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Mendoza - Argentina

# *A Feasibility Study on Sodium Propionate Use as an Alternative Antifreezing Material*

*Estudio de factibilidad sobre el uso de propionato de sodio como material anticongelante alternativo*

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# Japan Geographical Characteristics



- Climate: predominantly temperate but varies greatly from north to south
- Northern Japan has warm summers but long cold winters with heavy snow considering its latitude



# Hokkaido - Geographical Characteristics

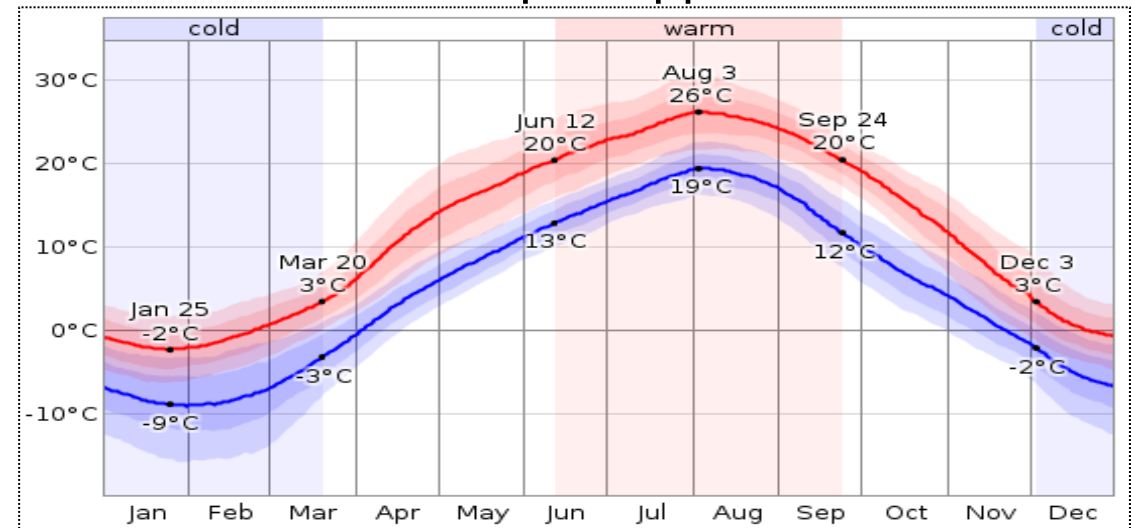
## Hokkaido:

- Northernmost island of Japan
- Area: 83,456Km<sup>2</sup>
- Population: 5.4 millions



## Sapporo:

- Population: approx. 1.9 million
- Latitude: 43° N
- Snowfall amounts: approx. 6 m
- Maximum snow depth: approx. 1 m



Temperature Average of Sapporo

Note: The daily average low (blue) and high (red) temperature with percentile bands (inner band from 25th to 75th percentile, outer band from 10th to 90th percentile).



# Winter Road Conditions in Hokkaido



# Snow and Ice Control in Japan

- In order to prevent the occurrence of icy roads, road administrators work to manage winter road conditions by removing snow, applying chemical agents and so on



Removing snow



Applying chemical agent

- Chemical agent has effect of melting snow and prevention of formation of ice on a road



# Introduction

- Application of chemical agents and other measures for preventing wet roads from becoming icy are important to "ensure safe winter roadway"
- Sodium chloride (NaCl) is the major material used




- Why NaCl is used?
  - Inexpensive
  - Easily available in large quantities
  - Highly effective in melting ice
  - Easy to deliver, store, and load onto vehicles



NaCl

# Background and Aim of Study

- Although NaCl is the major deicing material,...
  - ...there is a concern over negative impacts on the roadside environment caused by the application of chloride
    - Automobiles
    - Bridges and other roadside structures
    - Soil, vegetation, etc.
  - Development of a new chloride-free deicing agent that does not significantly damage the roadside environment

