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Québec 



# Challenges related to *Winter Operations* in *Urban Road Tunnels*

Alexandre DEBS, M. Eng., MBA  
Road Tunnel Operations (TC 3.3)  
Transport Ministry of Quebec



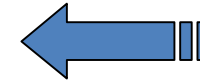
Transports  
Québec 

# Outline of the presentation

1. General Overview and Background
2. Tunnels' Sensitive Equipments and Durability
3. Winter Maintenance in Tunnels and Challenges
  - Cleaning of tunnel walls and electronic equipment
  - Snow and ice removal at tunnel portals;
  - Removal and hauling of snow at the portals;
  - Removal of icicles and ice patches;
4. Curative Maintenance Activities and Solutions
  - Joint Injection Campaigns
  - Drainage Rehabilitation
5. Conclusions and Recommendations

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# General Overview and Background

## Montreal underground road infrastructures

- More than 10 km of road tunnels ensuring urban mobility  
Canada's longest urban highway tunnel:
  - La Fontaine Tunnel crossing the St. Lawrence Seaway;
  - Ville-Marie and Viger Interchange under the downtown area;
- Built in the 1960s and the 1970s and operated by MTQ, they allow users to circulate safely and comfortably:
  - Sheltered from harsh weather conditions such as snowstorms, freezing rain, strong winds, and blowing snow;
  - Scrupulously monitored and well-lit environment, operated from 2 control centers for continuous remote surveillance of traffic lanes and of electromechanical equipment, such as ventilation, pumping, and other electronic systems.

# General Overview and Background

## *Ville-Marie and Viger underground Interchange*



# General Overview and Background

## *Louis-Hippolyte-La Fontaine Tunnel*



# General Overview and Background


## Recent Years Weather Observation

- Less but longer Intense Cold Spells with temperature under  $-20^{\circ}\text{C}$ ;
- More Winter Warm Spells with temperatures around the 0's;
- Less frequent but more severe snow falls on a longer time span;

## Consequence on Winter Operation

- New conditions complicate winter management and contribute to accelerated wear and tear on the systems;
- More frequent freeze-thaw cycles intensify the process of water infiltration resulting from deformation of expansion joints and the formation of icicles and ice patches;
- Increased hours of operations and increased use of road salt, de-icing material, with ensuing environmental impacts,

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# Tunnels' Sensitive Equipments and Durability

## Urban Long Tunnels ► An industrial installation

Tunnels are much more than asphalt and structures, they resembles more to a manufacturing plant operating in extreme climate conditions, to a roadway segment that requires snow removal.

## Systems and sub-systems found in Tunnels

- **Mechanical and hydraulic** : fans, pumps, motorized louvers and valves, compressors, elevators, hoists, winches, motors, etc.;
- **Electrical and Electronic** : breakers, switches, cables, generators, UPS, batteries, transformers, heating cables, coils, radiator, thermostats, etc.;
- **Lighting and Dynamic Signalling** : traffic and emergency lighting, variable message signs, illuminated signs, evacuation signs, etc.;
- **Monitoring and Safety** : cameras, fire protection, electronic sensors, gas samplers, temperature detectors, telephones, incident detections, etc..

# Tunnels' Sensitive Equipments and Durability

## Environmental resistance, durability and mitigations

Electronic equipments are very sensitive to the aggressive and corrosive environment found in tunnels, and require constant care and attention:

- Monitoring systems such as sampling gas analysers and cameras, are installed in pressurized climate-controlled housings to prevent contamination;

## Winter Cleaning ...

- Dome cameras gave poor results in winter because they require frequent cleaning of the dome cover. Fixed cameras capturing the back of the traffic, with washer-wiper are preferred and require less manual cleaning;
- LED technology in static and dynamic signals allowed to improve the visibility of signage as well as reducing energy costs and increasing the durability;
- LED technology is being considered for lighting traffic lanes and evacuation corridors, replacing the sodium lamps, currently in use.

# Tunnels' Sensitive Equipments and Durability



*Dome Camera*



*Camera in climate-control housing*



*Dome Camera in Dorval Tunnel*



*Camera in protective climate-controlled casing*



*Winter Cleaning of lane Signals using a water jet*

# Tunnels' Sensitive Equipments and Durability

## Subfreezing extreme temperatures and mitigations

Heating cables and grid are also used in some problematic areas (**expansion joints**) known to be susceptible to the formation of icicles;

**Heaters are installed in fire cabinets**, to prevent freezing of the fire protection equipment, such as valves, ducts, extinguishers, and extinguishing foam for hydrocarbons;

Strategic equipment, like fire protection **systems are monitored constantly by temperature sensors** that trigger alarms when necessary.



# Tunnels' Sensitive Equipments and Durability

## Freezing Hazard and mitigations

To prevent freezing, many systems are heated by electrical cables to prevent ice clogging and promote drainage:

- Water supply lines for fire-protection system,
- Gutter of the structural expansion joints,
- Drains under the pavement,
- Trenches and culverts.



