OVERVIEW OF THE RAIL GROUND HAZARD RESEARCH PROJECT (RGHRP) AND CANADIAN RAIL RESEARCH LABORATORY (CARRL)

MICHAEL HENDRY

UNIVERSITY OF ALBERTA

"uplifting the whole people"

— HENRY MARSHALL TORY, FOUNDING PRESIDENT, 1908

Introduction to the RGHRP

The Railway Ground Hazard Research Program (RGHRP), created in 2003, is a collaborative effort of the rail industry, academic institutions and the federal government.

The Program focuses on scientific research and investigations to better understand the mechanisms that cause various ground hazards, develop guidelines to manage the risks, and develop and identify tools and technologies to mitigate the hazards.

The Partnership

CN CP

Transports Canada Transport Canada

UNIVERSITY OF ALBERTA

Queen's UNIVERSITY

CANADA 1842 GEOLOGICAL SURVEY - COMMISSION GÉOLOGIQUE

NSERC CRSNG

Introduction to the RGHRP

The ***unique collaboration*** *among RGHRP partners; and, shows commitment to the safety of Canadians and their quality of life. Sharing their resources has led to an innovative platform to advance scientific knowledge and develop industry standards. CN and CP, despite the competitive environment in which they operate, provide invaluable direction for the research undertaken by the RGHRP leading to greater operational reliability and safety of rail service in Canada.*

Mechanisms, processes and engineering methods

Fig. 1. (left) Photograph of the derailment at mile 3.87 on the Lévis Subdivision (*TSB, 2008*). (right) Photographs of the installation of instrumentation at the Edson subdivision study site in 2007.

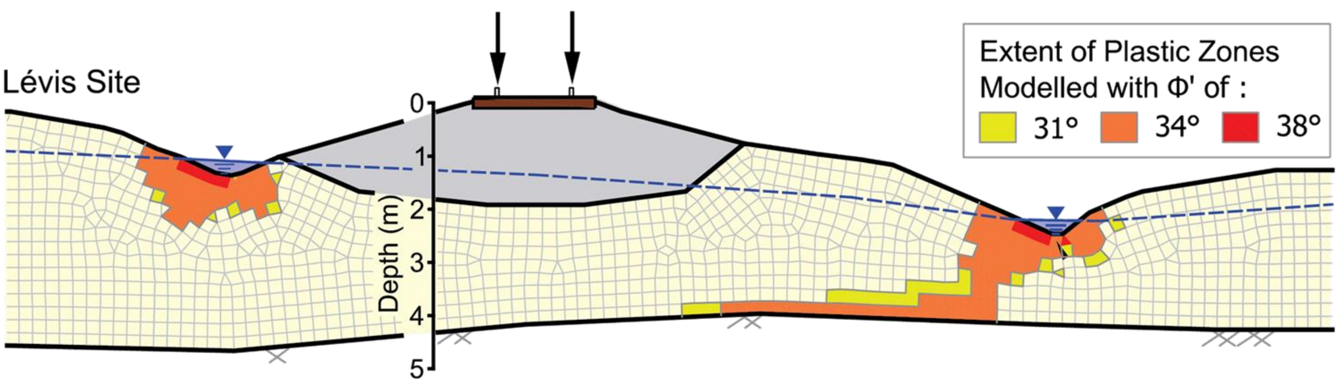
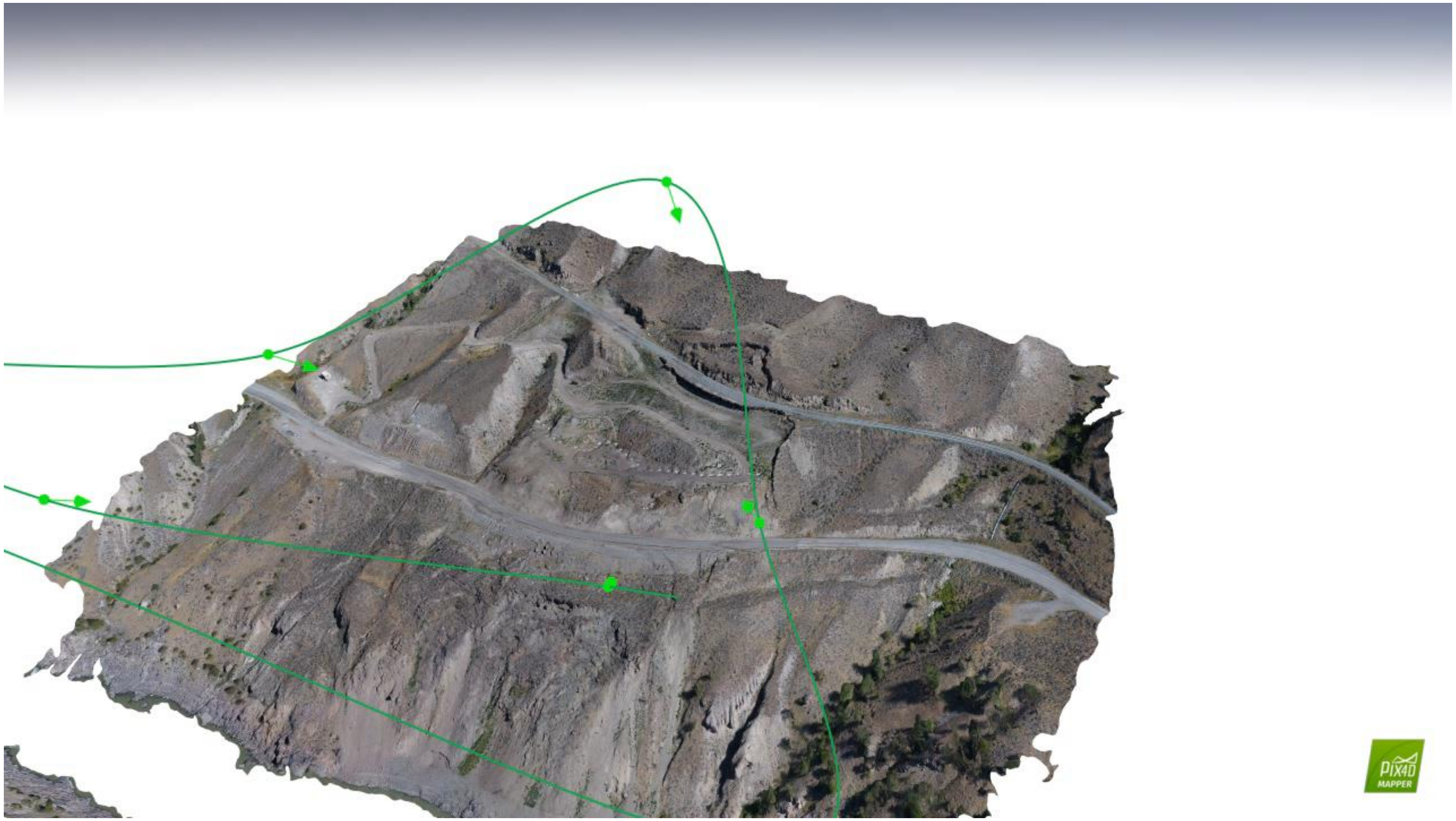


