GENERAL REPORT OF THE 14th INTERNATIONAL WINTER ROAD CONGRESS HELD IN ANDORRA

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The general theme of this Congress, *"Reconciling road safety and sustainable development in a context of climate change and economic crisis"*, recalls for us this imperative: from now on, we will be increasingly required to incorporate all types of highly fluctuating parameters to ensure user safety and smooth traffic flow while addressing sustainable development considerations.

For the first time, three Technical Committees contributed to the Winter Congress technical agenda: Technical Committee 2.4 on *"Winter service"* was naturally mobilized, as were TCs 3.3 *"Road Tunnels Operations"* and 4.3 *"Road Bridges"*, making it possible to cover an even broader array of topics than ever before tied to winter road service.

These three Committees were responsible for evaluating the abstracts and then full-length papers, in addition to coordinating and hosting technical sessions throughout the Congress. In all, 150 presentations were delivered with another 177 poster displays, submitted from 33 countries, to illustrate these topics, which were divided into the 8 themes discussed below one at a time.

THEME 1 - WINTER SERVICE AND CLIMATE CHANGE

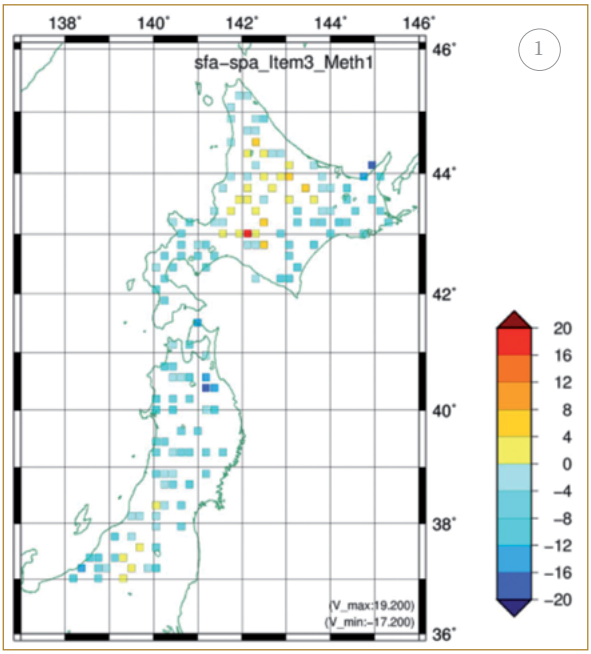
How has climate change affected winter conditions and what are the corresponding impacts on winter service? Winters have become harsher in some cases while milder in others. How have winter road servicing operations dealt with such changes, through weighing cost/benefit analyses, appropriate planning measures and technological improvements?

This theme was proposed for the first time at an international winter road congress; due to its novelty and the difficulties involved in grasping all relevant aspects, the subject generated just a small number of submissions, but no doubt interest will rise in the coming years.

Concerns expressed over this issue are starting to be raised in other themes as well, such as the observation of unusual and often extreme weather events and difficulties in balancing budget allocations with levels of service.

Winter service-related activities are directly affected by climate change. Some zones exhibit overall warming which is noticeable even at the scale of a snowplough operator's career. In contrast, other areas have been experiencing weather anomalies, as reflected by intense storms, atypically mild or harsh winters and, on the whole, events deviating from the norm. Service organizations must be capable of responding to such changes.

The papers delivered proposed some interesting and multifaceted approaches to analyzing the variations in snowfall over several decades, with