## Heating cables durability ...

- Rigid copper cables encased in a plastic material gave better results in La Fontaine tunnel than the one used in Ville-Marie that are made of neoprene covered with a rubber material.

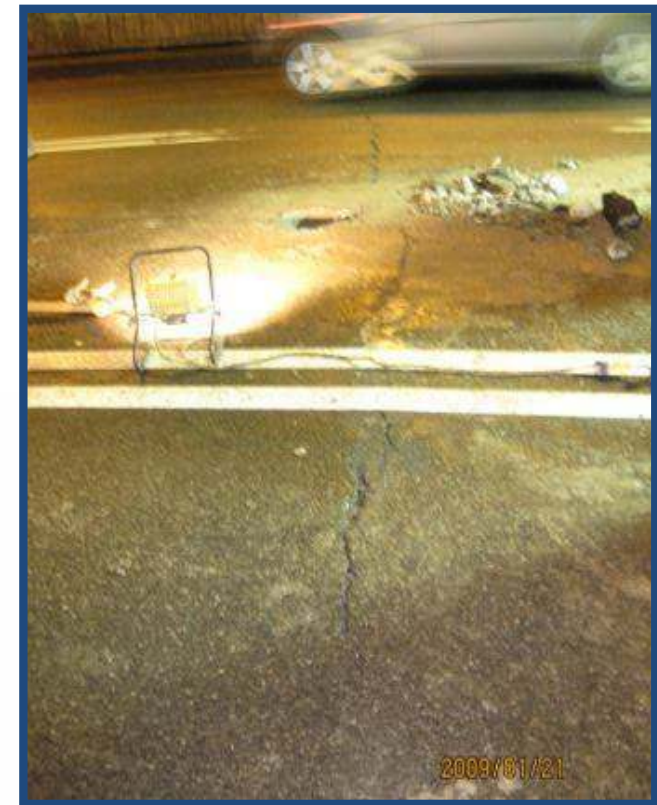
# Tunnels' Sensitive Equipments and Durability

## Damage caused by freezing In La Fontaine Tunnel


After a defective heating cable caused water to freeze in a drain under the pavement, a core boring sample showed the existence of an empty space under the drain, that occurred after freezing.

### Mitigation

Hot water was injected in the drain to melt ice and heavy static and dynamic loading was applied to eliminate the bump.



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# Winter Maintenance in Tunnels

## Tunnel Maintenance Program

The goal of the tunnel maintenance program is to ensure safe driving conditions for the public by maintaining the tunnel as the designed safety standards.

## General Maintenance versus Winter Maintenance

General (“**summer type**”) Maintenance refers to routine and periodic maintenance of a **preventive nature**, while **winter maintenance** refers to **keeping the tunnel clear and safe following weather disruptions**.





# Winter Maintenance in Tunnels

## General Maintenance (“summer type”)

General Maintenance is cyclical and repetitive and is carried throughout the year. The methods, tools, and frequencies vary as a function of weather conditions, manufacturer requirements, and standards

- Cleaning work (walls, signs, lights, drainage, cameras, doors, etc.);
- Lubricating and tightening connections (motors, louvers, vents, etc.);
- Calibrating sensors and alarm levels (detection, probes, etc.);
- Replacing parts (lamps, filter, and other hardware);
- Changing fluids (motors, pumps, fans).

## Challenges

Work is scheduled during off-peak hours and can only be carried out when traffic tube is completely or partially blocked over the entire length of the tunnel.

