3.0 – ROAD, BRIDGE AND FACILITY DESIGN

This is one in a series of Syntheses of Best Practices related to the effective management of road salt in winter maintenance operations. This Synthesis is provided as advice for preparing Salt Management Plans. The Synthesis is not intended to be used prescriptively but is to be used in concert with the legislation, manuals, directives and procedures of relevant jurisdictions and individual organizations. Syntheses of Best Practices have been produced on:

1. Salt Management Plans
2. Training
3. Road, Bridge and Facility Design
4. Drainage
5. Pavements and Salt Management
6. Vegetation Management
7. Design and Operation of Maintenance Yards
8. Snow Storage and Disposal
9. Winter Maintenance Equipment and Technologies
10. Salt Use on Private Roads, Parking Lots and Walkways
11. Successes in Road Salt Management: Case Studies

For more detailed information, please refer to TAC's Salt Management Guide - 2013.

INTRODUCTION

Once a roadway, bridge, building or other facility is designed and constructed, it is in place for a very long time, during which it must be maintained. Proper facility design can reduce the need for (and cost of) snow and ice control, a major component of operating budgets throughout Canada. Effective incorporation of quality construction materials and techniques, effective drainage, adequate snow storage, sufficient cross-fall, accommodation for effective plowing and snow storage, etc., will help to facilitate effective snow and ice control and salt management.

The primary purpose of this Synthesis of Best Practices is to increase the designer's awareness of the importance of considering operations from the outset. That includes the techniques, materials, configurations and design parameters to reduce the amount of snow and ice accumulation and to manage the impacts of salt on the infrastructure and the environment. This Synthesis of Best Practices presents basic principles to consider in design. For more detailed information, see TAC's *Salt Management Guide* - 2013.

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RELATIONSHIP TO SALT MANAGEMENT

Ice forms on pavement when freezing temperatures and water occur in combination on the traveled surface.

Salt is used to prevent the formation of, or break the snow/pavement bond and to remove ice that has formed.

Facility designers cannot do much about precipitation but can be instrumental in maximizing solar heating of pavement and managing onsite drainage and drifting snow so as to reduce the risk of ice formation and the need for salting.

Throughout all phases of facility development (location, planning, preliminary design and detailed design) designers have the opportunity to make decisions regarding the location, configuration and design details of the facility, which will affect, throughout the life of the facility, the potential for snow and ice accumulation.

If a roadway, building, parking lot or sidewalk has a lower potential for snow and ice accumulation, then the winter maintenance demands will be correspondingly lower and, therefore, the actual application of salt over a given period of time is likely to be lower. Design can also affect the ease of maintenance.

Research and case studies have confirmed that there is a direct relationship between certain design parameters, snow and ice accumulation and the ability to provide cost-effective winter maintenance. It is therefore suggested that, as a guiding principle, designers should consider maintenance requirements when determining the location, concept designs, preliminary designs and final designs for infrastructure.

It is possible that the incorporation of features to minimize snow and ice buildup into a design will add to the capital cost. It is also clear, however, that from a broader life-cycle view such initiatives are likely to increase safety and reduce maintenance costs throughout the life of such a facility. These trade-offs should be considered as an integral part of location planning, preliminary design and detailed design. Valuing design initiatives must be done on a life-cycle basis (including operations and maintenance costs). Therefore, it is essential that maintenance personnel be involved in design discussions.

SALT MANAGEMENT PRACTICES

Designers can influence the amount of maintenance effort and salt used in three key ways:

1. Maximizing solar heating potential
2. Minimizing the amount of water flowing onto, across or ponding on paved surfaces
3. Minimizing the potential for snow to blow onto paved surfaces.

Each of these is discussed below.

Maximizing Solar Heating

We have all experienced the warmth of the sun on a cold winter's day. The sun can increase pavement temperatures by 10 degrees Celsius or more. Even on cold days this solar heating can raise pavement temperatures above freezing and either melt snow and ice or prevent moisture from freezing.

Maximizing solar heating potential involves exposing pavement to the sun and reducing shade. In the case of building design, this can be accomplished by orienting building so that paved areas are on the sunny side of the building as much as possible.

Shaded areas will be colder than sunny areas. Therefore shading should be reduced where possible. Pavement shading can be reduced by removing obstacles that will block the sun on the south side.

