CANADIAN CONSULTING engineer

ASSOCIATION OF CONSULTING ENGINEERING COMPANIES | CANADA

COMPOSITE BARRIER WALL ROCKSHED STRUCTURE

MILE 109, CN ASHCROFT SUBDIVISION, BC

Klohn Crippen Berger

AWARDS SUBMISSION 2015

Name of Member Firm Submitting: KLOHN CRIPPEN BERGER LTD

Address of Firm: 500 – 2955 VIRTUAL WAY, VANCOUVER BC V5M 4X6

Tel: 604.669.3800

Fax: 604.669.3835

Contact Name: KATHY FOWLER

Email: KFOWLER@KLOHN.COM

Project Title: COMPOSITE BARRIER WALL / ROCK SHED STRUCTURE

Location of Project: MILE 109 ASHCROFT SUBDIVISION
BETWEEN LYTTON AND BOSTON BAR, BC

Category of Entry: TRANSPORTATION

Project Owner: CANADIAN NATIONAL RAILWAYS

Project Client: CANADIAN NATIONAL RAILWAYS

75-word Summary

IN NOVEMBER 2012, A 53,000 M³ ROCKSLIDE BURIED THE CANADIAN NATIONAL RAILWAY (CN) TRACK AT MILE 109.43, ASHCROFT SUBDIVISION, CAUSING A 4-DAY SERVICE DISRUPTION. KLOHN CRIPPEN BERGER WAS CONTRACTED TO ASSESS ROCK LANDSLIDE HAZARD AND DESIGN A PROTECTION STRUCTURE. USING A COMBINATION OF PRACTICAL AND INNOVATIVE TECHNIQUES TO OVERCOME THE CHALLENGES OF THIS PROJECT, KCB CONSTRUCTED A COMPOSITE BARRIER WALL/ROCK SHED STRUCTURE.

Name of Contractor involved: EMIL ANDERSON CONSTRUCTION INC.

PROJECT TITLE PAGE

Innovation

On November 25th, 2012 a 53,000 m^3 rock landslide occurred along the Canadian National Railway (CN) track, at Mile 109.43, between Lytton and Boston Bar, British Columbia. The slide debris covered 70 m of track with debris up to 10 m deep and destroyed a 21 m long concrete rock shed, causing a 4-day service disruption.

Klohn Crippen Berger (KCB) was contracted by CN to characterize and assess rock landslide hazard at the site; and recommend, design and implement passive measures to improve safety and protect train service at track level.

KCB designed and constructed two remediation structures: a mesh attenuation curtain (MAC) was required as a short-term rock fall barrier to provide safe working conditions to the onsite construction personnel, while a composite barrier wall/rock shed structure is a long-term structure to passively protect the track from all identified potential rock landslides.

The MAC design consists of a Geobrugg TECCO high tensile steel mesh connected to a 25 mm support cable with hooks. The support cable is anchored to rock at either end in safe areas. Based on measurements of block sizes at the site and dynamic rock fall analyses, a design impact load on the system of 250 kN was estimated. The support cable is attached to anchor systems on either side composed of two and three anchors at the east and west ends respectively. The support cable is connected to the anchor systems by a cable arrangement that allows even distribution of the load to each anchor. Pulleys are installed at locations where the support cable changes direction.

The composite structure comprises a barrier wall with backfill to absorb the impact of normal and drag forces and a sloped rock shed to guide the debris flow over the track and down to the talus slope below. Modular components of both the “wall” and “shed” are tied back to the rock slope with rock anchors. The wall and shed components are not connected, but are designed to act independently. In this way, landslide impact load-induced strains in the barrier wall are not transferred to the rock shed structure.

In order to obtain realistic estimation of design parameters for the protection structures, KCB incorporated innovative rock slope characterization and modeling techniques into the rockslide risk management process, including terrestrial LiDAR, discrete fracture network modeling and dynamic run-out analysis. The designed protection structure used modular components, facilitating construction under railway traffic and reducing track service disruptions.

Complexity

A number of challenges had to be overcome in order to obtain realistic estimation of design parameters for the protection structures and to deal with issues related to accessibility, construction personnel exposure to rockfall hazard, and ongoing railway traffic. KCB incorporated innovative rock slope characterization and modeling techniques into the rockslide risk management process including terrestrial LiDAR, discrete fracture network modeling and dynamic run-out analysis. The designed protection structure uses modular components, facilitating construction under railway traffic and reducing track service disruptions.