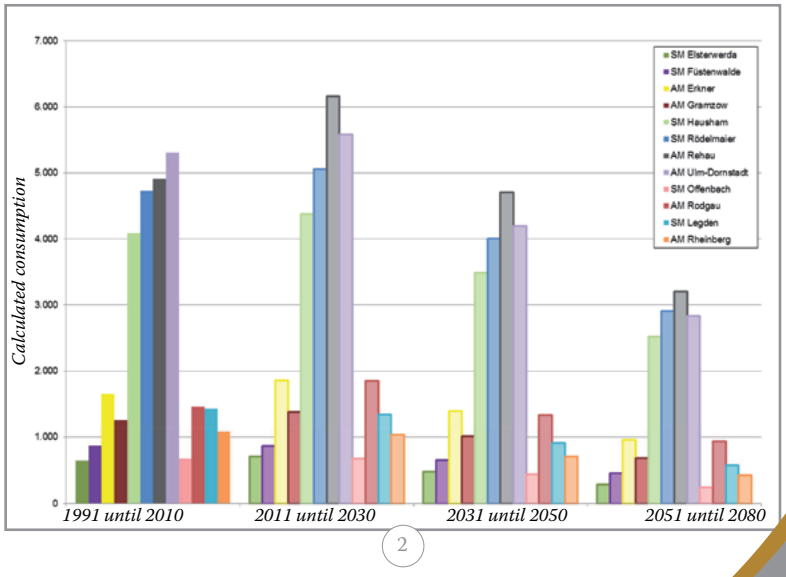
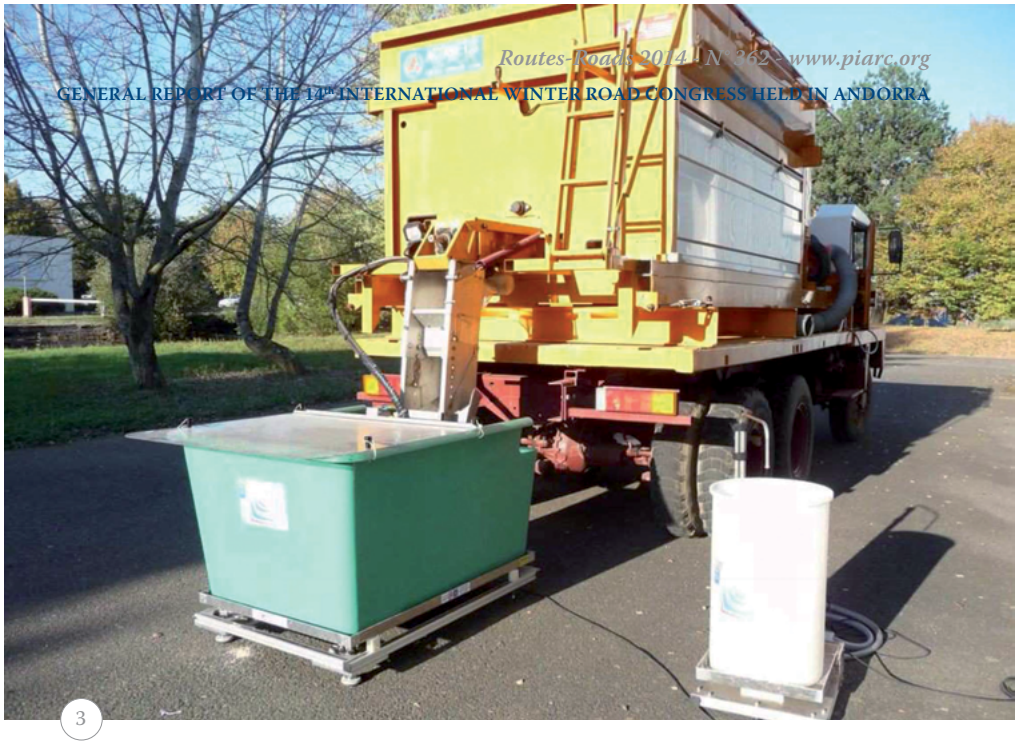


Illustration 1 (theme 1) - Variation with respect to the maximum 24-hour snowfall intensities in Japan; Comparison between the periods 1979-2003 and 2075-2099
Illustration 2 (theme 1) – Evolution in the consumption of deicing salts due to climate change



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one examining trends in accident statistics relative to climate and another projecting future personnel management and deicing salt consumption based on a statistical model.

An analysis from California demonstrated that the forecasted drop in snowfall events should lead to a decrease in accidents, though this improvement will be somewhat offset by rainfall events taking the place of former snowfall events.

In Germany, a climatological analysis covering the period 1951-2010, along with a simulation of the trend line through the end of this century, served by means of projection to assess the impact on winter service labor management and deicing salt consumption.

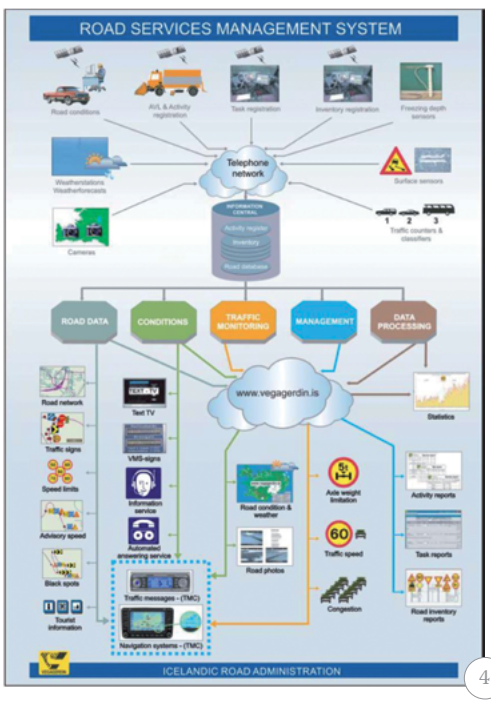
Moreover, a Japanese study correlated the evolution in accident rates with climate patterns using recent climatological data on snow precipitation and projected potential variations over several decades.

