Effect of Plowing and Sanding on Friction & Stopping Distance during Braking

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Introduction

- Significance of winter road maintenance in cold regions has been the motive for research on the effectiveness of these operations in creating safe driving conditions.
- Friction measurements have the potential to be used as a tool to evaluate different road conditions.
- Decelerometers are one category of friction measurement devices that are widely used due to their simple configuration and mechanism of measurement.
- Sponsored by the City of Edmonton, this study used Vericom VC4000 PC decelerometer to conduct traction tests on different road conditions on the University of Alberta's Integrated Road Research facility (IRRF) test road facility.

Equipment Description

Decelerometers calculate friction during a braking event, using stopping time and speed, through Newton's second law of motion:

$$a = \frac{V_2 - V_1}{\Delta t} = \frac{0 - V_1}{\Delta t} \qquad S = \frac{V^2}{2a}$$

- Δt = Time lapse between braking initiation and full stop (s)
- V_1 = Vehicle speed when braking is initiated (m/s)
- V_2 = Vehicle speed at full stop = 0
- a = Deceleration (m/s²)
- S = Stopping distance (m)

- Vericom VC4000 PC decelerometer mounts on vehicle windshield (Fig. 1).
- It is activated at deceleration >0.2G and is deactivated at 0G (G=9.81m/s²).
- Coefficient of friction (μ) is recorded at 100Hz at precision of 0.001.

Fig. 1. Vericom VC4000 PC.

Experiment Design

Table 1. Description of test events.

Test Date	Road Condition	Operations
14 Feb	100m of both lanes: Ice 200m of right lane: Dry with ice patches 200m of left lane: Bare dry	-
21 Feb		✓
4 Mar	Residual sand on dry surface	-
14 Mar	Light Snow (<10 cm)	-
18 Mar		-
21 Mar	Heavy Snow (>10 cm)	✓

- The experiment included friction measurements on six test days under a variety of road conditions (Table 1).
- Vericom VC4000 PC was mounted on a truck with the Anti-lock Braking System (ABS).
- A snowplow/sand spreader unit was provided to plow, and apply sand at 420kg/lane-km.

1. **Each run started at full stop (device is zeroed).**
2. **The driver accelerated to reach the target speed.**
3. **The driver applied hard braking to reach full stop.**

Speed Dependency

- Each run was conducted at three speeds of 30, 50, and 60 km/hr.
- Speed-dependency of Vericom for bare dry, ice, and snow was investigated (Fig. 2).

Linear regression ↓ Low R^2 → **No significant correlation between friction and speed ↓ Vericom data is not speed-dependent**

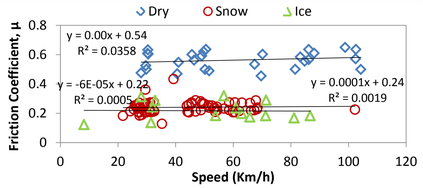

Fig. 2. Friction-speed relationship for Vericom measurements.

Acknowledgements

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Winter Road Conditions

- Friction (Fig. 4) and stopping distance (Fig. 5) were measured by Vericom on different road conditions.
- The changes in friction coefficient were very well captured in the total range of 0 to 0.7.
- **The comparison between friction coefficient and stopping distance data shows that ABS is effective in reducing the stopping distance on dry and icy roads, but it is not beneficial for snow.**

Fig. 3. Pictures of all tested road conditions.

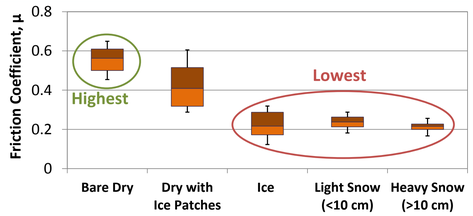

Fig. 4. Friction coefficient for different road conditions.

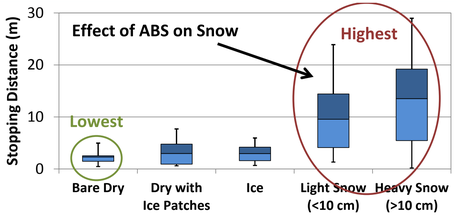

Fig. 5. Stopping distance for different road conditions.