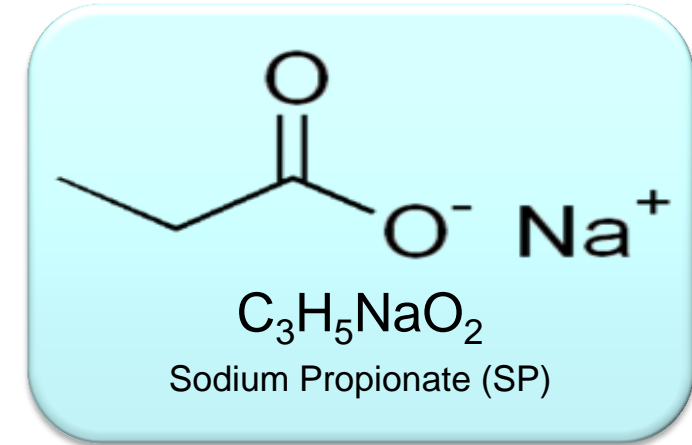


Survey of various compounds in search for the best available deicer

- Tests focusing on **Sodium Propionate** (SP)
  - Test for harmful substances
  - Laboratory metal corrosion test
  - Spreading at a test track

# What is Sodium Propionate?

- Sodium Propionate (SP) is the sodium salt of propionic acid
- Commonly used as a food preservative
  - Cheese, bread, cake, feed, adhesives, etc.
- Price in Japan: US\$10-15 per kg
  - US\$2 per kg for purchase of 10 tons at a time
- Freezing point:



Specimen (a 20% by mass solution)	Freezing Point
NaCl	-19.1 °C
SP	-16.4 °C
NaCl + SP (Weight Ratio 8 : 2)	-18.9 °C

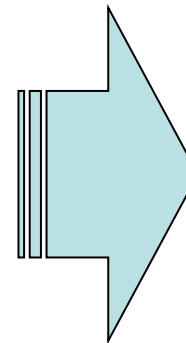


# State of Sodium Propionate (SP)

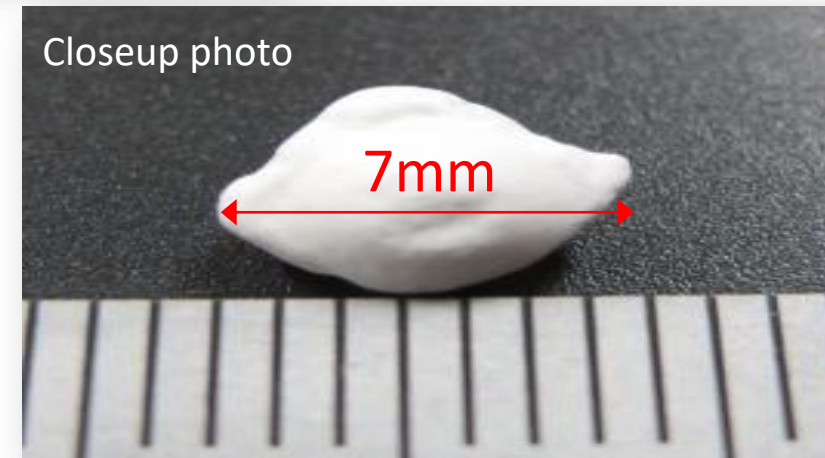
Pulverized



Granulated



Closeup photo



# Test on Harmful Substances

- In order to verify the safety of SP, a test for harmful substances was conducted on the basis of the quality requirements for NaCl used as an anti-icing/deicing agent
- Ministerial Ordinance Specifying Effluent Standards
  - Checking if SP complies with the quality requirements in terms of the acceptable levels of 16 harmful substances
  - A saturated SP solution (i.e., a 50% - by-mass solution of SP) was prepared and analyzed