When planning earth or rock cuts, road authorities usually remove equally from both sides of the road. There are many reasons for this. However, where there is flexibility, it makes sense to maximize the removal on the side that will allow solar heating. Removals also need to provide for snow storage when plowing so that the melt water does not flow back onto the pavement.

Both summer and winter cooling and heating can be affected by the type of vegetation planted adjacent to roadways and parking lots. Deciduous trees will provide shade in the summer and allow the sun through in the winter.

When planning vegetation removals and grade alterations, the effects on snow drifting and snow storage must also be considered.

Drainage Management

Proper roadway and parking lot design incorporates sufficient cross-fall to distribute saline brine across the surface which minimizes salt use.

Much of the salt used on parking lots, sidewalks and roadways is to address ice formed with water from poor drainage.

Many buildings are poorly designed and allow roof drainage to drop or discharge onto paved travel areas. This perpetual icing requires ongoing salt application to manage the risk.

Designers need to pay special attention to intercepting building and site drainage and directing it away from paved surfaces.

It is informative to view a site on a rainy day to understand how poorly designed facilities can affect drainage. The areas of poor drainage are clearly evident. These areas are prone to icing in cold weather and therefore are high risk areas for slips and falls and consequently become high salt use area. Effective drainage management can therefore reduce salt use over the life of the facility.

Drainage from melting snow pushed to the high side of paved areas is a particular problem. Parking lot designers often place catch basins such that water from snow piled around the perimeter needs to flow across travelled areas to reach these outlets. This water will freeze into sheets of ice if the pavement is below freezing.

The problem can be addressed by better grading of the lots and placing interceptor drains closer to the edge of the pavement.

Snow storage must be taken into account when designing roadways and preparing site plans. Ideally snow storage locations should be identified and designed so there is sufficient snow storage capacity and drainage is away from paved surfaces. In the case of roadways, sufficient shoulder area is required to ensure that snow can be plowed off the travelled surface and stored for the duration of the winter. In urban areas this may not be practical and therefore snow will need to be picked up and transported to snow disposal sites.

FUNDAMENTALS OF SNOW DRIFTING

In some locations a significant amount of the snow that needs to be removed from roadways, parking lots and sidewalks is deposited through drifting. Therefore effective drift control can reduce snow and ice control efforts including salt use. Designers can have a significant effect on whether or not a site will have drifting problems.

Operationally, drifting can be controlled through the erection of drift control devices such as snow fence (structural and living) and snow ridges and the strategic placement of buildings.

Understanding the cause of snow drift accumulations and designing to minimize the causes can reduce the severity of an icing problem, thus lowering the salt requirement.

Snow drifting will occur when a driftable source of snow exists in an open area upwind of a site and when the local wind speed (measured approximately 1 m above ground) exceeds the threshold speed of 15 km/h. Threshold speed is defined as the limiting speed below which the wind will not lift and transport snow particles. Once these conditions exist the wind will transport the snow in a thin layer close to the ground. As long as there are no obstructions to slow the wind, the snow will blow across the pavement and will not accumulate.

These snow particles will continue to be transported until they sublimate (change directly from solid to vapour state) or until wind speed slows to below the threshold speed and particles settle on the ground. If the wind speed increases, the turbulence caused by the friction at the ground surface causes a mixing action that increases the thickness of the blowing snow layer and usually causes reduced visibility. Reduced wind speed areas will be caused by obstructions to the wind such as changes in grade, vegetation, plowed snow banks, safety barriers, bridge abutments, buildings etc. (See Figures 1-4)

The reduced wind speed zones around these obstructions will accumulate snow that will affect the facility if the obstructions are close enough to the pavement.