Fig. 2. Modeled zones of yielding under current maximum axle loads for different strength values for the Lévis site (*after* Hendry *et al.* 2013).

Assessing and evaluating technologies



Assessing and evaluating technologies

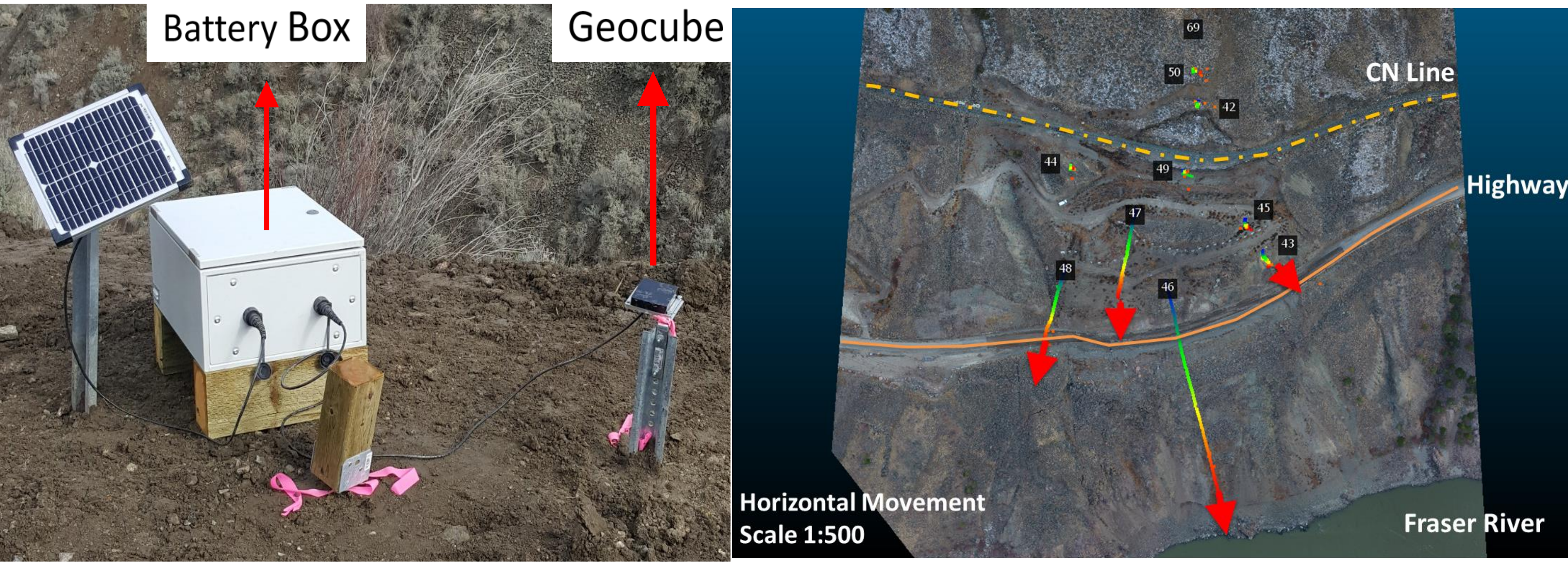
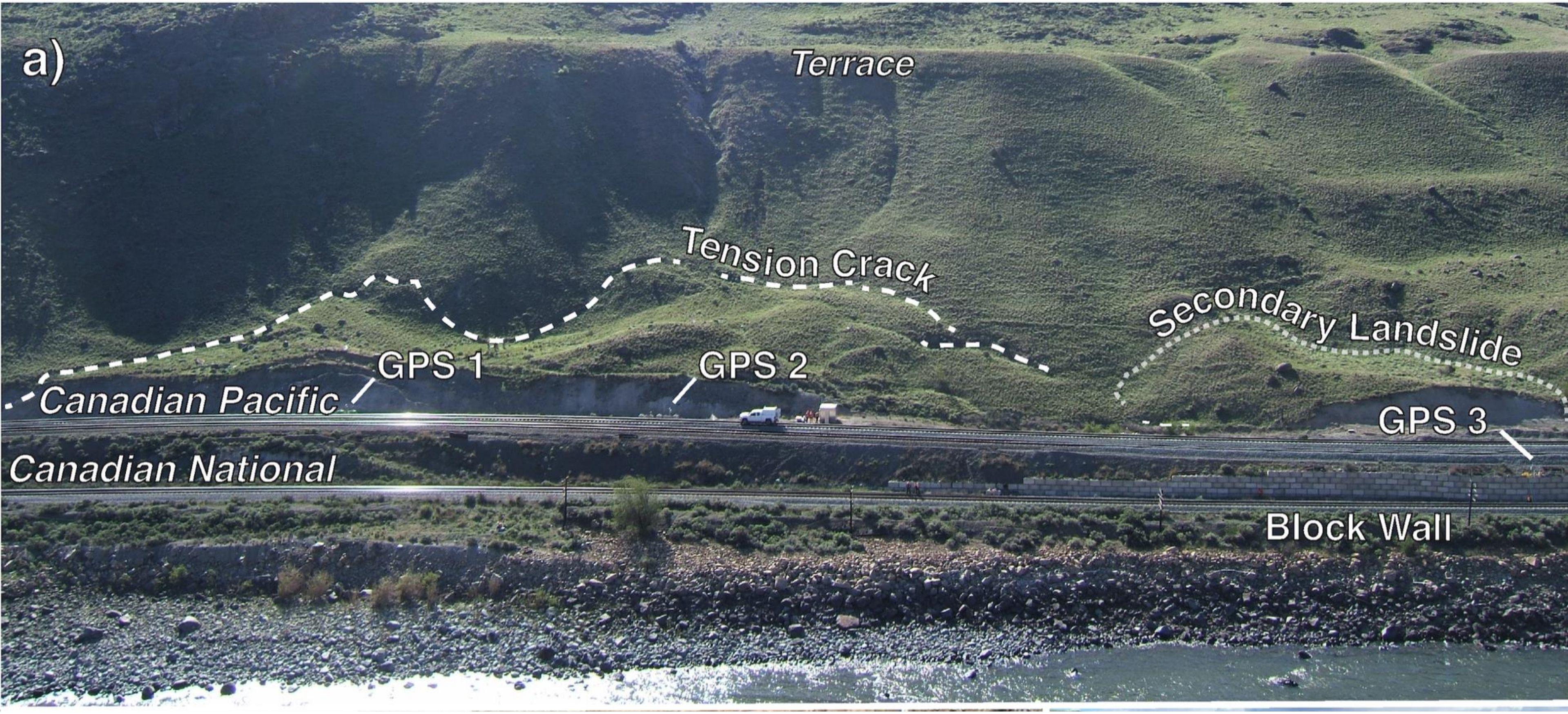


Fig. 3. (*left*) Photograph a Geocube GPS monitoring system installed on the 10-mile landslide near Lillooet BC. (*right*) Displacement vectors from Geocubes overlain on 3D image of the 10-mile landslide.