Harmful Substances	
✓	Cadmium
✓	Total cyanide
✓	Organic phosphorus
✓	Lead
✓	Hexavalent chromium
✓	Arsenic
✓	Total mercury
✓	Alkyl mercury
✓	PCB
✓	Thiuram
✓	Simazine
✓	Thiobencarb
✓	Selenium
✓	Boron
✓	Fluorine
✓	Ammonia, ammonium compound, nitrous acid compound, and nitric acid compound

# Test on Harmful Substances (Results)

Harmful substances	Unit	Reference value	Limit of quantification	Test results	Compliant/Non-compliant
Cadmium	mg/L	0.01	0.001	< 0.001	Compliant
Total cyanide	mg/L	Undetectable *	0.1	< 0.1	Compliant
Organic phosphorus	mg/L	Undetectable *	0.1	< 0.02	Compliant
Lead	mg/L	0.1	0.005	< 0.005	Compliant
Hexavalent chromium	mg/L	0.05	0.005	< 0.05	Compliant
Arsenic	mg/L	0.05	0.005	< 0.002	Compliant
Total mercury	mg/L	0.0005	0.0005	< 0.0005	Compliant
Alkyl mercury	mg/L	Undetectable *	0.0005	< 0.0005	Compliant
Polychlorinated biphenyl	mg/L	0.003	0.0005	< 0.0005	Compliant
Thiuram	mg/L	0.06	0.0006	< 0.001	Compliant
Simazine	mg/L	0.03	0.0003	< 0.001	Compliant
Thiobencarb	mg/L	0.2	0.002	< 0.002	Compliant
Selenium	mg/L	0.1	0.002	< 0.002	Compliant
Boron	mg/L	10 (for other than marine waters) 230 (for marine waters)	0.02	0.22	Compliant
Fluorine	mg/L	8 (for other than marine waters) 15 (for marine waters)	0.1	0.5	Compliant
Ammonia, Ammonium compound, Nitrous acid compound, Nitric acid compound	mg/L	100	0.22	0.18	Compliant

Note: The values shown after "<" are at the limits of quantification.

✓ "Undetectable" means that the concentration of an analyte in a solution measured by using a method specified by the Minister of Environment is lower than the limit of quantification for that method.

All quality requirements are satisfied



# Metal Corrosion Test


- Metal corrosion test by using various deicers
  1. A 3.0 g of test material is dissolved in 100 cc of distilled water for preparing a test solution;
  2. An iron specimen without zinc coating, which was weighed beforehand, was immersed in a solution of each test material for 24 hours and then left to dry for 24 hours;
  3. The immersion-and-dry cycle was repeatedly conducted for 7 days; and
  4. On the 8th day, the rust was completely removed from the specimen, and the remaining iron piece was weighed to see the difference in weight before versus after rusting



# Metal Corrosion Test (Results)

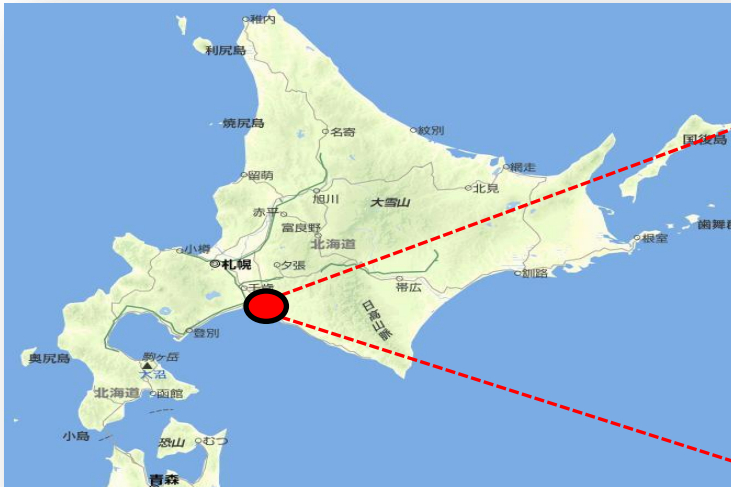
Materials	Amount of corrosion (mg/dm <sup>2</sup> /day)
Distilled water	8.6 mdd
NaCl	22.5 mdd
Calcium chloride (CaCl <sub>2</sub> )	27.5 mdd
SP	0.3 mdd
NaCl + SP (weight ratio 8:2)	4.4 mdd
NaCl + SP (weight ratio 9:1)	12.5 mdd
NaCl + SP (weight ratio 19:1)	14.6 mdd