# Winter Maintenance in Tunnels

## Cleaning work in winter

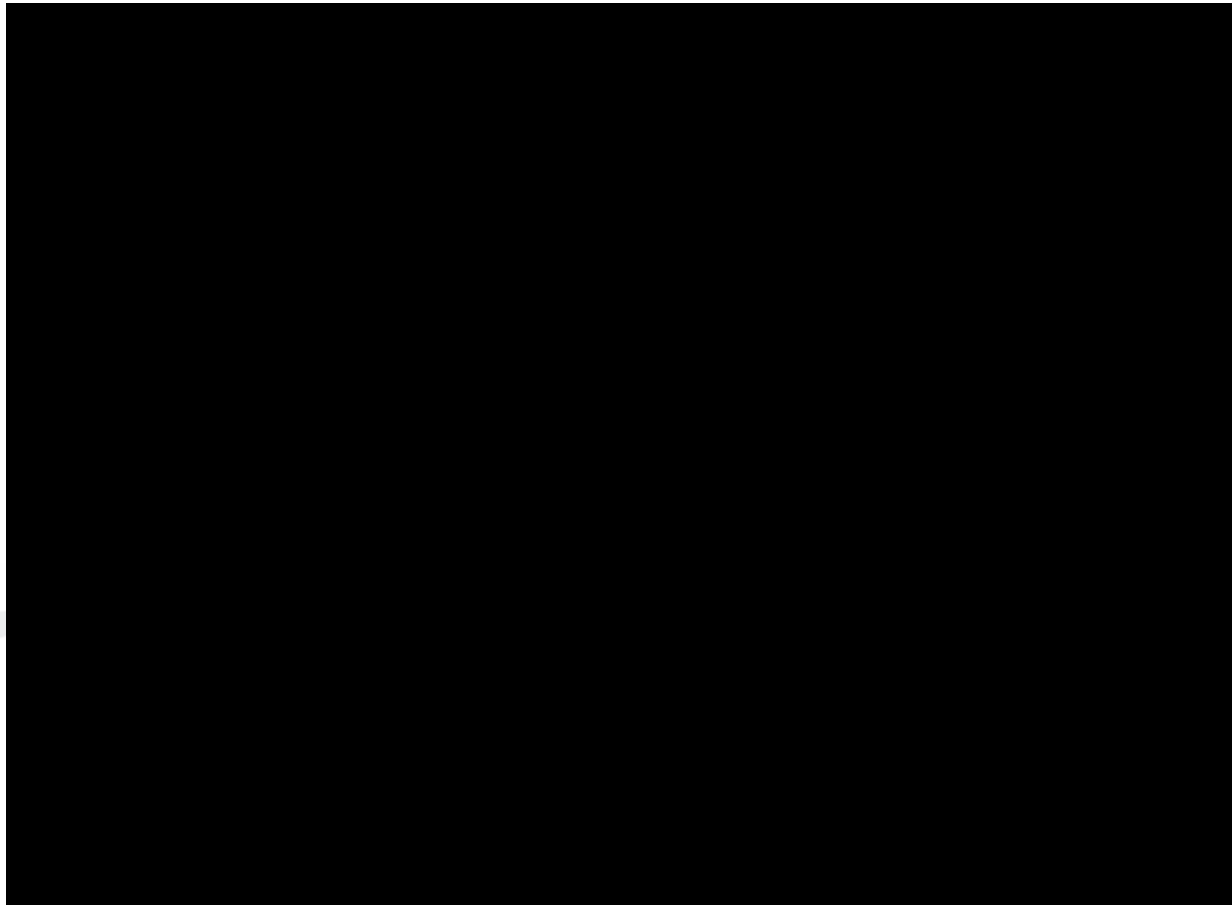
Cleaning work of signs, lights, and cameras is of prime importance for maintaining safety standard and allowing good surveillance.

Winter Logistics and methods required are quite different from those during the summer. The use of the brush-truck is not always possible and depend on temperatures. Winter-cleaning is done manually or during warm spell, using a water jet.



# Winter Maintenance in Tunnels

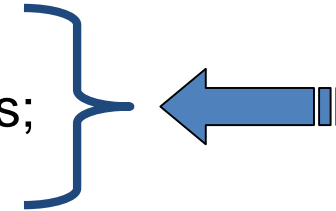
## *Wall Cleaning in Winter*



*VIDEO: Rinse-Truck with Water jet*

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# Winter Maintenance in Tunnels

The **main goal** of winter maintenance in tunnel is to **restore the safety level of the road**, in the tunnel and at its approaches **after** a specific **meteorological event** or after a major snowstorm.

The constraints imposed by the traffic are significant. However, the urgency of these interventions means that they must be carried out quickly:

- De-icing and snow removal in the tunnel;
- Removal and hauling of snow at the portals;
- Removal of icicles and ice patches



# Winter Maintenance in Tunnels

## 1. During precipitation event ...

### De-icing and snow removal in the tunnel

Initiated on the basis of monitoring weather conditions and forecast.

#### Performance criteria:

- Maximum tolerance of 5 to 7 cm of snow;
- Traffic lanes must be completely cleared within 3-5 hours after the precipitation.