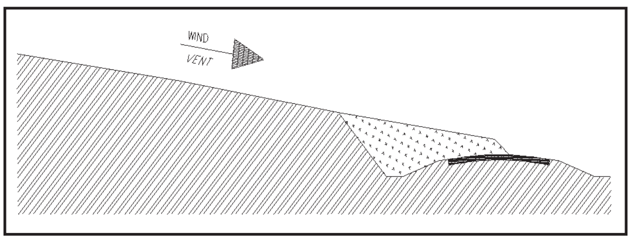

Figure 1 – Snow accumulation problem caused by change in grade

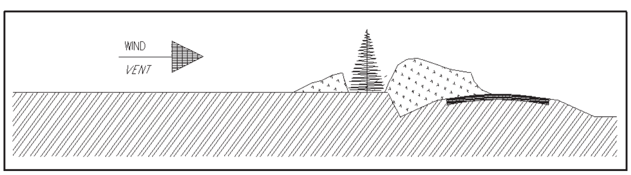

Figure 2 – Snow accumulation problem caused by trees

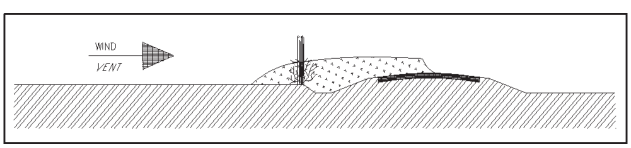

Figure 3 – Snow accumulation problem caused by fencerow obstruction

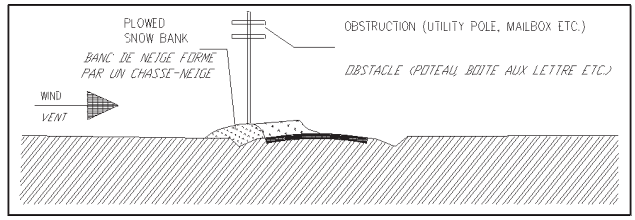

Figure 4 – Snow accumulation problem caused by utility pole obstruction

In some cases if the snow can blow across a paved area and high traffic volumes also occur, the vehicles will pack snow onto the surface and cause icing conditions. Equally if salt is applied to a surface in areas of low traffic volumes, the salt can form moisture and cause the snow to stick to the surface where it would otherwise blow across the pavement. This concept of not salting should not be implemented without careful consideration. A written plan should be in place that specifies when salting should and should not occur. Some jurisdictions may decide that not salting is inconsistent with their maintenance philosophies.

FACTORS TO CONSIDER IN ROADWAY AND BRIDGE PLANNING AND DESIGN

Below is a list of key factors to consider in the planning and design of roadway and bridge facilities in order to minimize the likelihood of snow and ice buildup. These concepts can also be used to identify solutions to snow accumulation problems on existing roadways. For more details the reader is referred to TAC's Road Salt Management Guide - 2013. In addition, on more complex projects the designer is advised to use the services of a specialist in the area of snow and ice control.

Meteorological Data

- The following meteorological data should be obtained as background information:
  - average daily and annual snowfall
  - prevailing wind directions and speeds
  - storm directions and the amount of snowfall typical to a winter storm
  - mean monthly temperatures and expected winter extremes
  - number of freeze/thaw cycles

- Facility maintenance staff is often familiar with local conditions and are a source of useful “hands on” information.

Surrounding Terrain

- The terrain surrounding a site will affect the amount of snow that can blow towards a facility.
- In establishing the location of a new facility bear in mind that the upwind terrain is key. The distance from the facility to any major upwind features (e.g., a ridge, a heavy tree line, a building line, etc.) is referred to as the “fetch”. The bigger the fetch, the larger the snowdrift potential and the larger the potential problem at the facility.
- The surface of the upwind fetch area is also a major consideration. A “smooth” area such as frozen water or short grass will not trap snow and hence will not assist in reducing drifting conditions. Rougher terrain, such as ploughed fields, crop stubble, long grass, shrubs or particularly mature trees with dense winter branch structure will trap snowfall and may reduce the potential drifting conditions at the facility.

Interchanges/Buildings

- Complex wind flows are associated with interchanges and buildings and usually it is necessary to conduct a model study to fully assess conditions.
- From the point of view of snow accumulation, at interchanges, the roadway with a higher level of service (LOS) should cross over the roadway with lower LOS as prevailing winds would blow snow off the major roadway.
- Open style abutments should be considered over closed abutments to reduce snow accumulation, although the higher cost of open style abutments and their typically rural nature may dictate the use of closed abutments in many instances.

Pavement Shading / Exposure to Sun

- In areas of high tree cover, consider the winter altitude and azimuth (bearing, measured clockwise from true north) of the sun, and the potential shadow effects of the tree cover which will affect the potential for ice melting on the pavement surface. Trees should be cleared back far enough to maximize the heating effect of the sun. Similar considerations should be given to site conditions where vertical walls are part of the facility design. In this case, the vertical wall should be replaced with a sloped embankment if possible. To the extent possible, buildings should be oriented so that paved areas are not shaded.

