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RESEARCH PROJECT TITLE
Optimization of Snow Drifting Mitigation and Control Methods for Iowa Conditions

SPONSORS
Iowa Highway Research Board (TR-626)

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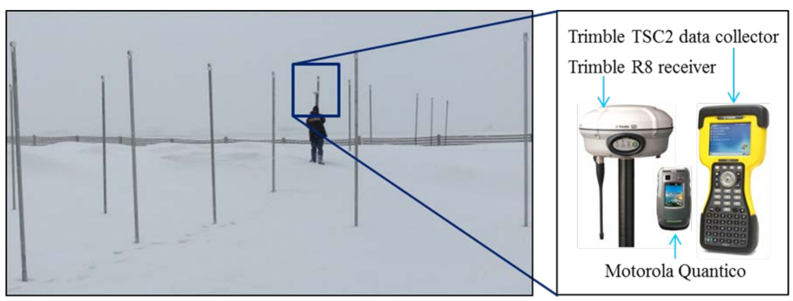
Problem Statement

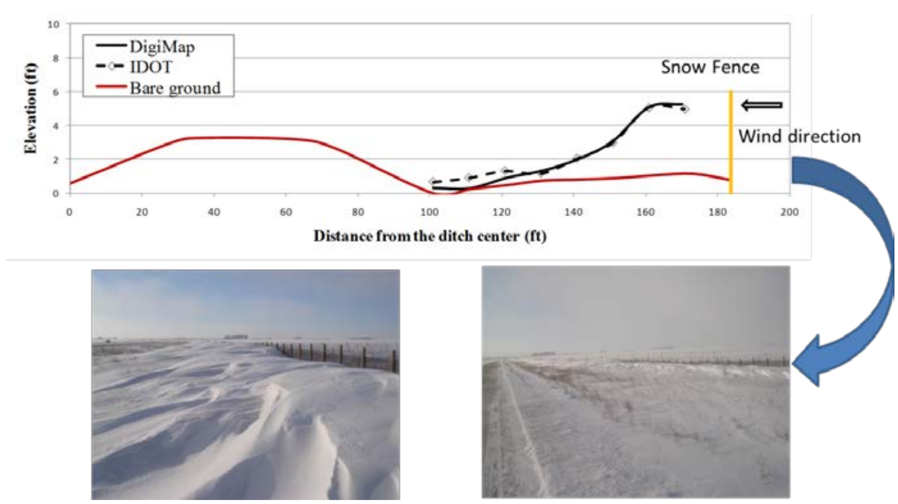
Blowing and drifting of snow is a major concern for transportation efficiency and road safety in regions where their development is common. One common way to mitigate snow drift on roadways is to install plastic snow fences. Correct design of snow fences is critical for road safety and maintaining the roads open during winter in the US Midwest and other states affected by large snow events during the winter season and to maintain costs related to accumulation of snow on the roads and repair of roads to minimum levels. Of critical importance for road safety is the protection against snow drifting in regions with narrow rights of way, where standard fences cannot be deployed at the recommended distance from the road. Among the critical parameters involved in fence design and assessment of their post-construction efficiency is the quantification of the snow accumulation at fence sites.

OBJECTIVES

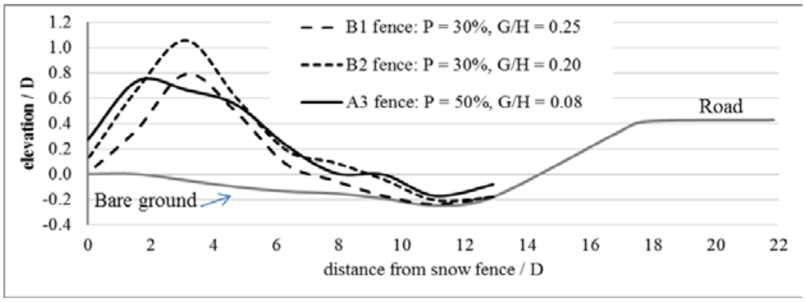
A major objective was to develop a joint experimental and numerical approach to monitor snow deposits around snow fences, quantitatively estimate snow deposits in the field, asses the efficiency and improve the design of snow fences. A related objective was to illustrate the capabilities of this methodology by applying it to improve the design of plastic snow fences that are commonly used by the IDOT. A second major objective was to propose, develop protocols and test a novel technique based on close range photogrammetry (CRP) to quantify the snow deposits trapped snow fences. A third objective was to attempt to estimate the snow relocation coefficient (SRC) based on readily available data and to make recommendations on how to accurately estimate this variable that needs to be provided to the standard snow fence design software used by IDOT.