- In comparison to distilled water and the solution of NaCl or of CaCl<sub>2</sub>, the amount of corrosion was significantly smaller for the SP solution and the NaCl-SP mixture with a weight ratio of 8:2

- 
- Metal corrosion damage to vehicles and roadside structures is reduced

# Spreading at a Test Track (method)

- Test date:
  - January of 2015
- Test location:
  - Tomakomai Winter Test Track (Length = 2,700 m)



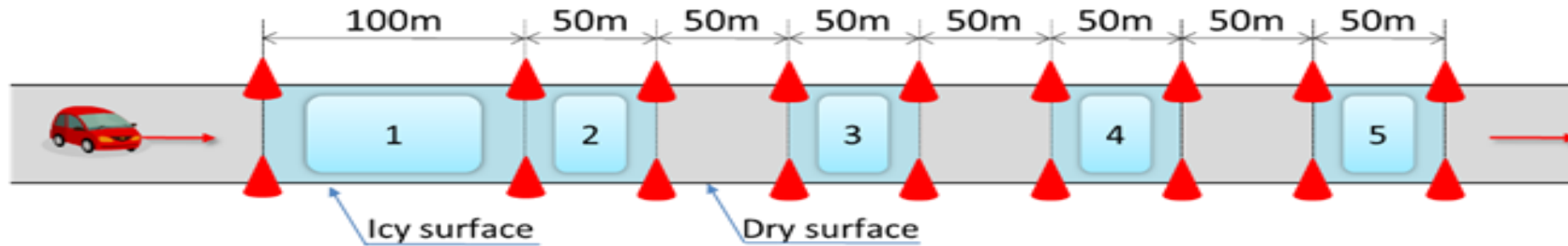
CERI's Tomakomai Winter Test Track



# Spreading at a Test Track (variables)

Date: Jan 2015, Weather: Clear, Air Temp.: -6.0 to -3.8, Road Temp.: -3.3 to -2.0

(a) Test track layout

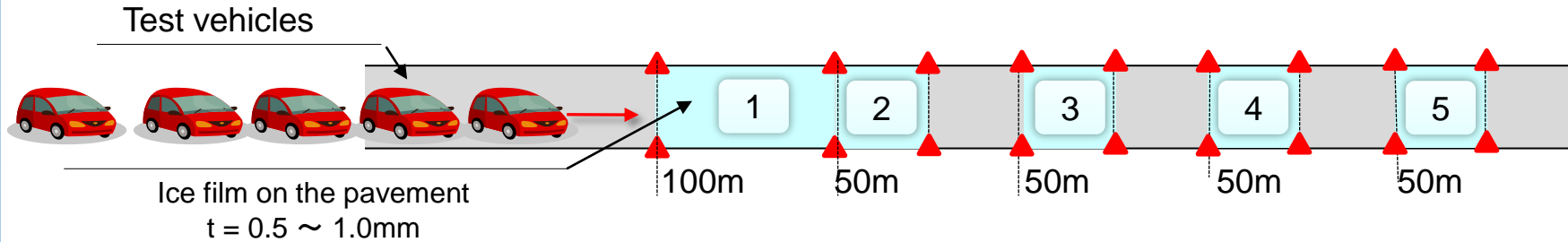


(b) Application method and application rate for each test section

Section No.	Type of spreading operation	Application rate
1	-	No treatment (control section)
2	Dry	NaCl (solid) 20g/m <sup>2</sup>
3	Dry	NaCl (solid) 16g/m <sup>2</sup> + SP (molded granule) 4g/m <sup>2</sup>
4	Pre-wetted	NaCl (solid) 18g/m <sup>2</sup> + 30wt% SP solution 2g/m <sup>2</sup>
5	Pre-wetted	NaCl (solid) 18g/m <sup>2</sup> + 30wt% CaCl <sub>2</sub> solution 2g/m <sup>2</sup>