Elevated Road on Fill Section

- With divided roadways and a median width which will allow the establishment of independent grades for the two directions of travel, it is desirable to set the elevation of the upwind lanes lower than those of the downwind lanes, or at least, at the same elevation as the downwind lanes.

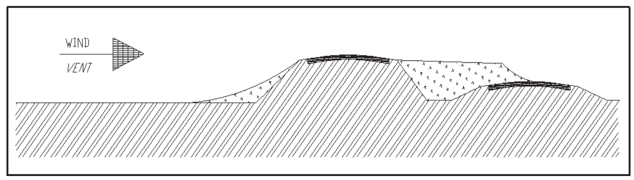

Figure 5 – Elevated roadway causes snow accumulation on adjacent lanes

Preferably the top of pavement should be approximately 1 m above typical snow depths in the area.

If possible eliminate the need for safety barriers, and therefore, the obstruction that causes snow drifting with slope flattening of fill side slopes. For minimum side slope without guide rail (in the range of 3:1 to 4:1), refer to TAC’s *Geometric Design Guide for Canadian Roads*. Ideally, side slope should be flattened to 7:1 for effective snow accumulation.

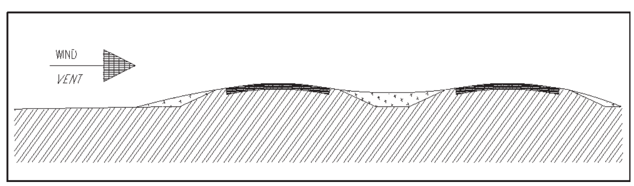

Figure 6 – Travelled surfaces at same elevation minimize snow accumulation on roadway

Generally, a road’s cross-section totally on fill without significant terrain features upwind is more likely to blow clear of snow than any other design configuration.

Wide Ditches

Wide ditches provide storage for plowed snow which otherwise would be piled along the edge of the roadway and would promote more snow accumulations. Refer to TAC's Road Salt Management Guide - 2012 for further details on calculating volume of drifting snow.

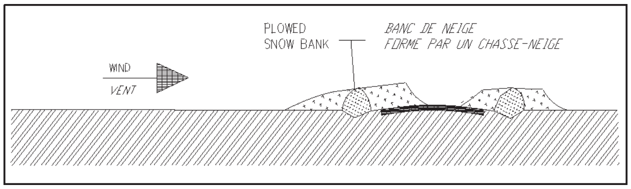

Figure 7 – Lack of storage causes plowed snow banks along road

Use of Guide Rails

Box beam / cable guide rails have the least obstruction and in theory, accumulate the least amount of drifted snow but in practice, plows push snow against box beam / flex beam to create a solid barrier, therefore, for the purposes of snowdrifting / accumulation, assume all barriers are solid.

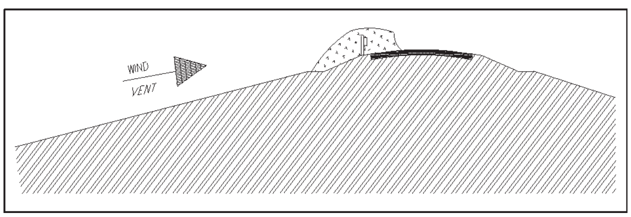

Figure 8 – Safety barrier causes snow accumulations along road

- Solid Jersey barrier is easiest to plow against.
- Tall solid barrier has increased drifting area and increased shaded area.
- Reduce the need for barrier at side of roadway through slope flattening.

Berms for Snow Accumulation

- Locate berms upwind of the roadway, setback 7 times the berm height.
- To obtain the maximum snow collection capacity, maximize the berm height and ensure berm slopes are as steep as practical.
- One tall berm is more efficient at accumulating snow than a number of rows of shorter berms.
- To maximize the effectiveness of tree plantings, locate coniferous trees on a berm. However, the setback should be 15 times the combined height of the berm and the mature tree.

Backslope

- Flatten upwind backslope (ideally 7:1 or flatter) to minimize drifted accumulations on pavements.