Assessing and evaluating technologies



Synthesizing case histories and practices

Fig. 4. (*left*) Photograph Debris flow, Forestry Trunk Road – June 2013; (*right*) Photograph of the installation of the Hardy Ribs Installation (courtesy of CN).

Benefits to the Railways

- Progress on projects that would not otherwise be undertaken by the engineers at the railway, and would not be cost effective to pay consultants to do the work.
- Research group to call upon for ideas, expertise, and try out and share new ideas.
- Steady stream of well trained persons, with an understanding of the railways, entering practice.

Benefits to the Universities and the Profession

- Provides *relevant* research opportunities.
- Steady, consistent funding for 15 + years is very rare. Provides the ability to attract and train high quality students.
- By end of Phase III expected to have trained more than **25 PhD** students, **22 MSc** students, and numerous MEng projects. All focused on Geotechnical, Ground Hazards and Risk.

CANADIAN RAIL RESEARCH LABORATORY

www.carrl.ca

CN Canadian Pacific

Transport Canada Transports Canada

NRC-CNRC Canada

TTCI Transportation Technology Center, Inc.

CaRRL Canadian Rail Research Laboratory

Alberta Innovates Technology Futures

NSERC CRSNG

Rail Research

With 48,000 route kilometres of track, Canada has one of the most extensive rail networks in the world. The importance of rail transportation to both the Canadian economy and the quality of life enjoyed by Canadians is significant. The system moves people, goods and services to their destinations, provides jobs and sustains economic growth.

The Canadian rail sector faces many challenges, such as high safety and security standards, long travel distances, sparse population, harsh environments and extreme climatic changes. In addition, industry experts predict that 30% of the skilled work force in the rail sector will be eligible for retirement within the next five to ten years, and therefore the need to attract high caliber candidates and provide sector specific university training at the undergraduate and graduate level is greater than ever.

For Canada to continue to grow and prosper, it is critical that the transportation system evolve to become more innovative, more efficient and more resilient to our harsh and changing environment. Two of Canada's premier rail research programs, the Canadian Rail Research Laboratory (CaRRL) and the Railway Ground Hazard Research Program (RGHRP), are important steps towards addressing the challenges.

Opportunities for Paid Education and Research Experience

CaRRL is looking for high-caliber candidates to conduct graduate-level research in railway-related engineering projects. The research projects conducted via CaRRL will transform how the railway industry in Canada operates.

Candidates must be critical thinkers, show creativity in problem solving and enjoy the challenge of working through difficult, real-world problems. Sound like you? Click here to find out more!

CANADIAN RAIL RESEARCH LABORATORY

www.carrl.ca

May 28 2010

Transport Canada | Transports Canada

Policy | Politiques

Transportation Technology and Innovation Directorate | Direction générale de la Technologie et de L'innovation en matière de transports

Place de Ville
Ottawa
K1A 0N5

May 28, 2010

Dr. C Derek Martin
Geotechnical Engineering
University of Alberta
3-071 Markin/CNRL Natural Resources Engineering F
Edmonton, AB T6G 2W2

Dear Professor Martin,

On behalf of the Railroad Research Advisory Boar
Canada's railway sector, I would like to invite your u
Interest and Capabilities to establish a Canadian
affiliated with the American Association of Railways
Centre Inc. (TTCI)'s Technology Scanning Program.

The mission of the AAR/TTCI's technology scannin
affiliated laboratories is *to identify and evaluate n*
application within the rail industry; to seek leveragi
quality, timelines, and cost-effectiveness of rail resear
learning curve of railroad technical officers and staff
refer to the attached document on the current US progr

Strategic Priority Areas

The RRAB recognizes the importance of establi
Laboratory to perform technology scanning to iden
improvement of safety, reliability, sustainability
transportation. This initiative will also benefit the
... of next generation science and engineerin
will also serve to facilitating closer collabo

RFP

June18 2010

UNIVERSITY OF ALBERTA

Department of Civil & E
School of Mining & Petrole

3-071 Markin/CNRL Natural Resources
Edmonton, Alberta, Canada T6G 2W2

2010 June 18

Merrina Zhang, P. Eng.
Research Coordination Officer
Transportation Development Centre
Transportation Technology and Innovation
330 Sparks Street
Ottawa ON K1A 0N5

Dear Ms. Zhang

Subject: Expression of Interest to establish a Canadia

I am pleased to respond to your letter of May 28, 2010,
establishing a Canadian Rail Research Laboratory (CRRL)
Canadian railroad industry at the University of Alberta. As
University of Alberta, the Faculty of Engineering and
Environmental Engineering strongly support this initiative.