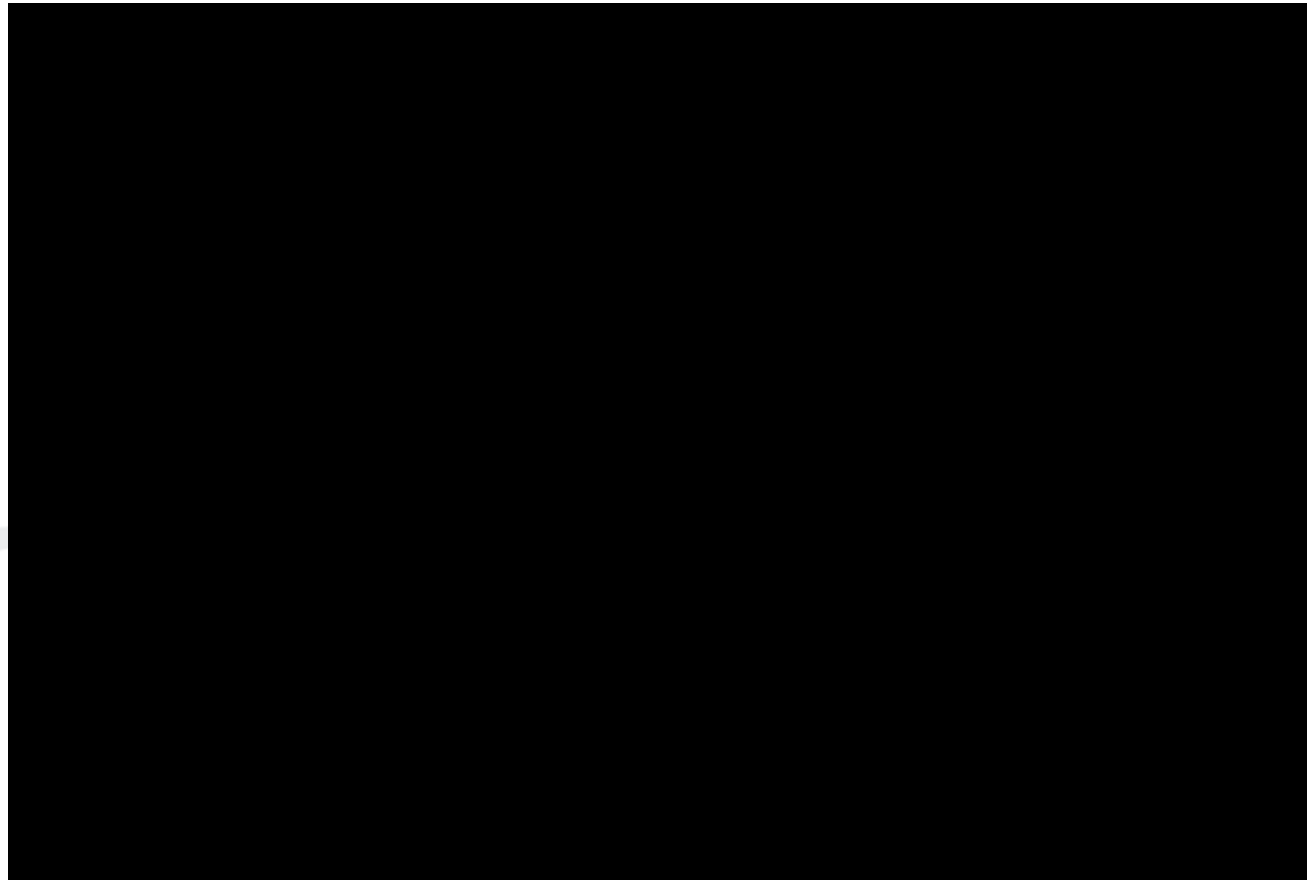
#### Critical areas:

- Tunnel portals (at entrance and exits)