Instrumentation used for the GPS-based real-time (RTK) surveys



Snow deposition profiles computed at one of the snow-fence sites monitored during the field study. Results are shown using the Mobile Large-Scale PIV –Digimap technique and the RTK surveys using the IDOT marker poles.



Snow deposition profiles behind plastic snow fences measured at the Williams site after a major snow event. Results show that the new designs with a porosity of 30% retain more snow over a shorter distance from the fence compared to the classical standard fence design with a porosity of 50%.

Approach and Main Contributions

A general approach to monitor snow deposits around snow fences, quantitatively estimate snow deposits in the field, asses the efficiency and improve the design of snow fences was developed and tested for a particular case (plastic snow fences). Of critical importance for successfully applying the proposed methodology is that a sufficiently long field test side was available, where several fence designs can be tested under close to identical conditions, and that accurate methods are used to determine the snow deposition profiles after major snow events at the site. A detailed field monitoring system was developed as part of the present study that included access to weather forecast and meteorological conditions at the monitored sites.

The present study investigated the effectiveness of plastic snow fences with a lower porosity than the standard design used by the IDOT because of the possibility that such fences retain more snow and/or the length of the region of significant snow deposit on the downwind side of the fence is reduced. The field monitoring campaigns demonstrated that lower-porosity plastic snow fences are a better option to protect roadways against snow drifting in regions with narrow right of ways.

Another major contribution of this study was to propose, develop protocols and test a novel technique based on close range photogrammetry (CRP) to quantify the snow deposits trapped by snow fences. As image data can be acquired continuously, the time evolution of the volume of snow retained by a snow fence during a storm or during a whole winter season can be estimated. Moreover, CRP is a non-intrusive method that eliminates the need to perform man-made measurements during the storms, which are difficult and sometimes dangerous to perform. As part of the present study, the novel CRP method was tested at several sites and based on these results, the technique was further refined.

Key Findings and Recommendations

-Plastic snow fences with a porosity of 30% and a bottom gap of about 20-25% of the fence height are a more effective way to protect against snow drifting compared to the standard design (50% porosity, bottom gap of about 15% of the fence height) used by the IDOT. The new design:

-has a higher capacity to store snow over less distance from the fence
-can work well in more severe storm events
-can be used with narrow rights of ways

-We recommend the use of the novel technique to assess the efficiency of snow fence design to other types of structural and living snow fences commonly used by IDOT to protect against snow drifting.

-Use of living snow fences appears to be a very effective way to protect against snow drifting. Quantification of the performance of this type of snow fence requires more research.

-Several methods can be used to accurately measure snow profiles in the field after major snow events (image-based, ground-based poles, lidar, GPS). GPS-based real-time (RTK) surveys are probably the fastest and most efficient, while providing very accurate results but they require man intervention during data collection.

-3D close-range photogrammetry can be used to determine the temporal variations of the volume retained by the fence. The results obtained in the study lead to the conclusion that CRP technique has unique capabilities to map snow elevations over large areas using only a pair of camera that is automatically operated. The new imaging technology offers the unique ability to simultaneously collect snow landscape panoramas and details with time steps commensurate with the in-situ development of the snow transport processes. Still, the reliability of cameras used to collect images needs to be improved such that uninterrupted data collection over a whole winter season is possible.

-Attempts to estimate the snow relocation coefficient (SRC) were not successful. In particular, it was demonstrated that the procedure given in Tabler (2006) to estimate the SRC gave unphysical results when applied to the test sites monitored as part of the present study.

-A main recommendation for future work is the development of an image-based LSPIV method to directly measure the snow drift fluxes and the amount of snow relocated by the fence, which allows direct estimation of the SRC at the monitored sites.