We understand that the research to be performed at the CRRI
the three US-affiliated laboratories currently supported by the
/Transportation Technology Centre Inc.'s (AAR/TTCI) Te
technical committee of the Canadian Railroad Research Adv
the areas of **Ground Hazards** and **Winter Service Reliability**
for the next five years. The priority areas may be expanded i
in the Canadian rail sector.

The CRRL will reside within the Department of Civil &
University of Alberta. The strengths of the Department are w
research identified by the RRAB. The Department is recogn
Geotechnical Engineering (Ground Hazards) and for its eng
Our current facilities are tailored for research in ground haza
The University of Alberta's Faculty of Engineering ranks in s
400 engineering schools in North America, with 4,000 u
students. Hence, we have extensive research capacity and faci
diverse enough to allow for expansion of the CRRL program
to be important by the industry. Education is the foremost pri
opportunity to introduce railroad engineering into the cu
rojects and transfer new tech

Submission

Sep 08 2010

Transport Canada | Transports Canada

Policy | Politiques

Transportation Technology and Innovation Directorate | Direction générale de la Technologie des transports et de l'innovation

Place de Ville
Ottawa
K1A 0N5

Your file | Votre référence
Our file | Notre référence

Dr. C Derek Martin
Geotechnical Engineering
University of Alberta
3-071 Markin/CNRL Natural Resources Engineering Facility
Edmonton, AB T6G 2W2

Dear Professor Martin,

On behalf of the Railroad Research Advisory Board (RRAB), Transport Canada (TC) and Canada's railway sector, I would like to inform you that the University of Alberta has been selected to be the lead university to establish a Canadian Rail Research Laboratory. I would like to congratulate you on an excellent submission.

For your information, the RRAB expressed some concerns over the interim nature of the current Program Director and will work with the university to select a permanent champion. In the interest of advancing rail related research in Canada, we would like to mention that strong proposals were received from the University of Calgary, University of Waterloo, McGill University and University of New Brunswick. The RRAB recommends that the University of Alberta seek to network with the other universities for the development of quality projects where appropriate during the course of the program.

It is expected that a visit to the university by the Technical Scanning Committee of AAR/TTCI and Canadian program sponsors would take place sometime during the Fall 2010. In the coming weeks, Merrina Zhang, TC Research Officer (613-949-1617, merrina.zhang@tc.gc.ca) will be working with you to make those arrangements, set up the program and complete relevant agreements.

We look forward to collaborating on this exciting opportunity.

Yours truly,

Marc Fortin
Director General

Appointment

Objectives of CaRRL

- To conduct high quality **research** with the faculty and facilities available at the University of Alberta and with collaborations across Canada to meet the developing needs of the Canadian Railroad industry.
- To train highly qualified **engineers** through integrated, multidisciplinary research projects and course work to meet the future needs of the railroad industry.

NSERC IRC Research Program (2012-2017)

Theme 1: Reducing frequency of slow orders resulting from ground hazards

Theme 2: Assessing and improving subgrade quality for heavy axle loads

Theme 3: Assessing ballast quality and fouling

Theme 4: Optimizing rail and rolling stock for cold environments

Theme 5: Assessing the impact of climate events on railway operations

Theme 6: Establishing a risk tolerance strategy for railway operations

Theme 7: Operational optimization

CANADIAN RAIL RESEARCH LABORATORY

www.carrl.ca

CANADIAN RAIL RESEARCH LABORAT

Building the future for Canadian railways.

Estimating Rail Stresses usin

Saeideh Fallah Nafari, Mustafa Gül, Michael T. He

Summary

Rail breaks are the leading cause of main track derailments i manage rail failures. Continuous variation of track modulus b stresses. MRail technology was recently used to measure rela framework was developed to quantify the modulus of the t distribution of maximum bending moment can be extracted fr

Introduction

Rail breaks are the leading cause of main track derailments i with many of these rail breaks occurring in the winter. While many ways a rail break can occur, the fundamental requireme the stresses in the rail steel exceed some critical value. The stresses considered when assessing the potential for breaks in are thermal, residual and in-service stresses. Accurate analysi stresses is often challenging because of the many unknown p that can affect the calculated stress magnitudes. This researc focuses on the analysis of the in-service bending stresses in modulus of the track/subgrade below the rail steel can sig impact the magnitude of the calculated bending stresses. A m can be used to constrain the track modulus is to measure the of the rail when subjected to a known applied load. While th done statically at discrete locations using specialized equipm does not provide a practical approach when dealing with a 48 long rail network.