These three papers, all presenting rather pioneering work, laid a number of valuable methodological foundations for future developments on the topic.

THEME 2 - WINTER SERVICE IN A CONTEXT OF BUDGET RESTRICTIONS

The current economic downturn is affecting many countries, without necessarily causing a decline in trip-making demand, which in turn requires adapting winter services to shrinking budgets. What are the resultant impacts on staff training? Have equipment fleets been modified, in particular through enhanced modularity? What solutions appear to be feasible? This short-term focus generated roughly a dozen papers.

The group of authors sought to describe the reactions by public authorities to dealing with a combination of relatively harsh winters and tighter maintenance budgets. Various strategies were exposed. For starters, an economic approach: Japan and the United Kingdom have analyzed both the direct and indirect benefits of winter service, so as to justify the economic cost. In the Baltic countries, this calculation reveals that for every euro invested in winter service, the benefit to society during severe winters amounts to 20 euros.



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Elsewhere, the snow removal protocol itself is subject to revision. It was decided in Iceland, for example, to lower the level of service over the short term and completely restructure the organization to achieve optimization, in the aim of returning to the initial situation with fewer resources. The Czech Republic, on the other hand, has been working on its procurement procedures with contractors. Levels of service sometimes get revised as well, and users may be requested to actually partner in the effort through installing devices or participating themselves in winter service actions.

Technical approaches have obviously not been overlooked. Treatment optimization is part of the panoply of available solutions: it consists

Illustration 3 (theme 2) - Equipment verification: the basis for saving on deicing salts
Illustration 4 (theme 2) - Optimizing organizations by adopting management systems (Iceland's shown here)

of defining fine-tuned strategies and using high-quality products to limit expenditures; spreading brine has often been cited for such an application. Infrastructure-based responses are also proposed, led by special surface techniques combining scouring properties with mechanical attributes, plus the possibility of applying just a thin coat. Greater attention to preparing pavement conditions is required, as are higher-performance models. As for investments in specific facilities like roadside weather stations, a very well-documented perspective was provided by our German colleagues: multiuse equipment consuming less fuel may indeed be better adapted for this purpose.

Another potential lead focused on personnel training. When salt consumption doubles without a commensurate change in winter severity, the training and guidelines provided need to be rethought, as aptly demonstrated in a French paper.

Lastly, striking an effective overall compromise must necessarily incorporate accident rates and their associated costs; South Korea has conducted an analysis on expressways during winter weather episodes, while not overlooking the other risk factors like alcohol, wearing of seat belts and driver's age.

THEME 3 - EXTREME EVENTS

Some winter weather events have been severe enough to leave many motorists stranded on motorways or even entire communities isolated, in which case typical service organizations are no longer capable of intervening.

Case studies describing such events have analyzed these organizations and their management systems, as well as the cooperation existing between road authorities and other bodies.

Topics addressed featured: resource depletion during extreme events lasting extended periods (e.g. strategic salt reserves), manpower limitations, equipment reliability, agreements on assistance stemming from other sources, in addition to communication plans aimed at road users, truck and commercial vehicle management strategies and emergency vehicles.

Whether the consequence or not of climate change, extreme events seem to be occurring more frequently and qualifiers like extreme, harsh, severe or rare, though accurate, deserve attention. A Finnish paper provided a cogent overview of these concepts. They sometimes result from other natural phenomena, e.g. volcanic eruption, in conjunction with winter service difficulties, as exhibited in Argentina.
Over the past few years, many countries have had to cope with heavy snowfall, prompting them to establish new rules for: managing salt stockpiles (described in a German paper), improving road communication and information

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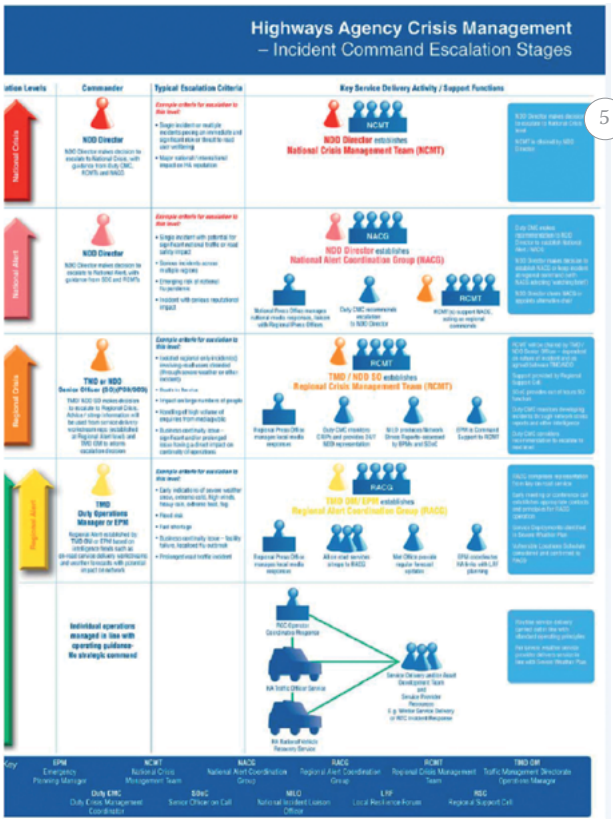