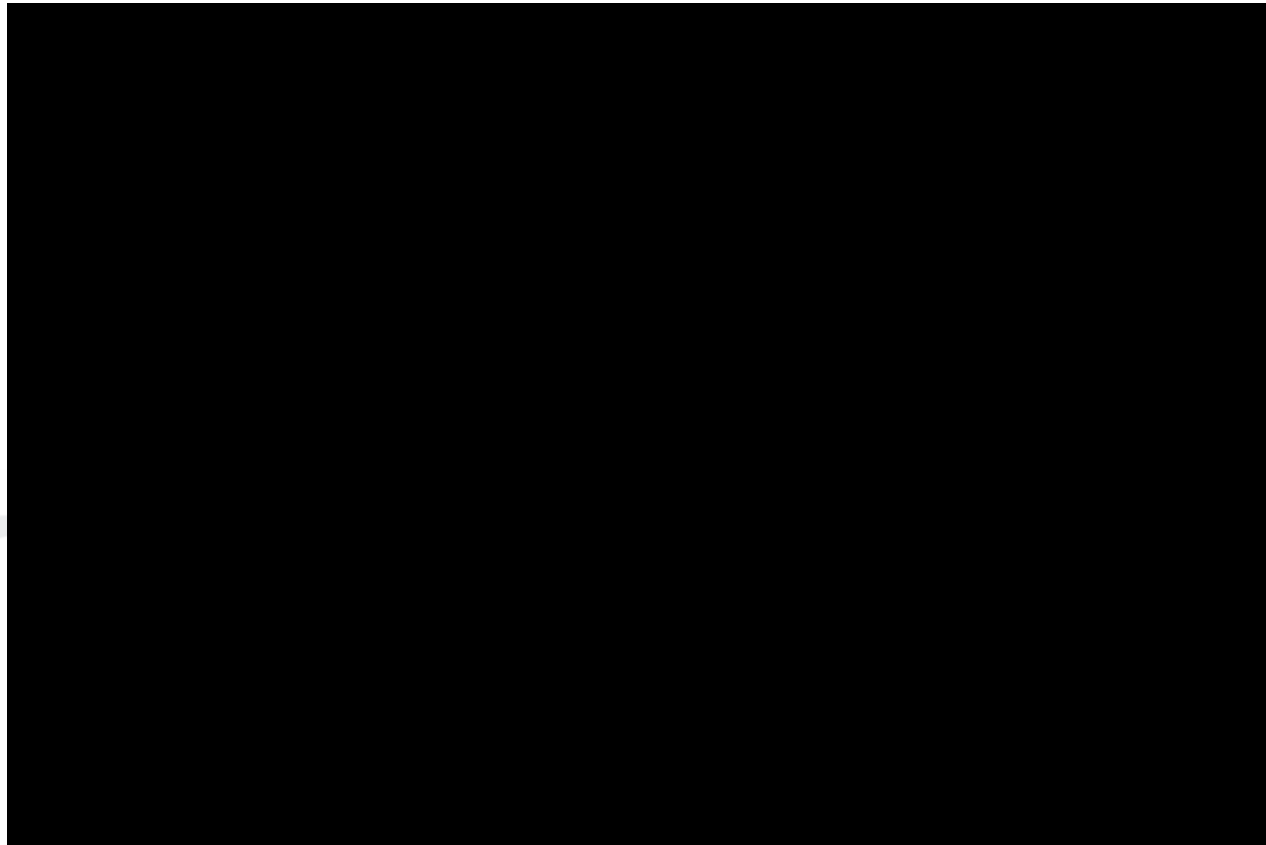
# Winter Maintenance in Tunnels

1. During precipitation event ...  
De-icing and snow removal in the tunnel (part 1)



# Winter Maintenance in Tunnels

1. During precipitation event ...  
De-icing and snow removal in the tunnel (part 2)

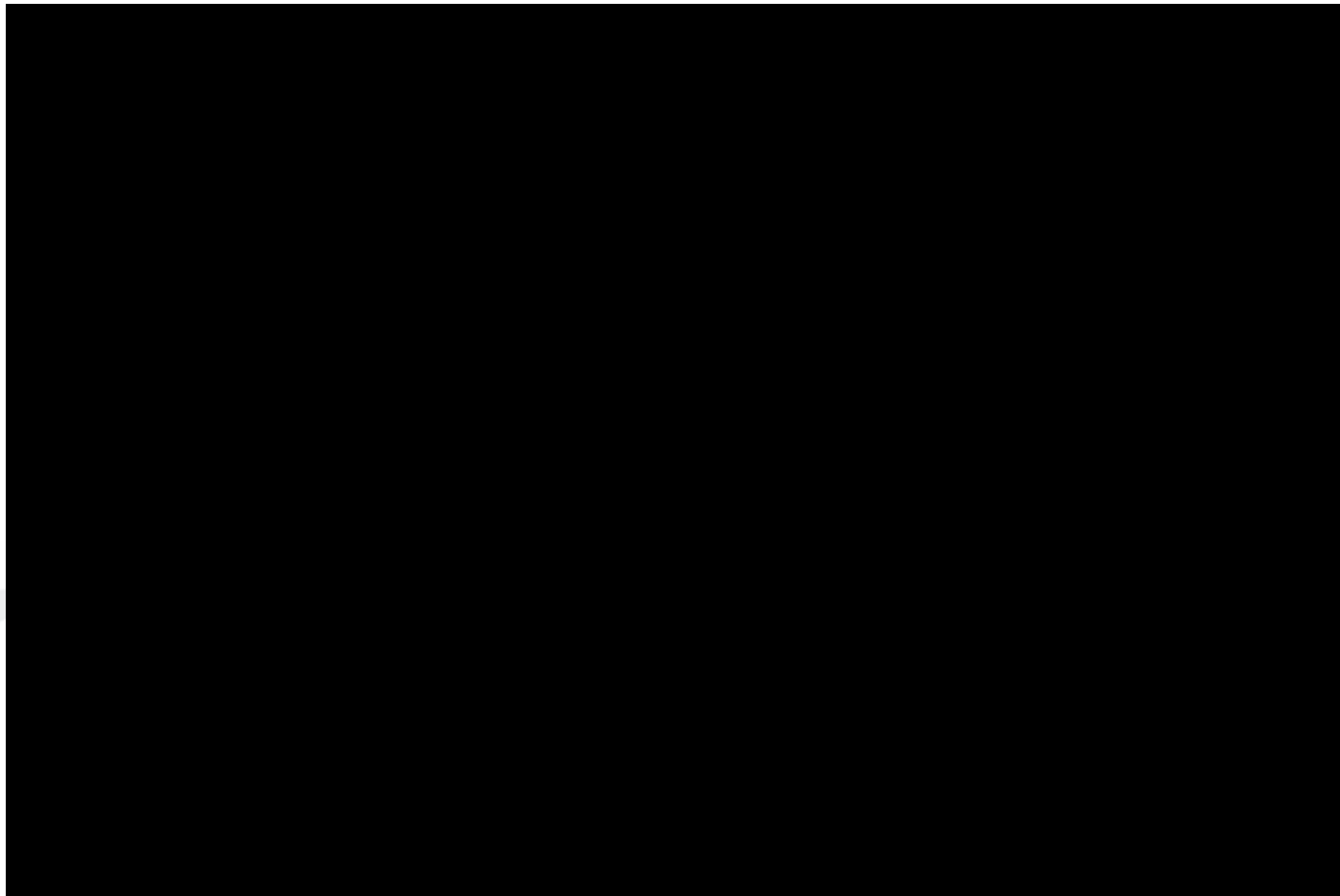






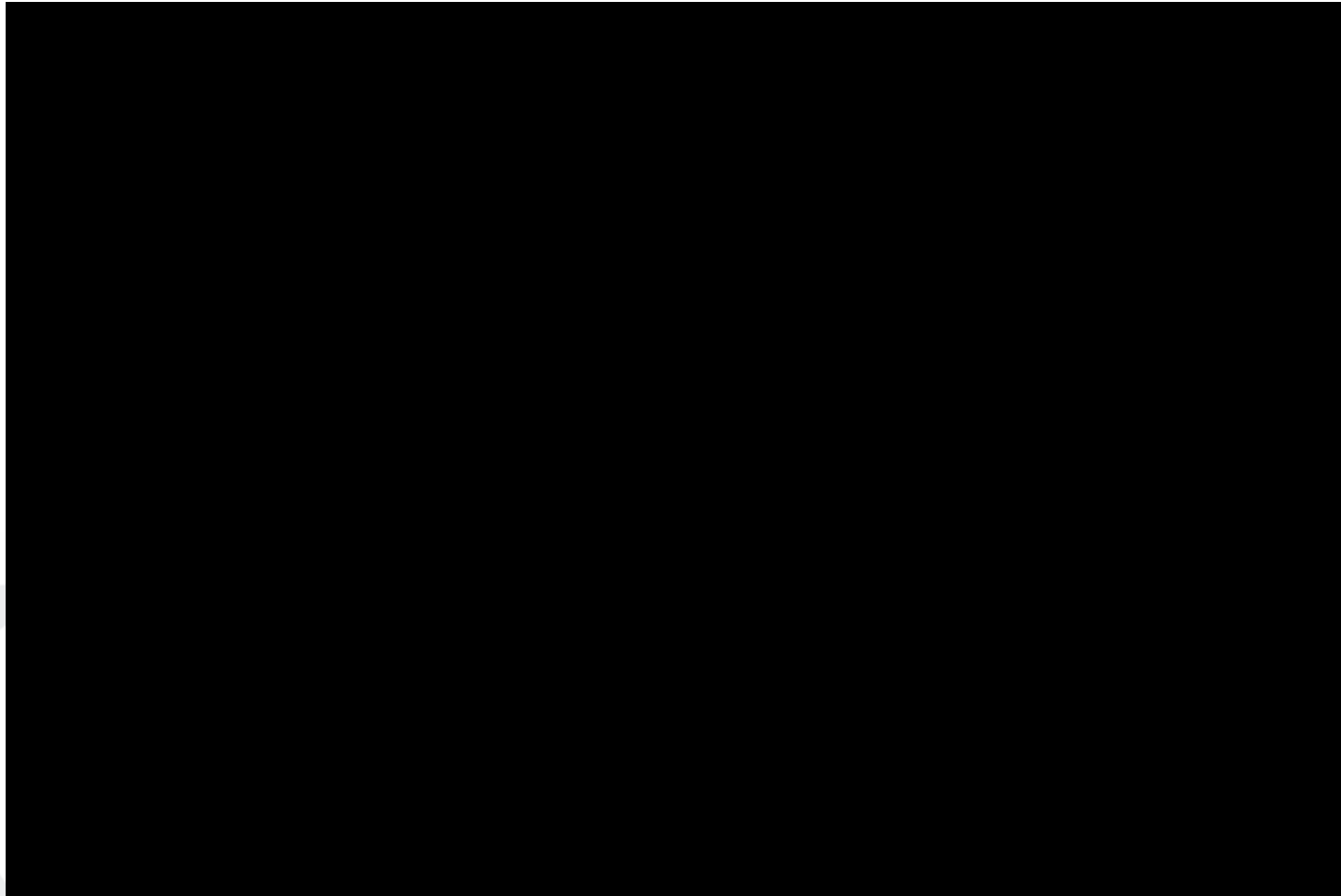
# Winter Maintenance in Tunnels

## *Car Accident at La Fontaine Tunnel Entrance*



# Winter Maintenance in Tunnels

## *Car Accident at La Fontaine Tunnel Exit*



# Winter Maintenance in Tunnels

## 2. After the precipitation event ...

### Removal and hauling of snow at the portals

Initiated after the storm and by night with the complete or partial closure of the tunnel.

Performance criteria:

- Maximum delay of 48 hours;
- No snow accumulation on the side wall

Critical areas

- Tunnel portals (at entrance and exits)



# Winter Maintenance in Tunnels

## 3. Removal of Icicles and Ice Patches

Initiated on the basis of monitoring weather conditions and forecast.