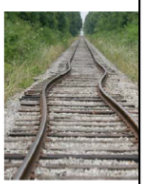


Figure 1: Abnormal stresses in the rail steel can result in rail br (left) and buckled tracks (right)

MRail technology was used to measure relative verti deflections (Y_{rel}) from a loaded boxcar on 4,000 km of CN framework was developed using finite element modelling a measurements to constrain the track modulus. Once the track is constrained, the range of bending stresses in the rail ste loaded train can be determined. Knowing the characteris modulus for different physiographic regions and track conditio be possible to establish a spatially varying reliability index fo sections of the network. Stresses caused by external factors extremes in weather temperatures, can also be simulated a demonstrate the temporal variability in the reliability index.

Background

The correlation of rail deflection with track modulus is c explained using the Winkler model for an infinite beam on a c elastic foundation. Figure 2 illustrates the vertical deflection an RE100 rail, which is supported by a uniform track modulu MPa and subjected to a 159 kN wheel load. Figure 2 also s MRail relative deflection measurement (Y_{rel}). The relationship Y_{rel} and track modulus can be estimated by changing the va uniform track modulus and calculating the deflection profil

CANADIAN RAIL RESEARCH LABORATORY

Building the future for Canadian railways.

Evaluating Vertical Track Deflections fo

Alireza Roghani, Michael T. Hendry and C. Derek Martin

Introduction

Canada's railway infrastructure passes over varied terrain with large stretches of soft glacio-lacustrine clays and very soft peat/muskeg subgrades. The subgrade forms the foundation of a railroad, and the performance of the subgrade affects the performance of all other components of the track structure. Soft subgrades have been linked to increased wear and degradation of track and ballast. Additionally, soft subgrade materials are prone to ongoing settlement and plastic deformation, which can lead to sudden failure and safety issues for rail operations.

The current inspection technologies used by the railway industry (e.g. track geometry) are mainly based on the evaluation of track surface condition and do not provide quantitative information on track substructure. Figure 1 shows a segment of track along Canadian National's (CN) Lac la Biche Subdivision (LLBS) in northern Alberta, where excessive deformation has resulted in a dip in the track. An analysis of track geometry car data collected prior to development of the dip at this location was not able to predict the problem nor was it useful in determining its root cause.

Figure 1: Location with excessive subgrade deformation along the LLBS.

To address these challenges, researchers at the Canadian Rail Research Laboratory (CaRRL) at the University of Alberta are investigating new methods to quantify the track and subgrade condition. The objectives are to provide industry with a better understanding about the implications of soft subgrades on train operations and track maintenance; quantify the risk associated with poor quality subgrades; and assess whether specific track sections are able to support an increase in axle load or traffic prior to any change.

MRail technology

CaRRL in collaboration with CN has been evaluating the potential of the MRail rolling vertical track deflection measurement system to map subgrade variability across CN's network. The MRail system uses lasers and cameras to measure the relative deflection (Y_{rel}) between the wheel/rail contact point at a distance of 4 feet from the nearest wheel of the instrument truck (Figure 2). Two lasers on top of each side of the rail continuously shine two lines on the head of the rail and a camera takes pictures at a frequency of 90 frames per second. These pictures are then processed in real time to determine Y_{rel}. The distance between two consecutive measurements is a result of the train speed. For

example two mea on a tri maintain other da values coordina is suffic hereafte version CN ha the sprin Council instrume Western

Figure 2

Interpr

Figure 3 20 miles welded a data f other th irregular substruc

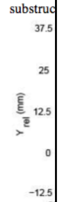


Figure 3 continuo

Figure the LLB ground this sect location correlat

CANADIAN RAIL RESEARCH LABORATORY

Building the future for Canadian railways.

RESEARCH UPDATE

Ultrasonic Leakage Detection for Air Brakes

Cynthia Ying, Michael G. Lipsett, Michael T. Hendry and Vivek Poddar

Summary:

Air brake reliability during the winter has been an on-going concern for railway operators in Canada. Despite the efforts to improve air brake reliability, methods to detect air leaks still rely heavily on manual inspection. Ultrasound Leakage Detection (ULD) was initially investigated as an alternative to visual inspection and manual testing. Initial field trials were conducted in Canadian Pacific's Golden Yard in British Columbia, and bench-scale experiments were conducted in cold room labs at the University of Alberta. The results from these initial trials demonstrated that ultrasound methods were capable of air brake leak detection. Additional investigations were initiated in May 2015, and this Research Update summarizes those findings. The application of ULD in air brake inspections may increase air brake reliability, increase the efficiency and accuracy of air brake leakage identification and minimize costs associated with prolonged inspection time and schedule delay.