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Illustration 5 (theme 3) - Extract from the "Crisis Management Manual"
Illustration 6 (theme 3) - Closure of the E136 Highway in Norway

processes, organizing and supplying deicing salts in Great Britain (systems overloaded by the string of harsh winters between 2008 and 2011), and controlling traffic on mountainous itineraries to protect against avalanches (e.g. E136 Highway in Norway).

These winter episodes serve to exacerbate pavement distress, both on the surface and in the structural layers; several pertinent analyses were also shared.

THEME 4 - WINTER SERVICE MANAGEMENT

This theme, which has become a program standard at PIARC's International Winter Congresses, encompasses a wide range of topics: level-of-service analyses; relationships between operational and mobility strategies (accident rates - type and severity); consistency of travel times; and updates on latest innovations, technologies and state-of-the-art decision-making aids. Measures dedicated to vulnerable users (cyclists, pedestrians, the mobility impaired) were presented.

Winter climatology and index definition are current concerns given the wide fluctuations in winter weather; Lithuania has developed a toolbox that allows drawing insightful comparisons. Winter service also implies managing stockpiles of deicing salts; the German Federal Research Institute has devised a model that uses roadside weather station data and meteorological forecasts as inputs. A French guide on deicing salt storage was introduced. Other papers focused on service intervention strategies by type (preventive, curative, brine), whereby the determination of residual quantities helps optimize salting operations; moreover, sensors are used to justify: snow removal strategies, the choice of most efficient salt, and even the size of maintenance facilities.

A good number of phenomena still need to be explained, such as the effect of traffic when transforming ice and snow; Denmark sought to quantify this effect in using a carrousel to simulate traffic. Various models have been developed; the data being input include a historical record of maintenance operations, traffic volumes, weather conditions, and a pavement state of repair, with the objective of predicting the quality of surfaces, maintenance work, etc.

Beyond keeping roads open to traffic, winter service operations must also ensure user safety; Finland and South

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Illustration 7 (theme 4) - Conditions can become hostile in Scotland
Illustration 8 (theme 4) - Accommodation for bicycle traffic in Quebec City

Korea conducted analyses of winter accident statistics with respect to level-of-service. Accidents have been invoked to rewrite rules and reorganize user information processes: Norway has tested the implementation of such a process that informs motorists of wind speed and direction, visibility conditions and skid resistance when driving through a mountain pass.

Users are obviously very interested in driving conditions, which determine the level of skid resistance. Multiple solutions, methods and facilities exposed over the course of the Congress offered considerable insight. Given the lack of literature on tire quality, a Norwegian team of researchers set up an experiment using trucks.

Winter service requires skill and the potential to validate knowledge acquisition; Norwegian and Swedish authorities have adopted a set of personnel certification procedures that comply with the European standards framework. Finland's Roads Administration, which relies heavily on subcontractors, has developed a real-time monitoring system that posts output to the Internet, for consultation mainly by users. Such an approach can also be used to manage client satisfaction. Another paper discussed a quality approach, via winter service provision contracts, that accounts for increasing levels of difficulty, from basic to extremely complex.

The management of winter services entails societal aspects as well; for over 20 years, the Japanese city of Sapporo has delegated a predominant role to users/citizens, with the intention of creating bona fide winter governance, with announced quantitative objectives and indicators. Pedestrians and cyclists receive full consideration from facility managers; the issues of sidewalks and bicycle lanes were raised by the city of Quebec, renowned for its pioneering work.

THEME 5 - OPERATIONAL APPROACHES, SPECIFIC EQUIPMENT AND PRODUCTS

The upgrades to equipment, technologies and products for removing snow and ice were on display through a series of presentations focusing on: properties, performance, life cycle analysis, and environmental impacts due to scraping methods, spreading vehicles, deicing salts and abrasives. The sustainable nature of winter service operations also received attention.

The technical sessions provided the opportunity to suggest alternatives to traditional approaches, along with snowdrift control steps, by means of installing snow barriers or grading the land, plus avalanche detection and protection, and use of geothermal energy sources.