Test track layout and the application method

# Spreading at a Test Track (procedures)



1. NT
2. NC ( $20 \text{ g/m}^2$ )
3. NC + SP ( $20 \text{ g/m}^2$ )
4. NC + SPS ( $20 \text{ g/m}^2$ )
5. NC + CCS ( $20 \text{ g/m}^2$ )

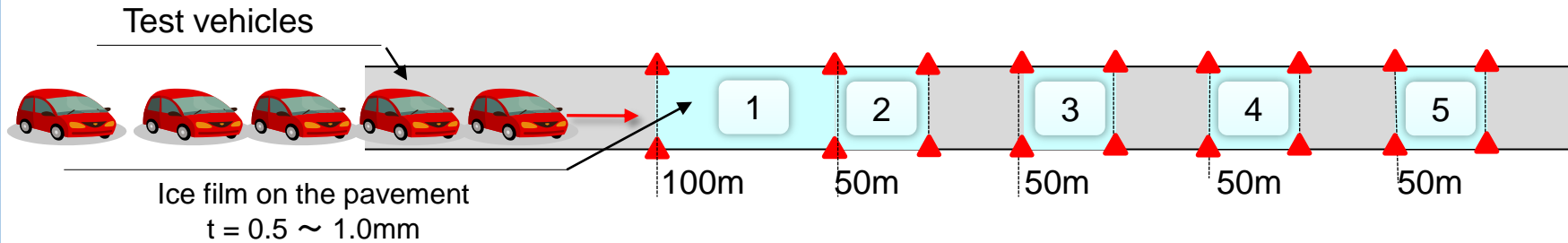


**Sprinkling water for making ice film on the surface**



**Spreading**

# Spreading at a Test Track (procedures)



1. NT
2. NC ( $20 \text{ g/m}^2$ )
3. NC + SP ( $20 \text{ g/m}^2$ )
4. NC + SPS ( $20 \text{ g/m}^2$ )
5. NC + CCS ( $20 \text{ g/m}^2$ )