Introduction

Trains rely on compressed air to operate their braking system. Air compressors pressurize the air reservoirs, and this pressure is transferred to the brakes via a mechanical steel piping system with rubber hose and glad hand connections between adjacent rail cars in the train. The reliability of this air brake system decreases during winter operations, which can impact railroad operations. Most inspections for air leaks in the yard are performed manually. In cold weather, leaks in air brake pipes and flexible air hoses are more common. Moreover, manual brake inspections to detect leaks and their locations in a cold and noisy rail yard environment can be difficult and time consuming. The accuracy of the inspection results in such an environment can be compromised, resulting in delays in departure and extended track occupancies in the yard. Ultrasonic Leakage Detection (ULD) was tested in Canadian Pacific's (CP) Golden Yard in 2013 and in Canadian National's (CN) rail shop and Walker Yard in Edmonton, Alberta, in 2015 to assess the reliability of the technique for enhancing manual air brake inspections. The ULD method was also evaluated as a stationary rail-side mounted system to replace manual air brake inspections in rail yards.

Figure 1: Example of soap and bubble testing of air brake components at CP's yard in Golden, B.C.

Ultrasonic Leak Detection (ULD)

Most of the small air brake leaks generate sound frequencies that are over the upper limit of the human hearing range (i.e. in the ultrasonic frequency range). These ultrasonic frequencies can be heterodyned (*shifted*) to audible ranges using sensors and equipment. This essentially allows manual inspectors to listen for leaks which were previously only detectible with soap bubble tests (Figure 1). The benefit of using ULD is that the sound waves are directional, allowing the detection of where the sound waves are being generated. The portable ultrasound device used in these studies was a commercial ULD device (SDT 270) with a flexible sensor and a directional distance sensor (Figure 2). The flexible sensor is useful for proximity leakages that are present in accessible locations or hidden locations. The cone-shaped direction sensor allows the isolation of the direction from which the ultrasound emanates.