Product certification remains a current topic; French and Lithuanian studies set out to determine product performance and safety relative to the environment, based on both laboratory work and full-scale testing. The theoretical quantities of deicing salts to be spread onto roads are in fact quite small; for icy roads, many maintenance operations lie in the preventive realm and increasingly rely on slurry or brine. Spreading on a pavement needs to be even and involves at most in the tens of grams of product per square meter, sprayed from a vehicle moving faster than 50 km/h: a delicate operation to say the least.

Optimizing equipment and spreading techniques, determining the quantities released and verifying results remain critical facets of the winter service activity. From this standpoint, work towards standardization has been undertaken at the European level: tests on dedicated sites in Denmark; tools *("Odemie")* and methods for limiting transverse and longitudinal dispersion in France.

Assessments made by operators can however lead to erroneous actions, as revealed by tests carried out in Germany to analyze differences

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Illustration 9 (theme 5) - Limiting the transverse dispersion of product (France)

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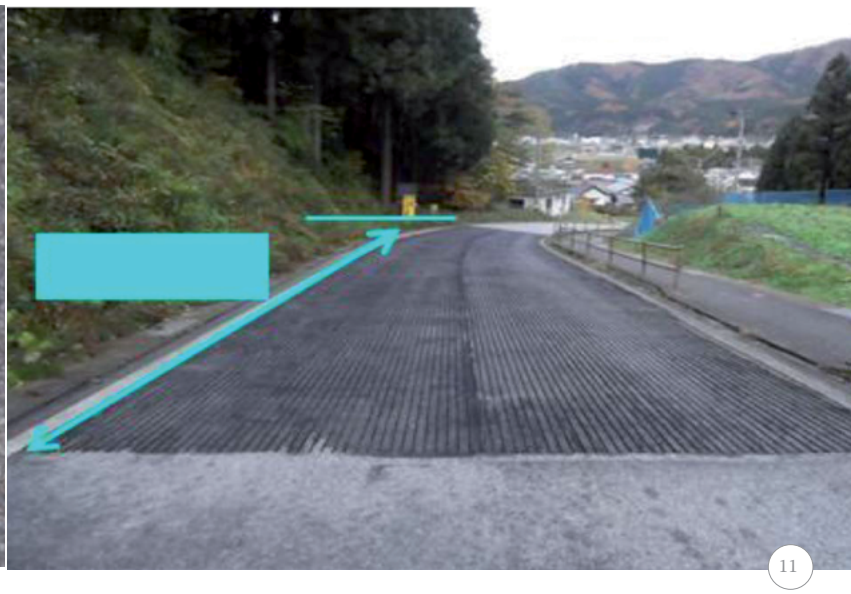

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stemming from the evaluation of a roadside weather situation. From this perspective, operator training would need to be improved.

Characterizing an outcome and using information to decide on the best maintenance practice have become absolutely necessary; one solution calls for measuring skid resistance. This step naturally applies to road pavements, but is also valid for sidewalks and cycling lanes, as several papers underscored.

Under all circumstances, acquiring varied data is key to successful implementation. A range of techniques were presented, including an optical method developed in Spain to measure residual salinity. Some approaches used sensors to facilitate real-time decision-making or characterize itineraries and situations; this step involved: thermal mapping, use of onboard vehicle data, and transmission of weather information.

Moreover, the pavement itself may be beneficial. Research on surfacing materials with anti-icing properties is not recent yet has still not yielded its anticipated results. Research is ongoing in a number of countries including Japan, Andorra and Germany.

Environmental concerns have become central to winter services and lie at the very heart of operational strategies. A study on chloride filtration systems in retention basins indicates how ions migrate into soils. Alternative methods are also on the drawing board. In Japan, geothermal energy powers not only snow melting systems, but the direct heating of pavements as well. Germany has extensively studied the potential for implementing heating systems, in evaluating both their benefits and limitations.

Moreover, the natural and artificial obstacles to winter service were not ignored. Avalanches and snowdrifts are a chief cause for concern among facility managers and received attention at the Congress, which included an Andorran paper assessing 30 years of experience in an interesting study on the Col de la Fageole mountain pass (on France's A75 motorway), along with various avalanche modeling and forecast systems. As for artificial obstacles, presentations focused on the strength of guardrails when coming into contact with snow removal blades and on handling flanges during the construction of roundabouts in Japan.

THEME 6 - THE ROAD USER COPING WITH WINTER CONDITIONS

The road user is an important partner in the provision of winter services. Users' needs during the winter season vary depending on their type of travel, giving rise to appropriate management plans and communication modes. As an example, smartphones, custom applications, onboard communication systems or social media may all be viable means for opening two-way lines of communication between road authorities and motorists. Vehicles have evolved and now possess many assistance systems and devices for driving, safety and communications with facility operators. This progress has also enhanced wintertime mobility.