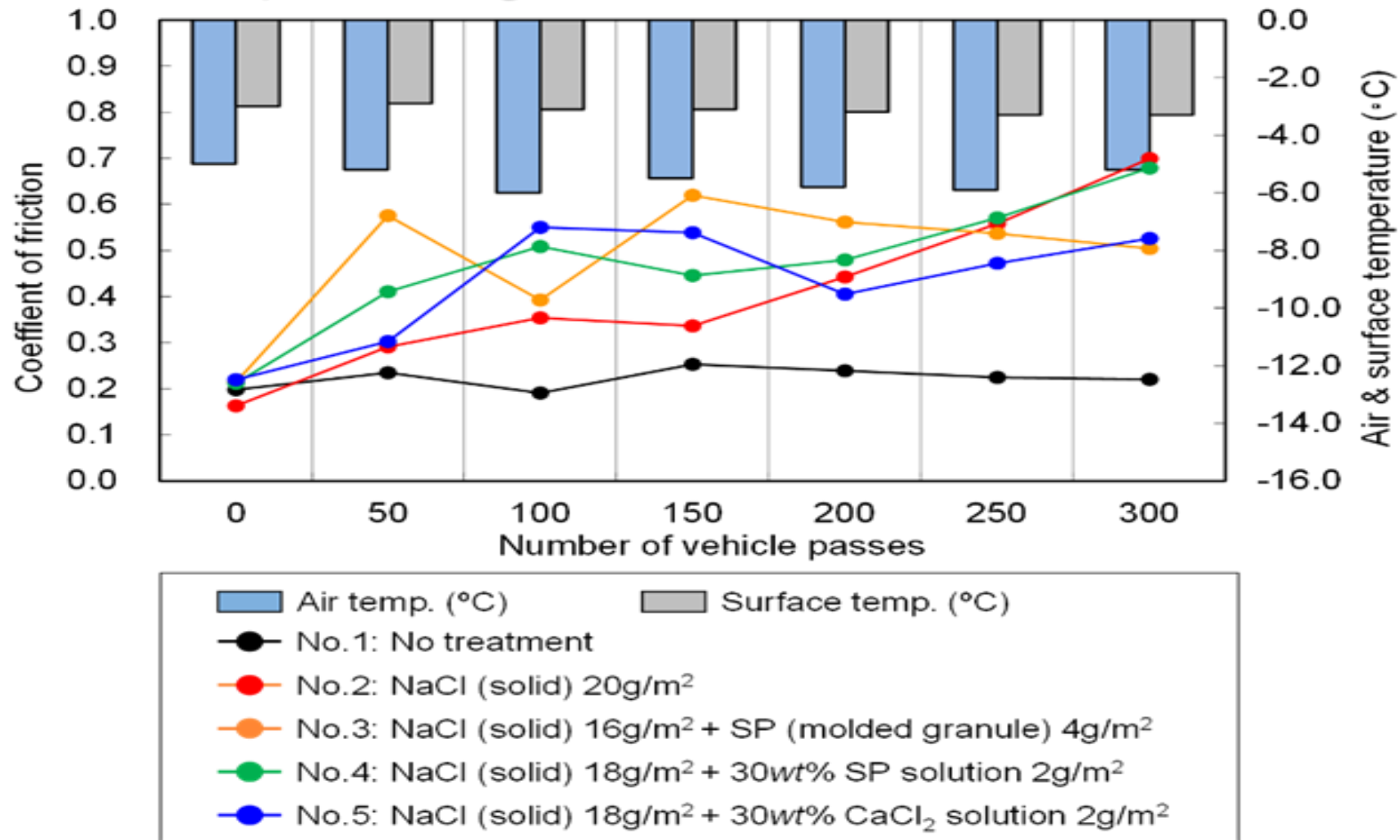
Friction measurement



Vehicles running on the test sections



# Spreading at a Test Track (results)



Changes in  $\mu$  as a function of the number of vehicle passes

# Summary & Future Studies

## ➤ Results of the test for harmful substances

- SP satisfies the quality requirements regarding all 16 harmful substances specified in the effluent standards

## ➤ Results of the metal corrosion test

- SP helps reduce the amount of metal corrosion even when it is mixed with sodium chloride

## ➤ Results of the application test

- Dry application of an NaCl-SP mixture as well as wet application of NaCl mixed with an SP solution is as effective as dry application of NaCl and wet application of NaCl mixed with a  $\text{CaCl}_2$  solution in increasing the skid resistance



## Summary & Future Studies (cont.)

- Although SP is more expensive than sodium chloride, costs can be controlled by using a mixture of SP and sodium chloride
- We are continuing the research in the following topics:
  - Effects on concrete structures
  - Impacts on soil, vegetation, and other aspects of the roadside environment
  - Performance tests on real road
  - Feasibility study on other materials as anti-icing/deicing agent



*Thank you for your attention!*  
*¡Gracias por su atención!*

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# Continuous Friction Tester (CFT)

- This device measures friction values on roadway continuously in real time
- In the northern countries, some road authorities are already using this device to measure friction value on winter roadways
- This device calculates friction value by measuring the axial force created by installing a test tire 1-2 degrees off axis from the direction of travel
- This device does not require braking of the test tire, thereby making it possible to continuously measure surface friction



Continuous Friction Tester