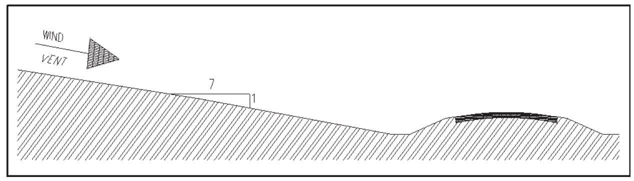

Figure 9 – Flatten backslopes

- With roadways in cut sections, consider a wider cut on the upwind side than on the downwind side, ideally meeting the 7:1 minimum gradient discussed above. If the roadway cut is a source of material for other sections of the roadway, consider taking the majority of the material from the upwind side of the cut.

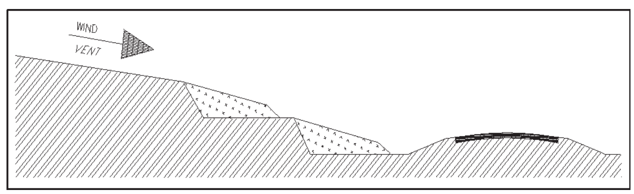

Figure 10 – Use wide cut to store drifted snow

Obstruction Close to Facility

- As shown in Figures 2, 3 and 4 obstructions that can cause snow accumulation problems are as follows:
  - trees too close
  - mail boxes
  - utility poles
  - guide rails
  - plowed snow banks
  - fence rows
- Consideration should be given to eliminating / minimizing these obstructions if they are causing snow accumulation problems.

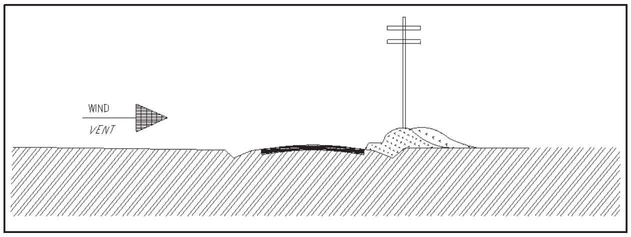

Figure 11 – Locate obstruction on downwind side of road

- Where possible locate obstruction on downwind side of facility.
- As a general rule of thumb a 50% solid obstruction (snow fencing, vegetation) should be placed a distance of 15 times its height from the facility/ right of way, on level ground. A solid obstruction (buildings, double vegetation) should be placed 10 times its height on level ground.
- Noise walls do not typically present a problem with snow accumulation as they usually are located in residential areas that limit snow movement towards the wall and the roadway, however, snow drifting at end details should be considered.

Vegetation Management

- With appropriate landscape design, many snow drifting problems could be solved or lessened. Similarly, improper design or placement of vegetation can aggravate a snow accumulation problem (particularly at interchanges).

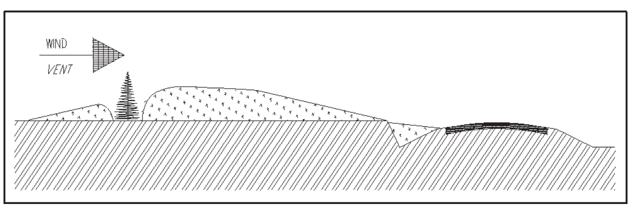

Figure 12 – Properly located trees will reduce snow accumulation on road

- Before vegetation is removed for the construction of new facility (or for existing facility expansion) designers should evaluate existing site conditions in order to determine whether or not existing vegetation could prevent a snow related problem or could cause a future snow related problem. Preserving existing vegetation is more economical and time efficient than planting new vegetation. This approach also allows existing vegetation to be incorporated into new landscape plans.
- The objective of upwind snow fences (non-living or living) is to encourage a snow drift immediately downwind of the fence or vegetation with the result that little snow is left to drift onto the facility/roadway.