Retrieving information on driving and traffic conditions is essential to the user; in this vein, Japan unveiled a dedicated Website called *"Drive traffic"*. Another Japanese site provides

Illustration 10 (theme 5) - Incorporate texture into treatment strategies, from theory to practice
Illustration 11 (theme 5) - Japan: research on surfacing materials with anti-icing properties

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users round-the-clock forecasts of road conditions, helping them decide whether or not to take the wheel.

Information must be easily understood; for this reason, the United States identified the most efficient format for communicating with users, in producing a dissemination guide addressed to facility managers.

The combination of heavy vehicles, slope and snow most often creates driving difficulties. Nonetheless, only a few objective investigations exist in the literature to qualify each of these components individually; a Norwegian study showed that it was indeed possible to associate the capacity to cross a mountain pass with various types of truck designs.

It can be quite difficult to predict road weather phenomena, many of which are capable of occurring very suddenly and/or within very localized areas, without the operator's liability necessarily being protected. As a matter of fact, road accident victims due to snowy or icy conditions can file suit against the facility manager for substandard maintenance. French and German papers delved into this subject, specifying the extent of manager liability and potential remediation.

While reducing the number of road accident victims remains a major objective, the perception of the road environment during winter is still subject to modification, as demonstrated in a Quebecois study.

THEME 7 - ROAD TUNNELS EXPOSED TO WINTER CONDITIONS

The inclusion of this theme in the event's technical program stems from the interest generated by various papers presented at the previous Winter Road Congress held in 2010 in Quebec City.

Inside road tunnels, temperature conditions are reasonably uniform and constant throughout the year; nonetheless, when outside temperatures are very low, exceptional operating measures may be required, especially at tunnel entrances and in the vicinity. Design of the structure and its equipment must account for such variations. Papers submitted to the Andorra Congress sought to demonstrate this point.

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Illustration 12, left page (theme 5) - Competition of the best climber on a snow-packed road: right or left truck?
Illustrations 13 and 14 (theme 7) - The Two Valires ("Les dos Valires") Tunnel.
Built between 2005 and 2012, it connects Encamp and La Massana, in Andorra

One paper described the operating experiences encountered in many tunnels in the region around Aragon (Spain), whose elevation at over 1,000 meters necessitates adopting maintenance measures that guarantee service despite the risk of snowfall. A close-up was provided of this region's Somport cross-border tunnel, describing in detail the activities and knowledge acquired here while addressing the various problem areas:

- human resource requirements, notably in critical zones like tunnel entrances;
- interactions with the user via local as well as regional information services;
- maintenance tasks required to ensure tunnel infrastructure and installations are operating properly.

A second paper investigated the challenges raised by two urban tunnels in Quebec City, with weather conditions imposing tremendous planning and organizational efforts throughout the year, in order to meet all preservation, maintenance and safety criteria. Spectacular videos and photos no doubt helped grasp the magnitude of these challenges.

The third and last paper presented the experience with Andorra's Envalira Tunnel, the highest major tunnel in Europe. The benefit of adopting a global approach encompassing the user and safety could be substantiated, while providing concrete examples of design measures that noticeably influence tunnel operations.

These analyses highlighted two fundamental aspects:

- the need to incorporate operations and the challenges created by extreme conditions, as of the project design phase. An appropriate design of the structure and its installations will lead to tremendous savings in operating costs, with more cost-efficient facilities required throughout the useful life cycle of the infrastructure;
- significant efforts deployed by the various agencies to expand and improve interaction channels opened with users, who are the ultimate beneficiaries of these upgrades.

THEME 8 - ROAD BRIDGES UNDER WINTER CONDITIONS

Under this heading, two sessions were dedicated respectively to the impact of deicing salts on bridges and related protection methods, and the maintenance of road bridges under winter conditions.

The specificity of road bridges (deck exposed to cooling) leads to observing, at the level of the surfacing and the bridge structure itself, temperatures below those of the adjacent road. Also, wind conditions are often more unfavorable where the bridge begins, further amplifying this temperature drop. Air drafts present in some tunnels may be the cause of increased cooling for a bridge located near a tunnel entrance. This effect was effectively documented on a section of Croatia's A2 motorway.

These unique microclimatic conditions impose special winter treatment at bridge sites. An improved knowledge of temperatures at these sites, by means of additional measurements, allows optimizing such treatment, thus reducing the quantity of salts spread.

The salt spread, NaCl for the most part, is discharged via the bridge drainage system. In the event of direct discharge or a break in a drain pipe, bridge piers may become degraded, and sometimes quite rapidly, as was the case for a ten-year-old Andorran viaduct.