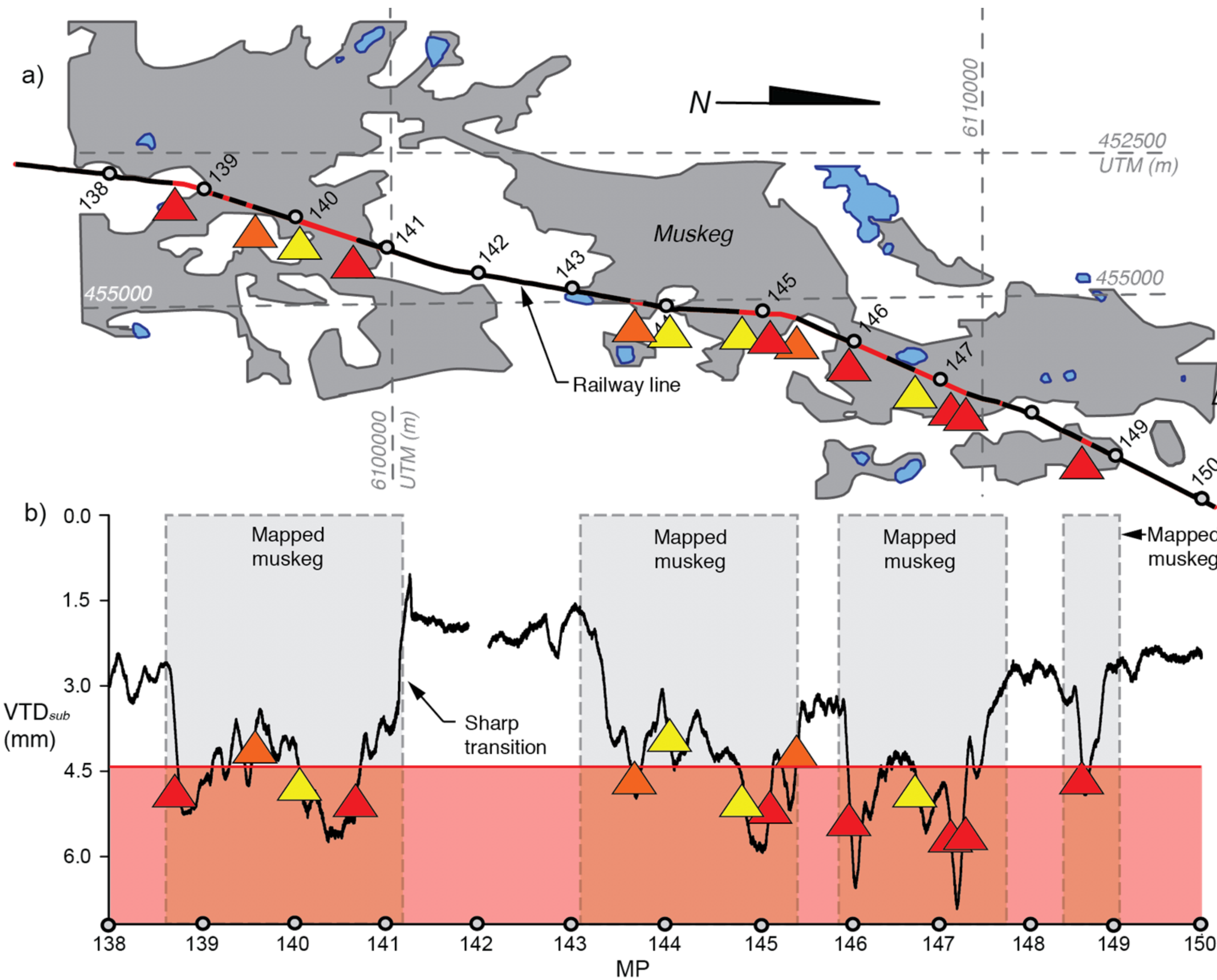
Field Trials

Field verification of the ULD device was performed with audio recognition tests and post analysis. The first trial was conducted at CP's Golden Yard under temperatures ranging from -15°C to -20°C (December 2013). This testing was conducted with a representative from Wabtech, the Golden Yard manager and a member of CP's mechanical group. A second set of testing was conducted at CN's Walker Yard concurrently with the manual inspection of the rail cars (May 2015). These tests demonstrated the ULD device could readily detect major leaks that were found through manual inspections as well as many smaller leaks that were not. The range of detection was up to 10 m (32 ft). However, operator judgement is required as end-of-train device turbines, hand brake chains, nearby train brake releases and air brake line bleeding and venting were all found to sound very similar to leaks. As well, loud sustained noises can obscure the ultrasound signature of leaks.

Figure 2: ULD cone-shaped direction sensor at CP's yard in Golden, B.C.

Fig. 6. Photographs of the CN and University of Alberta instrumented rail car (NOKL 322034) complete with a MRail / vertical track deflection (VTD) measurement system (*courtesy of* A. Roghani, 2015).

Fig. 7. Extent of VTD measurements taken with the instrumented car. The final tally was 12,000 km of track over 14 different subdivisions ~ 4 million track displacement measurements.



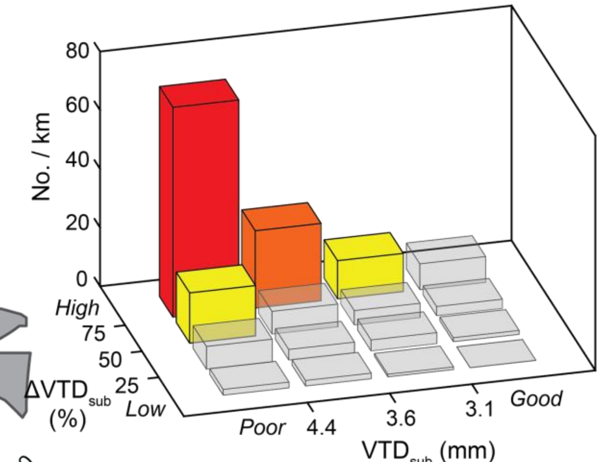


Fig. 8. Comparison of the VTD$_{sub}$ data (calculated with a 20 m filter) with the locations of the muskeg terrain identified from existing surficial geological mapping and air photo interpretation (*after* Roghani & Hendry, 2016). *Red does not mean unsafe.*

Mechanisms of funding

- Most readily accessible funding is from Natural Sciences and Engineering Council of Canada (NSERC).
- Available for collaborative research programs with Universities.
- NSERC will match funding (cash and in-kind) *with conditions*. (e.g. NSERC Collaborative Research & Development grant).
- No-risk funding for starting research projects through NSERC-ENGAGE grant.
- Funding (cash and in-kind) is tax deductible.

Suggestions for Maintaining Collaboration

- Regular meetings and discussions (monthly)
- Engaging multiple researchers seems to provide more consistent progress.
- Focused program, with projects aligning with the interest and expertise of the researchers.
- Secretariat position to keep everyone engaged.

Questions?