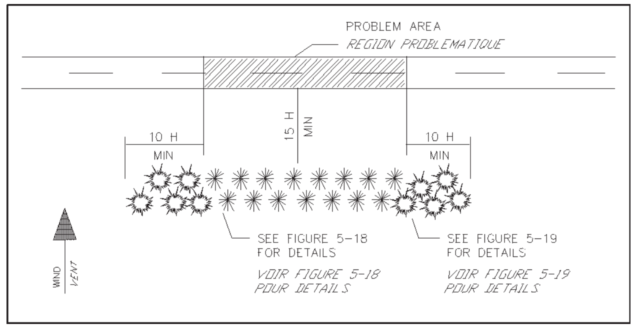

Figure 13 – Details of typical landscape layout

- Upwind vegetation planting can have a similar effect to snow fences providing the configuration and location is appropriate and the planting is not close to the roadway.
- Plants with dense branch structure will hold snow to approximately one half its height. Trees and woody plants are better as they do not tend to bend as much under the weight of the snow.
- Corn stalks left in agricultural fields on the upwind side can slow wind speed and reduce drifting and blowing snow. Five or six rows of corn with a similar setback to that shown in Figure 13 will be effective in reducing snowdrifts.
- Uncut grass in the ROW is better than cut grass as it keeps snow from blowing with the exception of grass directly adjacent to the roadway, which ideally should be cut short to avoid drifts that would extend onto the roadway.
- If there is sufficient land area available, at least 60 metres, a snowbreak forest is a viable option. However, a much more economical solution for new facilities is to retain existing forest. This saves the time required for newly planted vegetation to reach their required height. Snowbreak forests also provide substantial benefits to wildlife and may be managed for timber production.
- As many facilities are too small to accommodate the setback required for living snow fences, cornrow fences, snowbreak forests or even structural snow fences; it may be necessary to enter into land use agreements with private landowners.

- See also the Vegetation Management Synthesis of Best Practices.

Urban Considerations

- In an existing urban environment, little can be practically done to reduce snow accumulation, as roadway rights-of-way are constrained and adjacent lands typically built-up; accumulated snow is removed as per the municipalities' snow removal program.
- Many traffic-calming measures, such as speed bumps, curb bulbs or chokers, raised crosswalks and platform intersections can create difficulties for snow removal equipment and can affect drainage and maintenance efficiency, and as such, their use should be carefully considered.
- Channelization in the form of raised medians and islands can also create difficulties for snow removal equipment.
- Many roadside fixtures (mailboxes, bus shelters, parking meters, light standards, etc.) can hinder snow removal.
- Snow storage in an urban environment is often a challenge and consideration should be given to providing larger cul-de-sacs, bicycle paths and wider curb lanes (especially across bridges) for temporary snow storage. Developments should also factor snow storage and melt water drainage into their designs.
- Care should be taken to avoid snow storage in locations viewed as "pedestrian areas" (i.e. kill strips) to avoid potential liability in slip-and-fall claims.
- Meltwater should always be directed away from paved area where it could freeze, creating slip-and-fall risk.
- Consideration should be given to plow path in road design (corner radii, cul-de-sac radii, turning roadways, etc.).
- The type of sidewalk (e.g. curb line) and width of the boulevard may define whether a grader and/or a speed plow are used.

Rural Considerations

- Raised medians and islands can create difficulties for snow removal equipment.
- In a rural environment, the roadway right-of-way tends to be less constrained and cluttered than in an urban environment, providing more temporary and permanent snow storage locations.

Drainage

- Good facility drainage will lead to reduced ice accumulation, and as such, reduced salt usage (this includes intersecting roadways and accesses as well as the main roadway, parking lots and sidewalks).
- Set maximum and minimum grade to help maintain an even distribution of salt, and to allow melted ice/snow to drain to catch basin.
- Optimize salt usage by using lower superelevation rates (to help maintain even distribution of salt).
- Use crowned roadways, and good crossfalls (2%-3%).
- Mark all culvert ends to make them easier to locate for cleaning and thawing activities.
- Design parking lots with catch basins located near the perimeter so melt water from snow storage areas does not have to flow a long way across paved surfaces where it could freeze and require excessive salting.
- Ensure that building drainage does not cause icing of travel ways and walkways.
- Drainage is discussed in further detail in the Drainage and Stormwater Management Synthesis of Best Practices.

Sub-base Considerations

- Underground springs can affect pavement conditions and should be taken into account.
- Frost prone areas may cause heaving of the pavement surface and can be treated with insulation. However this can affect the thermal properties of the paved surface.

Automated Spray Systems

Areas that experience a high number of frosting or black ice events each winter season have traditionally required a significant amount of labour and road salt to manage properly. Short icing events, some lasting only minutes near sunrise, require a proactive approach, as the application window is small. Missing even a few events can be hazardous.

Maintaining material on the road to deal with frosting events can be difficult and expensive on roads with higher traffic volumes. Applying the material just prior to an anticipated event is ideal. Automated liquid anti-icing spray systems have been developed to help organizations better manage their icing problems.