The rockfall and rockslide hazard assessment highlighted that the greatest threat for the railway track was a potential retrogressive failure of the remaining rock mass. The results of the site investigation suggested that the failure would initiate as a rockslide along a stepped failure surface and turn into a rock avalanche. Rockslide modeling was performed using finite element modeling; and a discrete fracture network was incorporated in the finite element analysis in order to reproduce the stepped geometry of the failure surface and provide more realistic estimations of potential future rockslide volumes.

These volumes were incorporated in the software DAN-W for run-out simulations of the rock avalanche. The dynamic run-out analysis was used to derive impact loads for design of the new protection structure. The model was calibrated by finding best-fit frictional rheology for back-analysis of the 2012 rockslide. A modified version of the pseudo-three-dimensional runout analysis software DAN-W was used, allowing output of normal and shear stresses at the base of a sliding frictional mass. This was the first use of DAN-W for such a purpose.

Social and/or Economic Benefits

This section of CN's single-track mainline is part of the CN/CP Rail joint running initiative which sees all CN and CP Rail westbound traffic (Kamloops to Vancouver) running on CN tracks. The service disruption on this line caused significant business losses to both railways.

One of the challenges of the construction of this composite structure along the operating railway was to deal with the ongoing train traffic. KCB's innovative design solution was to use modular components, including the retaining wall, rock shed concrete roof panels and rock shed footings, which could be pre-cast and transported to the site. The structure consists of pre-cast concrete footings, steel frames and concrete roof panels. On the down-slope side of the structure the concrete footings were attached to micropiles which extended down through the talus and heavily fractured bedrock. The retaining wall and shed components are independent; rockslide impact forces on the wall are not transferred to the shed. This design methodology for landslide protection structures is transferrable to other sites.

Environmental Benefits

Particularly hazardous conditions were experienced while scaling the rockslide area. During the summer of 2013, a gully formed from wind in the dry overburden above the head scarp of the landslide, generating constant raveling and unsafe working conditions on the slope and at track level. Due to these unsafe conditions, the initial plan to install a dynamic rockfall barrier to protect the work site during construction of the composite barrier wall/rock shed structure, had to be abandoned as it required work on the slope and the raveling could not be mitigated. An alternative was required that could not only protect the work site at track level but could also be installed without exposing the personnel installing the protection system to the raveling debris. The solution adopted was a mesh attenuation curtain (MAC) draped across the active slope that could be installed without exposing personnel to the active raveling.

Ground hazards are CN's third most costly type of railway hazard, with rock and debris landslides contributing to 10% of annual accident cost. These statistics highlight the importance of a structured ground hazards risk management system in addressing both emergency situations and potential future accidents. The benefit of KCB's rock slope risk management approach utilized in this project is to reduce the number of service disruptions and associated costs for the operator; and avoid environmental contamination and dangerous consequences to the public.

Meeting Client's Needs

Realizing there remained a significant but uncertain amount of residual risk associated with the disturbed rock slope, CN retained KCB to undertake a study aimed at assessing the residual risk and determining the most appropriate control measure to bring the risk at this site to an acceptable level. The designed protection structure uses modular components, facilitating construction under railway traffic and reducing track service disruptions.

The rockslide investigation and subsequent design and construction of both the mesh attenuation curtain and the composite barrier wall/rock shed structure at Mile 109.43 of CN's Ashcroft Subdivision represented a complex and challenging project which required the collaboration of several parties including: Canadian National Railways, Klohn Crippen Berger Ltd., Geobrugg AG, Emil Anderson Construction Inc. and Roca Surveys Ltd. Additional modeling support was provided by Dr. Doug Stead and Dr. Oldrich Hunger from Simon Fraser University and the University of British Columbia, respectively.