Winter Road Maintenance Operations

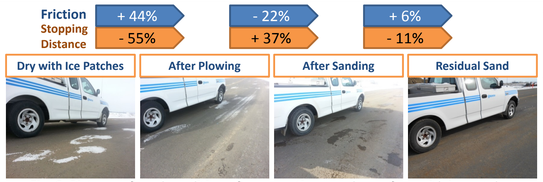

Fig. 6. Pictures of road condition after operations on dry surface with ice patches

- Plowing removed ice patches from the surface, improving the surface friction (Fig. 7).
- Sanding the dry surface reduced friction and increased stopping distance (Fig. 8).
- Wind had scattered sand particles, so friction increased on residual sanded surface compared to freshly sanded.

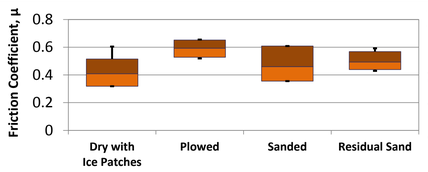

Fig. 7. Friction coefficient after operations on dry with ice patches.

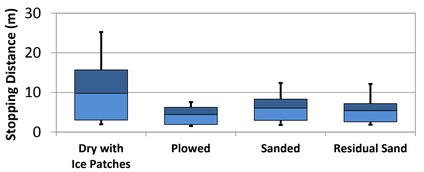

Fig. 8. Stopping distance after operations on dry with ice patches.

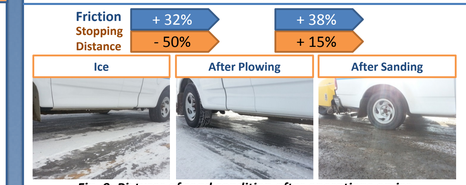

Fig. 9. Pictures of road condition after operations on ice

- Plowing removed some of the ice and snow, and improved the driving condition.
- Sanding the ice sheet, helped melt the ice and snow contamination, and provided more traction (Fig. 10).
- The changes in stopping distance are mostly due to the effect of vehicle's ABS on ice (Fig. 11).

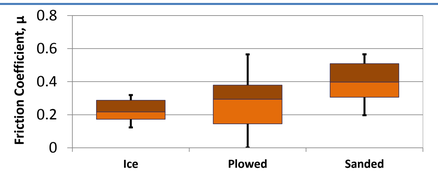

Fig. 10. Friction coefficient after operations on ice.

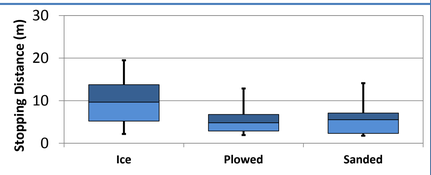

Fig. 11. Stopping distance after operations on ice.

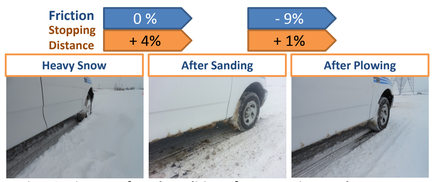

Fig. 12. Pictures of road condition after operations on heavy snow

- Sanding heavy snow did not improve friction, since sand particles were buried in snow (Fig. 13).
- Plowing removed a great amount of snow, but friction did not change according to the measured friction and stopping distance (Fig. 13 & 14).
- The vehicle's braking performance, thus Vericom data, is negatively affected by ABS in snowy conditions.

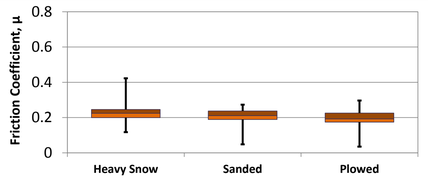

Fig. 13. Friction coefficient after operations on heavy snow.

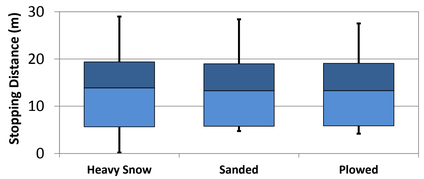

Fig. 14. Stopping distance after operations on heavy snow.

Conclusions

- Vericom VC4000 PC friction measurements on bare dry, ice and snow were not speed-dependent.
- The device is able to capture the changes in road condition (i.e. ice patches and snow amount).
- The vehicle's ABS affected the stopping distance data from Vericom measurements.
- ABS provides better stopping distance on dry surface and ice, but increases the stopping distance on snow and sanded surfaces.
- Plowing removed ice patches and improved both friction and stopping distance.
- Sanding compromise the driving condition on dry surface, but it provides greater traction on ice
- The effect of operations over snow was not captured by Vericom, potentially due to the ABS effect.
- Vericom is small and easy-to-use for but it is not recommended for winter maintenance purposes, since measurements are highly influenced by vehicle properties and driver's braking behaviour and require frequent hard braking.