However, a large proportion of these salts are discharged through drainage and enter into contact with the upper surface of the bridge structure, as well as with the lower surface through infiltration paths located at breaks in the seal, dilatation joints or around the drain periphery, etc. This generates significant corrosion on the reinforcements, post-tensioning cables and guardrail anchorages, as pointed out in a British study. Chlorides exacerbate this corrosion yet are not consumed by the electrochemical reaction, as was well described in one

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Illustration 15 (theme 8) - Damage at abutment, sidewall and surface due to freeze-thaw cycles


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of the presentations; they therefore remain harmful for an unlimited period of time!

Chlorides also affect the behavior of concrete exposed to freeze-thaw cycles and raise the level of hazard. In Spain, such a chloride effect is considered predominant by authorities. Moreover, deicing salts contain sodium, which can speed the development of internal swelling reactions in concrete (known as the alkali-aggregate reaction), as observed in Spain and Denmark.

One initial possible treatment consists of preventing chloride penetration into the concrete. A Japanese presentation featured such an impregnation treatment using a silane-based solution *(illustration 16)* that clogged the surface porosity and thus prevented the penetration of water charged with chlorides into the concrete, while remaining permeable to water vapor.

This water-repellent impregnation technique is applied to the surfaces in direct contact with deicing salts, such as bridge rails, concrete retaining systems and sidewalks. The solution penetrates a thickness of 5 to 10 mm but must be repeated at least every 6 years; however, ease of application is what makes this option attractive. For a raised rail with a 100-year life span, renewing this layer every 6 years represents a 15% to 60% cost savings compared to replacing the element after 50 years subsequent to chloride damage.

Preventing all contact between chlorides and a bridge structure often proves to be impossible, once managing this pollution risk has become a real concern. In the United Kingdom, this chloride risk management process now includes climate change, which is expected to produce warmer and wetter winters, resulting in less frequent chloride spreading periods, yet accompanied by higher salt consumption due to increased precipitation during winter. Chloride risk management promotes bridge inspection techniques at greater frequencies for the purpose of detecting chloride-charged water infiltration as quickly as possible.

In many countries, the number of bridges greatly increased during the 1960's and 70's. Some of the most exposed elements might already be at the end of their life cycle *(illustration 17)*. Denmark's Roads Directorate, based on current experience, has estimated that during the intervening period, a bridge pier exposed to chlorides saw its life cycle reduced to 15-20 years. For a bridge rail, the life cycle had been from 20 to 30 years, climbing to 30-40 years with a proper seal.

The detailed inspection of a degraded bridge, in the aim of preparing its rehabilitation, requires implementing several non-destructive methods (e.g. potentiometric mapping, coating measurements, high-frequency radar, infrared thermography, impulse response) in combination with samples extracted for laboratory analyses (chloride content, humidity, alkali-silica reaction evaluation). These procedures are conducted in a number of countries, including Denmark, Spain and the Principality of Andorra.

Thanks to these findings, the Danes recognize that below a value of approx. 0.05% chlorides relative to the total concrete mass, no corrosion risk exists. Beyond this threshold, if corrosion traces are observed, then the polluted concrete must be withdrawn. If this pollution rate reaches 0.1%, then the material is to be withdrawn even in the absence of corrosion.

Let's note that in the presence of prestressing strands, these thresholds are to be cut by half. Moreover, the consequences of chloride-induced strand corrosion are much more serious for overall bridge stability.

In cases where the concrete is replaced locally, questions are raised over the

Illustration 16 (theme 8) - Treatment by impregnating a silane-based solution
Illustration 17 (theme 8) - Degradation of a bridge exposed to chlorides

durability of repairs (due to fatigue, freeze-thaw cycles, skid resistance, etc.). In Japan, these repairs are performed with fast-setting concrete in order to limit the impact of repair duration on traffic. Fatigue tests with the traffic simulator run on a test slab repaired in its central section over a minimal thickness indicate that while skid resistance appears to be sufficient between the repair and the slab concrete, this fast-setting concrete displays less fatigue resistance.

Following the testing campaign, it also appeared that a test slab placed under freezing conditions exhibits a fatigue resistance 2.5 times greater than the same slab once thawed.

When it is impossible to withdraw the polluted concrete, the solution of installing cathodic protection is advised in several countries, in order to prevent such corrosion from advancing. This relatively simple step still necessitates continuous monitoring and an electrical supply even at such a low power level.

The maintenance budgets for concrete bridges are shrinking in many countries due to economic hardship. The exchanges held during this Congress were particularly beneficial, and it is now possible to draw the following lessons:

- In regions with cold winters, it is advised to prevent the penetration of deicing salts into the concrete. To achieve this, it is necessary to set up sealing systems in addition to embedding joints.
- Once salts have penetrated into the concrete, chloride ions remain and cause permanent damage, hence the need to intervene as of the first signs of deterioration.
- It is possible to reduce the use of deicing salts by taking into account both the temperature and level of service of each individual structure.