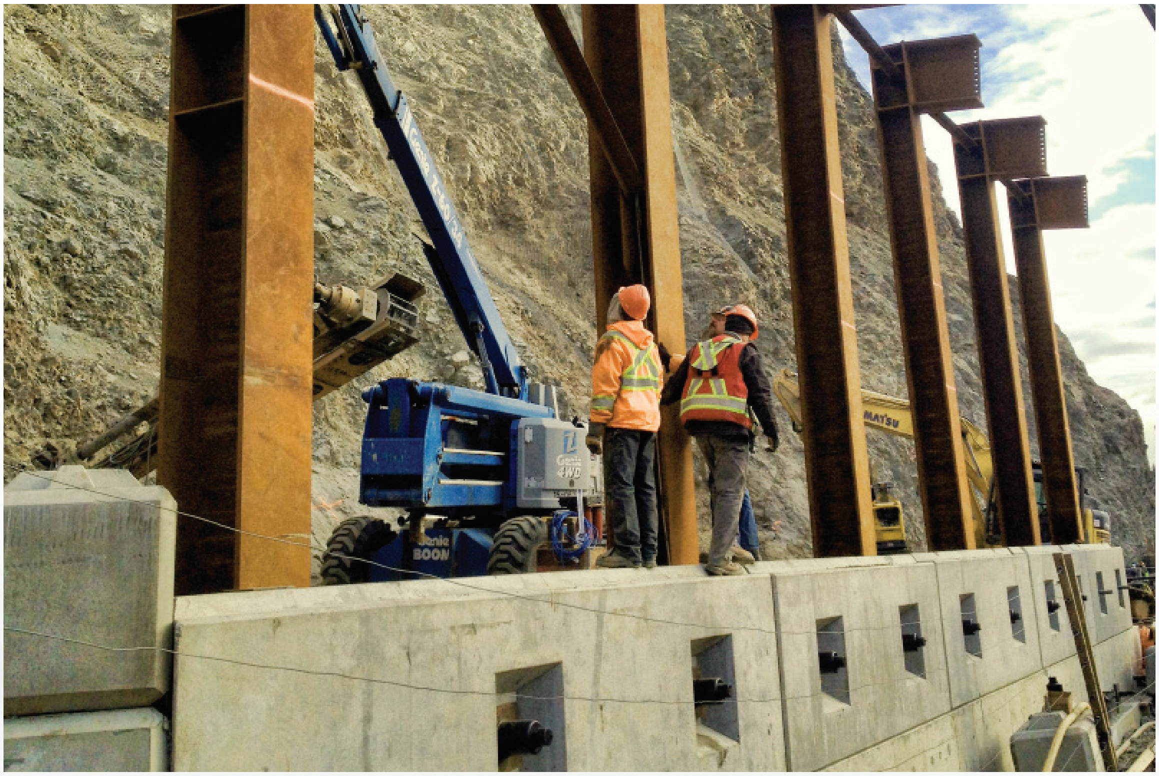
The team successfully developed solutions for each challenge the project presented.

LANDSLIDE

53,000 m^3 rock landslide on November 25th, 2012

LANDSLIDE

Debris covered 70 m of track with debris up to 10 m deep; destroying a 21 mlong concrete rock shed



MODULAR CONCRETE COMPONENTS

First row of modular pre-cast concrete panels tied back to the bedrock with rock anchors