- High level, long span bridges over water or river valleys are especially susceptible to frequent and sudden icing conditions. The combination of humid air and the fast cooling bridge deck will produce a significant number of frosting and black ice events. The sudden change from a warmer, ice free, at grade road surface to a colder, icy, bridge deck leaves little transition time for drivers to react to the hazardous road condition.
- Elevated highway ramps, curved sections of roads with downgrades and intersection approaches at the bottom of hills are also areas where icy conditions can be difficult to manage.
- Fully automated chemical delivery systems have been developed that use sensors embedded in the roadway and mounted on towers, site mounted computer hardware and software and nozzles embedded in the roadway or the parapet wall, to automatically apply liquid anti-icing chemical to the road surface just prior to a forecasted icing event.
- Automated systems can be designed and installed as a component of a new bridge or road section or retrofitted during a bridge rehabilitation or roadway upgrade. Incorporating automated systems during the initial design and construction is considered more economical than retrofitting a system after construction.
- Automated systems help organizations meet the 4 R's of Salt Management by placing the right material, in the right amount, in the right place and at the right time.
- Where the temperature ranges allow, chloride based liquid anti-icing chemicals can be used. Systems on bridges over water tend to use non-chloride based liquid anti-icing chemicals to reduce corrosion of the bridge deck and chloride impact on the water system below.
- Because the liquid storage tanks and piping are usually unheated, chemicals with very low freezing points (e.g. magnesium chloride, potassium acetate) tend to be preferred.
- The tower sensors or RWIS component of automated systems can be used as part of a regional RWIS network.

PAVEMENT OVERLAYS

Pavement overlays have been developed to serve the same function as automated spray systems. The overlay holds deicing chemicals like a sponge and deliver them to the surface to deal with frost and icing events. The principle behind them is that a residual of chemical that has been applied to the pavement is retained within the pavement and then automatically released when snow and ice conditions develop much as the automated spray system would be activated when frost or snow/ice conditions are present.

FACTORS TO CONSIDER IN REDUCING HARMFUL EFFECTS OF SALT ON STRUCTURES

The use of salt is an integral component of most winter maintenance programs and is necessary to maintain proper operating standards. While the purpose of this Synthesis of Best Practices is to present ways of ultimately reducing salt usage, it is accepted that salt will be applied at appropriate levels to bridges, parking garages, walkways etc. to maintain operating standards. The adverse effects of road salt on infrastructure, however, are well documented. In recent years, many practices and materials have been adopted by various jurisdictions with the objective of reducing the adverse effects of de-icing salts. This section summarizes what can be done to minimize the impacts of road salts.

In those areas where salt will be applied to maintain operating standards, it is prudent for the designer to stipulate construction methods and materials that will provide durable structures.

The designer should consider the most appropriate structural form or type, the appropriate choice of materials, advantageous construction techniques and the effective control of drainage, all in an effort to minimize the potential for accelerated deterioration caused by road salts.

Factors to be considered in the design of durable structures can be divided into three major groups; Structural Considerations; Material Considerations and Drainage Considerations.

Structural Considerations

Structural considerations refer to the structural systems that are chosen to minimize impacts of road salt such as:

- The presence of expansion joints is regarded as a principal cause of premature deterioration of structural elements. Salt brine eventually breaks through joints, resulting in compound deterioration. The use of expansion joints can be minimized through the use of longer expansion lengths and in the case of bridges, the use of integral and semi-integral abutment bridges. Additionally, for bridge rehabilitation projects, bridge expansion joints often can be eliminated by the use of flexible concrete hinges to make a concrete deck continuous over a series of simple spans.
- During the fabrication process, the flanges of steel plate girders can "curl" towards the web, creating an area where moisture can collect. In roads over road crossings, salt spray can accumulate in these areas. The use of steel I-girder sections on road over road crossings should therefore be minimized, in favour of concrete or steel box girders.