Performance criteria:

- Daily inspection at 1:00 AM and 1:00 PM;
- Team immediately mobilized to intervene before rush hour (5:00 AM or 3:30 PM)

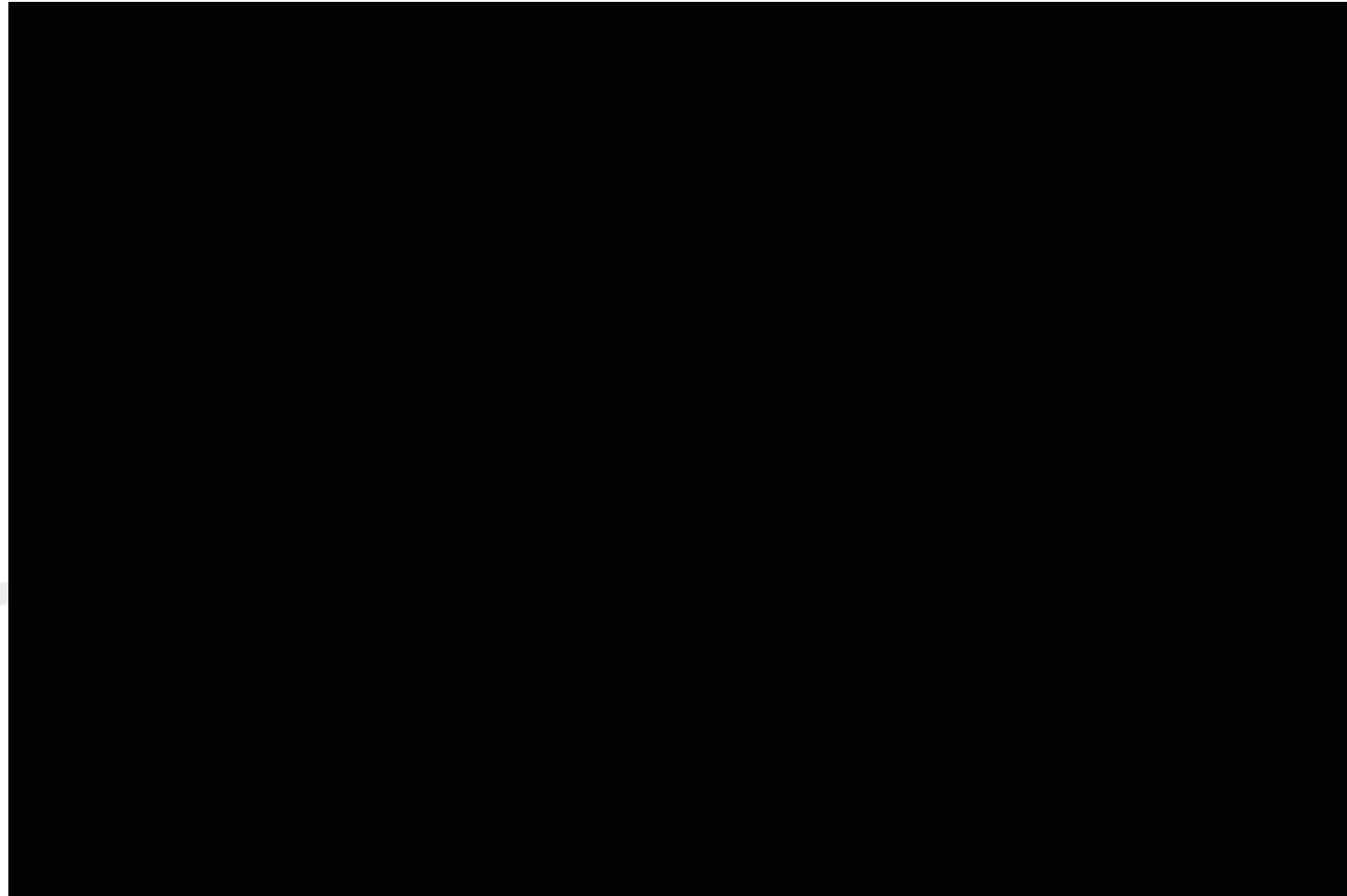
Critical areas

- Leaking construction joints
- At the ventilation shafts



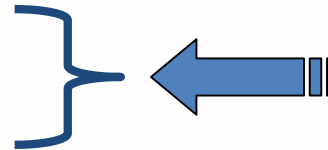
# Winter Maintenance in Tunnels

## 3. Removal of Icicles and Ice Patches



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# Curative Maintenance

Water leakage develops seasonally in the tunnels. Even small amounts of water leakage can hinder winter use of the tunnel due to the formation of icicles ice patches, obliging the operator to monitor closely and intervene quickly upon detection of ice.

These phenomena are caused by a range of factors:

- Leaking of construction joints and cast joints;
- Blocked drainage pipes and obstruction from ice;
- Formation of microcracks in the slabs and walls;
- Concrete contraction with low temperatures (freeze-thaw cycle);
- Presence of a significant water table.

# Curative Maintenance

## 1. Joint Injection Campaigns

### *La Fontaine Tunnel ...*



### Problem:

At the time of construction, joints were concreted in the springtime, rather than in winter, altering the tunnel's stress environment, and producing tension in the joints during cold spells.

### Mitigation:

Chemical substance that swells on contact with water was injected during the winter, while the joint was under maximum tension.

### Results:

Encouraging results have been observed, over the past years. The remainder of the water is drained off into culverts that are heated by electric cables.



