured to the temperatures of:

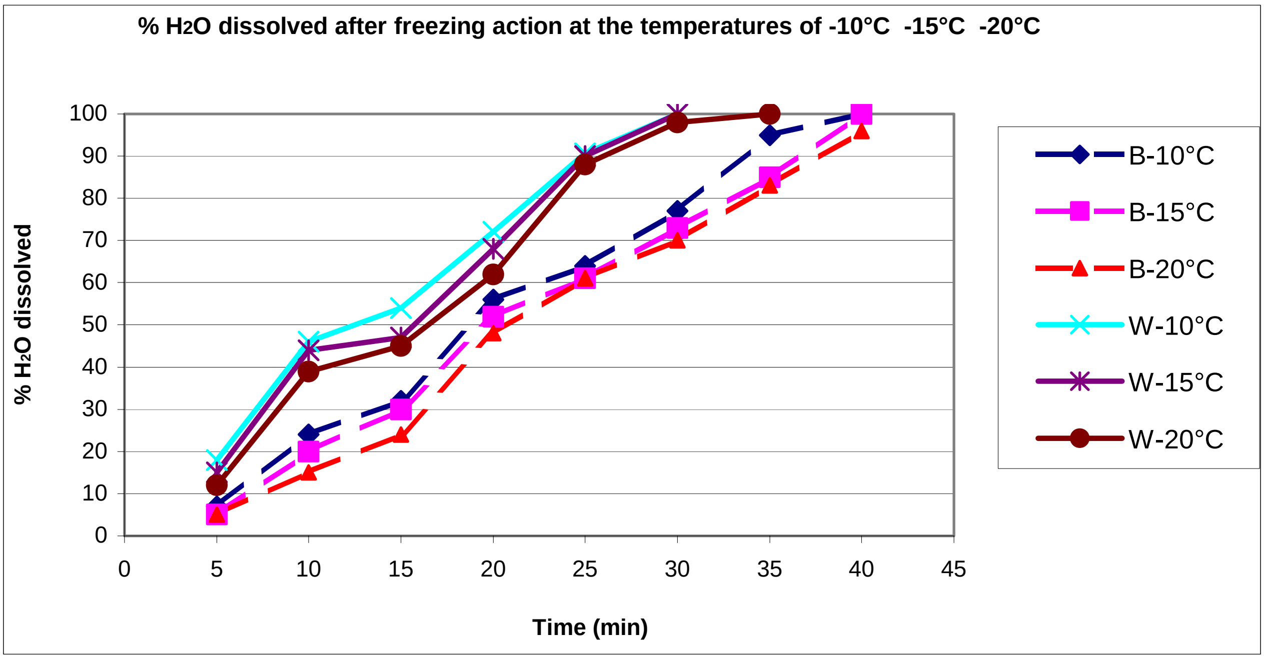
- 10 ° below zero (2 hours)
- 15 ° below zero (1 hour and 45 minutes)
- 20 ° below zero (1 hour and 30 minutes)

The freezing and heating processes were then repeated with the foregoing recorded times but with the use of different types of container (figure 8) in order to better illustrate the contact surfaces and the formation or otherwise of non-icing pockets of water that give rise to the rapid flattening action noticed earlier.
The results illustrate the very high level of validity of products that did not contain chloride salts and also preferable because they do not have aggressive action on road structures.
However, in all tests on treated samples involving salts of the latest formulation, it was shown that a film of water remained between the bitumen and the overlaying ice at all test temperatures, while with non-treated samples the ice layer was continuous and adhered to the bitumen until almost the end of the test.

Figure 8

	B			Wi		
Time (min)	B-10°C	B-15°C	B-20°C	W-10°C	W-15°C	W-20°C
5	7	5	5	18	15	12
10	24	20	15	46	44	39
15	32	30	24	54	47	45
20	56	52	48	72	68	62
25	64	61	61	91	90	88
30	77	73	70	100	100	98
35	95	85	83			100
40	100	100	96			

Table 3
Figure 9



	B	W
T (°C)	time for the change of state ice ->H_2O (min)	
-10	35	30
-15	40	30
-20	45	35

Table 4

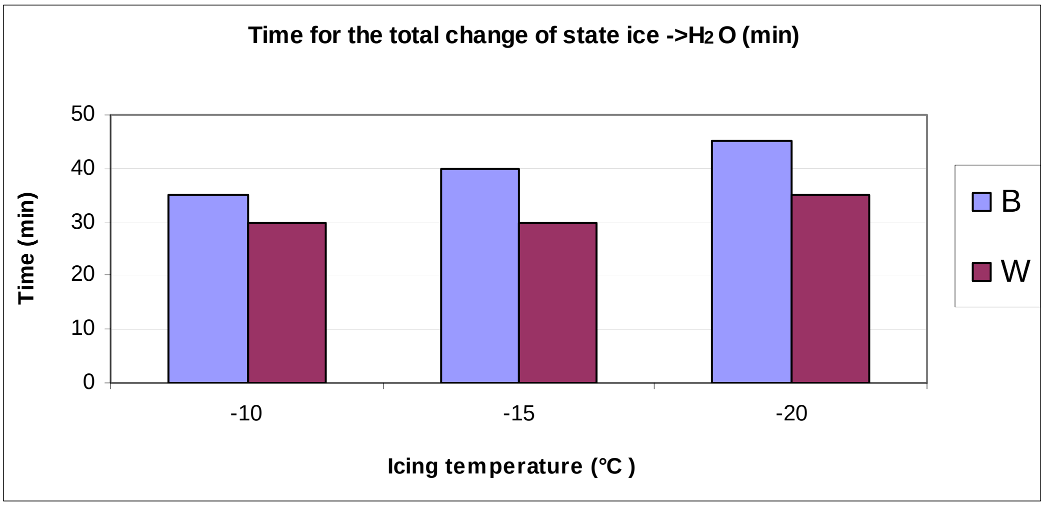


Figure 10

V CONCLUSIONS

On the basis of the foregoing research we can conclude that we are dealing with a valid technology for the fabrication of self de-icing bituminous conglomerate pavements, both closed and porous, that will prevent or delay in time the formation of ice adhering to the pavement.

These pavements can eliminate or limit to the maximum degree possible, the loss of safety due to the diminution of rolling and braking adherence of road surfaces in winter conditions. They offer greater time for traditional measures (sprinklers and snow-clearers) in conditions of above-average snowfall when the mere action of crushing the snow by vehicles in transit could be insufficient. Moreover, it does not create problems in conditions of rain or other wet conditions at non-winter temperatures.

The technology can partially reduce the aggression upon road structures and the pollution of water sources and land adjacent to the road alignment because the more advanced chemical compounds do not contain chlorides.

An additional result of the washing tests is the finding that these chemical compounds with their de-icing function are released gradually in the performance of their function and that they migrate from the inside (where they are in contact with conglomerate aggregates) to the outside (in contact with the air external or internal to the conglomerate) of the bitumen film and in so doing present new elements that have proven themselves to be active and effective in terms of de-icing action.