Material Considerations

Material considerations refer to standard construction materials and methods that are used to prevent the premature corrosion of steel components by providing a barrier to salt brine infiltration, or by use of materials that do not corrode. These considerations may include:

- The assurance of a durable concrete by adherence to standard codes of practice for concrete design (e.g. use of air-entrained concrete), taking into consideration exposure conditions.
- The use of High Performance concrete.
- The use of corrosion inhibitors in the concrete mix design.
- The use of durable, barrier type waterproofing systems.
- The use of stainless steel reinforcing.
- Adherence to standards and codes of practice with respect to detailing, concrete cover and other practices designed to enhance structure life.
- The use of non-metallic materials for non-structural components such as drain pipes and reinforcing steel supports.
- The use of coating systems (galvanizing, epoxy coating, metallizing) for embedded or exposed accessories such as handrail, utility poles, deck drains, expansion joints, door frames, etc.
- The use of Advanced Composite materials. These materials are generally non-metallic and hence not subject to corrosion.
- The use of concrete surface sealants to prevent or decrease the rate of salt brine penetration.

The above can be considered individually or jointly as part of an overall system to enhance durability.

In addition to the appropriate choice of materials, details must be used to minimize as much as possible the exposure of structural components to salt brine. For example, weathering steel is used extensively throughout North America for bridge girders. These steels form an oxide layer that reduces the rate of corrosion, eliminating the need to paint the girders, reducing maintenance costs. If, however, the steel is allowed to continuously come in contact with salt solution, the rate of corrosion accelerates, thereby eliminating the benefit of weathering steel. Also, the use of asphalt without waterproofing should be discouraged. Asphalt can trap the salt solution, and does not permit the natural "flushing" of the deck. Bridge decks with an asphalt riding surface without waterproofing will exhibit an accelerated rate of deterioration.

Drainage Considerations

It has been demonstrated that moisture, in combination with road salts, is a key element in the onset of corrosion. Providing adequate drainage is essential to a durable structure. Factors to consider include:

- Adequate longitudinal gradient to provide surface run-off. Inadequate gradients can result in ponding leading to accelerated deterioration and a icing hazard.

- Elimination of deck joints and deck drains. These elements are invariably the first to fail in a bridge deck. When failure occurs, other bridge components are exposed to salt brine; resulting in premature deterioration.
- Use of details to keep moisture away from vulnerable components (i.e. raised bearing pedestals, drip grooves, asphalt tunes, etc.). It must be assumed that during the life of the structure, most components will come in contact with salt brine, either from direct application to the structure, or from salt spray from below the structure. The use of details that will minimize the exposure of structural components to salt, or prevent spread of salt brine, will extend the structure's life. Additionally, a maintenance program that includes the flushing of areas prone to debris and salt brine accumulation (bearing seats, bearings, expansion joints, deck drains) is beneficial in extending the service life of a structure. Such flushing operations should include a pre-flush sweeping program and measures to contain and dispose of impacted water.
- Adequate drainage of bearing seats. Bearing seats should be sloped to facilitate drainage and prevent ponding of salt brine adjacent to bearings.

SALT VULNERABLE AREAS

Most major new road improvements will go through an environmental assessment process that generates and evaluates alternatives on the basis of their environmental impacts. When generating alternatives, transportation planners should take into account the location of salt vulnerable areas and avoid them to the extent possible. Where avoidance is not possible, route location and roadway design should endeavor to minimize the potential for salt runoff and spray to cause adverse environmental effects. This could include effective stormwater management (see the Drainage and Stormwater Management Synthesis of Best Practices), use of pavements that minimize spray (see the Pavements and Salt Management Synthesis of Best Practices) and the selection of alignments on the downwind side of salt vulnerable areas.

The planning and design of industrial, residential, commercial and institutional facilities should protect salt vulnerable areas, where possible, and everywhere incorporate salt management strategies to reduce or eliminate the potential adverse effects of salt impacted drainage on vulnerable areas.

MONITORING

Facility owners should monitor their roadways/sites and identify areas that are prone to drifting and icing problems. This will allow for a proactive approach to drift control and resolving shading problems. Maintenance-related design issues should be brought to the attention of the designers so that problems can be corrected in future designs.

RECORD KEEPING

There are no special salt-related records that need to be kept with respect to facility design although it would be advisable to document any specific actions taken to reduce salt impacts during design. This may help in obtaining approvals in sensitive areas.

TRAINING

There is a definite need to incorporate winter maintenance considerations into facility planning and design. Many high salt use areas can be avoided through proper location and design. Road and bridge designers and architects should be given training in winter maintenance so that they can anticipate potential winter maintenance problems arising from specific designs and take corrective measures during the design process. Staff involved in erecting drift control structures should be trained in proper placement and maintenance of these structures.

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