## 2. Drainage Rehabilitation Campaigns

### *Ville-Marie Tunnel ...*



### Problem:

Imperfection in the concrete or in the sealants application resulted in sweating because the tunnel is under a very important water table pressure since it is situated down-hill the Mont-Royal Hill.

### Mitigation:

A number of injection campaigns were carried with polyurethane and cement grouting but gave temporary results.

### Results:

Rather than trying to stop the leakage, we chose to redirect the water to our heated drainage systems, conditional to full rehabilitation.

# Curative Maintenance

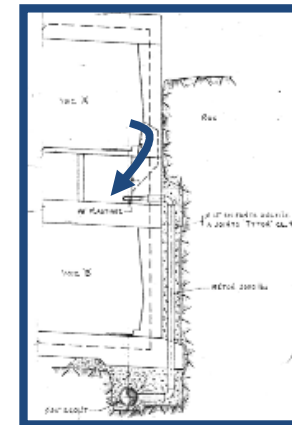
## 2. Drainage Rehabilitation Campaigns

*Ville-Marie Tunnel ...*



### Drainage Obstruction

- Stagnant water mixed with sediments creates a sludge that hardens and block the pipes (64% calcium carbonate and 19% silica);
- Deposits are generated by a chemical reaction that releases minerals from the water when exposed to heat from the heating cables;
- Presents of silica explains the hardness of the deposits, and explains why it is becoming difficult to clean using conventional methods;



*Leakage from the top tube  
to the lower tube*

# Curative Maintenance

## 2. Drainage Rehabilitation Campaigns

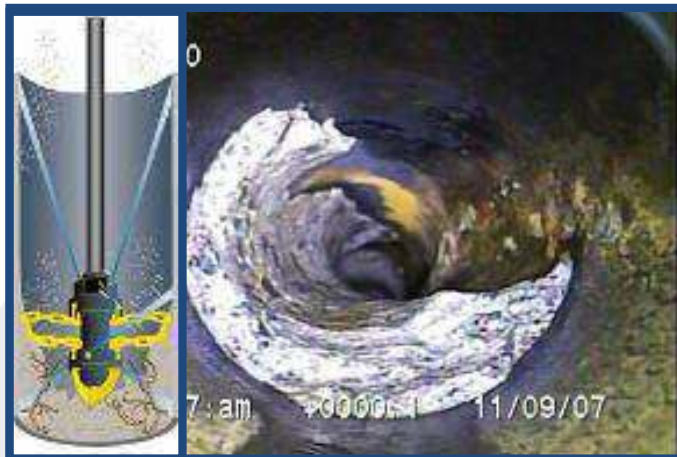
*Ville-Marie Tunnel ...*

### Mitigation Measures :

- Pumping of sedimentation deposits;
- Regular cleaning using scourers;
- Reaming and pipe replacement;



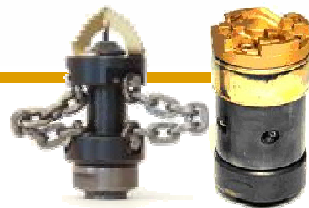
*Mud Pumping in  
Ventilation plenums*



*Reaming Nozzles with chain  
head and cutting head*



*Mud Pumping in structural elements*



## 2. Drainage Rehabilitation Campaigns


### *Ville-Marie Tunnel ...*

#### Results:

- Very encouraging results have been seen over 2008 and 2009;
- Excess water is now drained by culverts heated with electrical wiring;
- Although icicles formation persist, they were reduced significantly.



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# Conclusions

- Winter Maintenance in Tunnels entails many **challenges**
  - Electronic systems are sensitive to the aggressive winter conditions;
  - Heavy duty systems and regular cleaning and maintenance required;
  - Monitoring systems involving low-temperature alarms are crucial;
  - Maintenance requires interruption of the traffic with resulting impact;
  - Winter cleaning is dependent of the temperatures and the weather;
  - Use of abrasives blocks the drainage systems and impacts visibility;
  - Removal and hauling of snow at the portals is a critical activity;
  - Daily removal of icicles and ice patches disrupt free flowing traffic.
  
- Curative Maintenance gave encouraging results (**drainage**)
  - Joint Injection Campaigns in La Fontaine tunnel
  - Drainage Rehabilitation in Ville-Marie tunnel

For urban frequently congested road tunnels ...

- Change our **design** philosophy of underground structures
  - Design should entail control and drainage of water outside the tunnel;
  - Use of a heavier-duty waterproof membrane should be explored;
  - Sealing materials must be tested under very low temperatures;
  - Construction joints must be made more watertight;
  - Design enough space, at the portal for snow accumulation.
  
- Change our **maintenance** habits and procedures
  - Explore other de-icing materials, other than sand and salt;
  - Regular cleaning of pipes, drains and frequent sediment pumping.



*Winter Operations of Road Tunnels in Québec  
The Ville-Marie and Louis-Hippolyte La Fontaine Tunnels*

Alexandre DEBS, Eng., M.Sc., MBA  
Ministère des transports du Québec

Contact: [alexandre.debs@mtq.gouv.qc.ca](mailto:alexandre.debs@mtq.gouv.qc.ca)