CONCLUSION

Some 1,500 Congress participants, plus another 3,000 visitors, 600 spectators for the snowplough contest and 150 speakers spanning 38 sessions and 170 poster presentations: this initial quantitative assessment provides a scale of the event, a first for the Principality of Andorra and an undisputed success.

A Congress program includes an entire portion devoted to making connections, with exhibits and meetings at the stands, equipment demonstrations, technical field trips, a snowplough competition and cultural activities.

The 2014 Andorra Congress gathered winter service experts from the world over and achieved its objective of streamlining knowledge sharing and exchanging ideas on the latest developments and challenges facing winter road services. This success provides a powerful incentive to continue the effort, in preparing the World Road Association's 15th International Winter Congress in 2018, to be held in Gdańsk, Poland.#

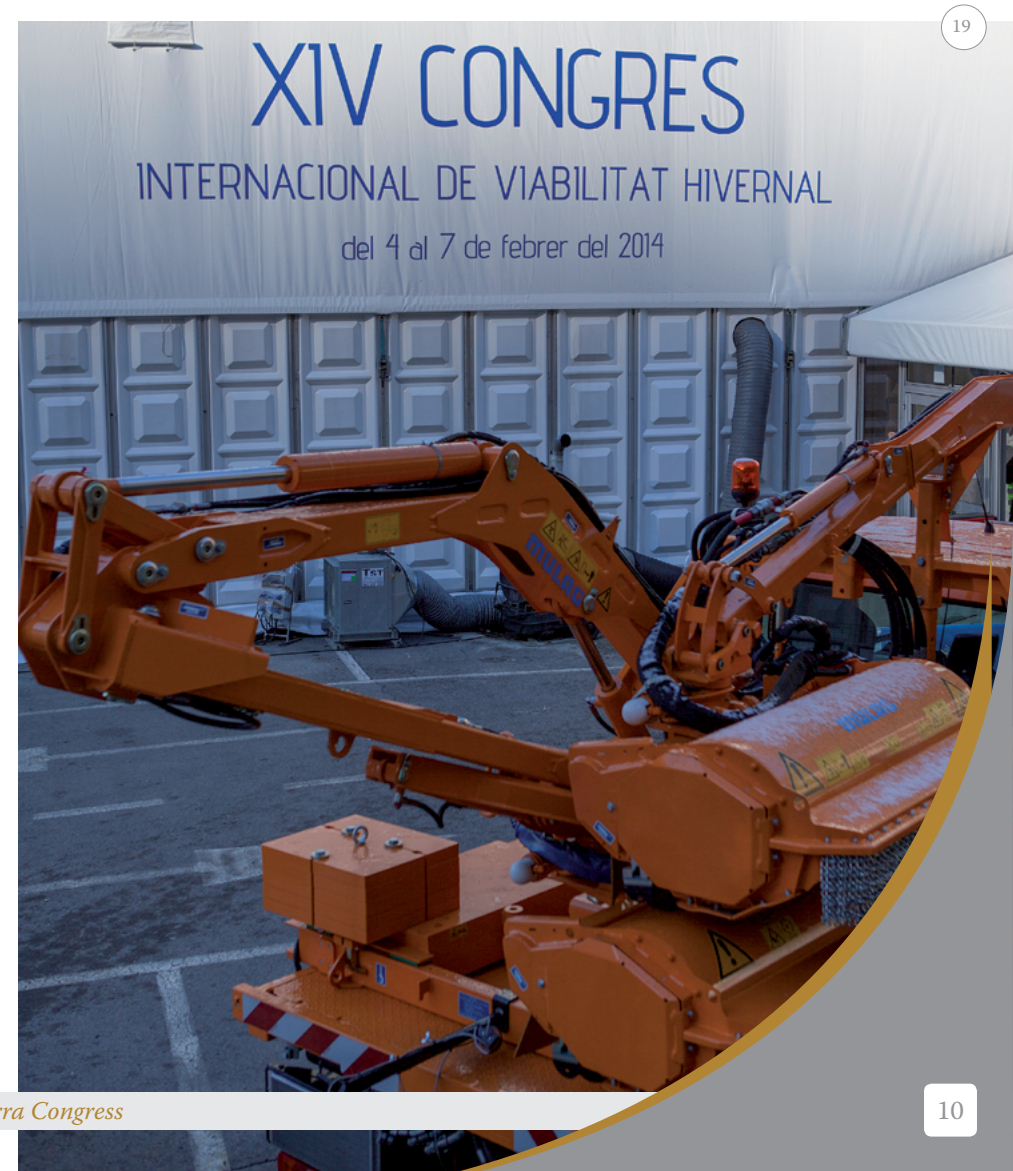

Illustration 18 - The exhibition area at the Andorra Congress