MESH ATTENUATION CURTAIN

View of the mesh attenuation curtain across the rockslide area

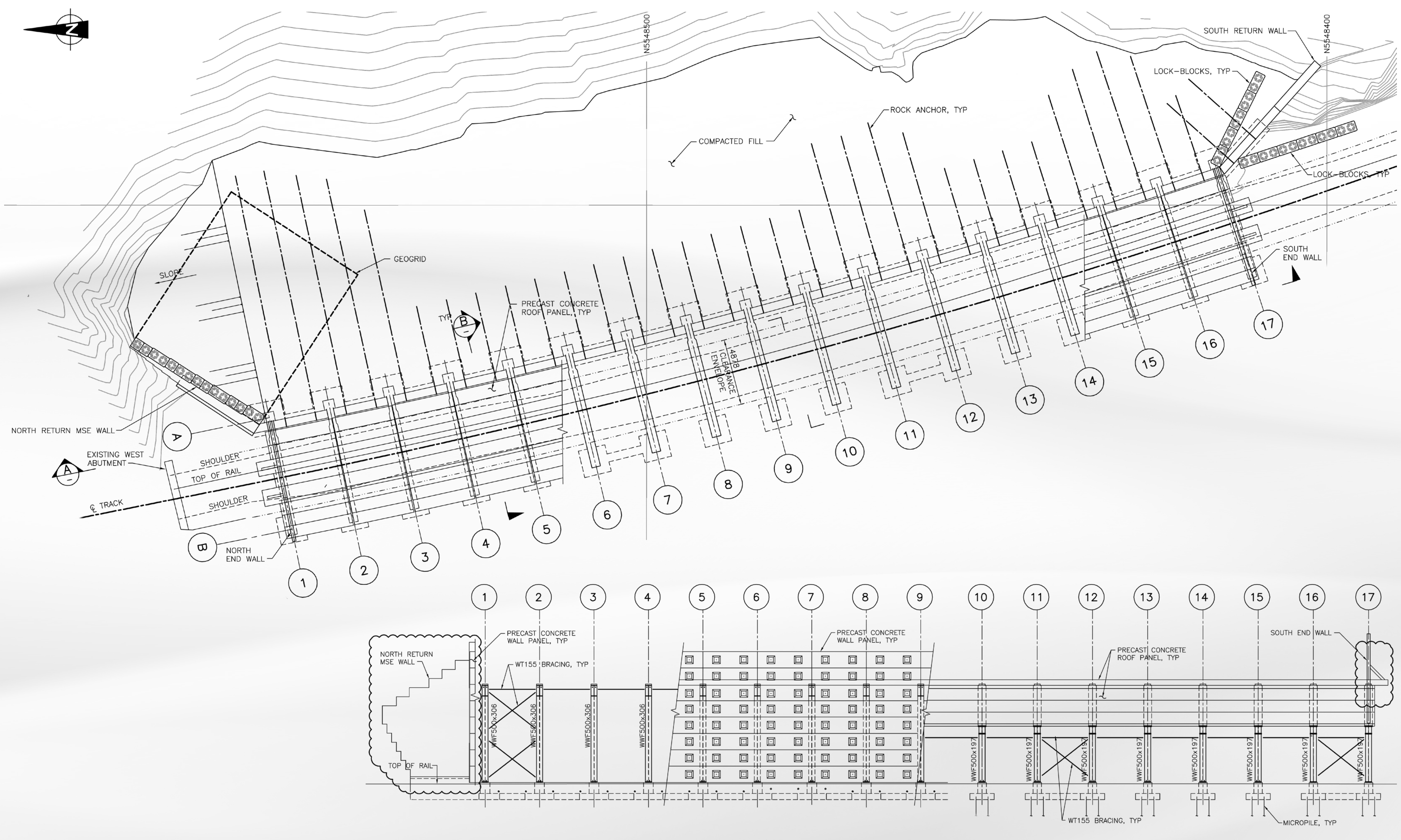
ROCK SHED

Completed rock shed

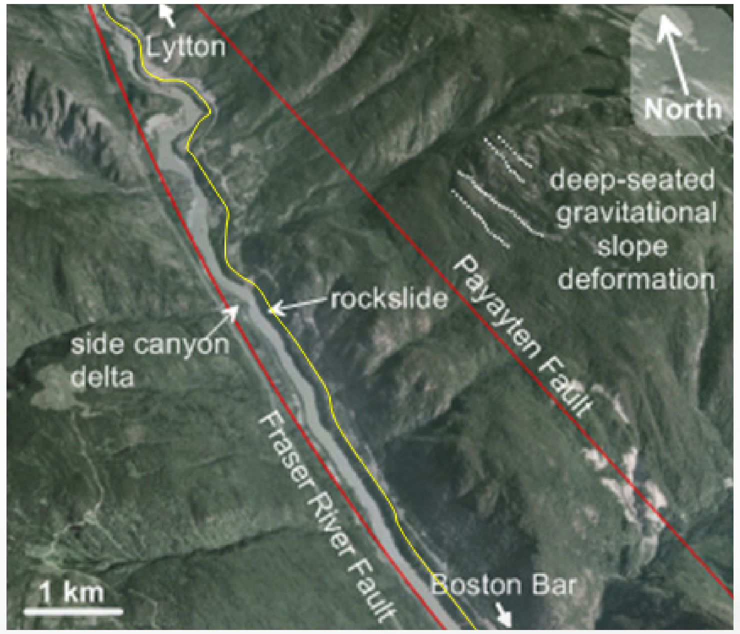
ROCK SHED

Completed rock shed with mesh attenuation curtain above

GENERAL ARRANGEMENT

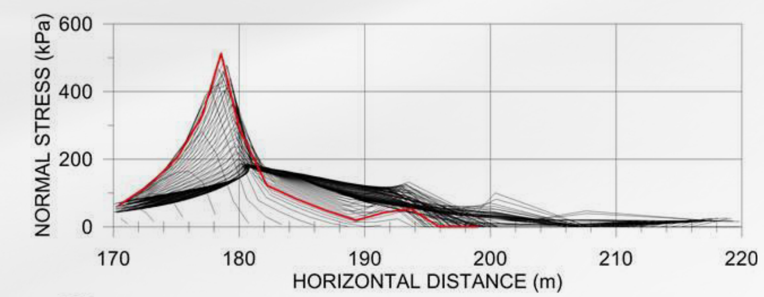


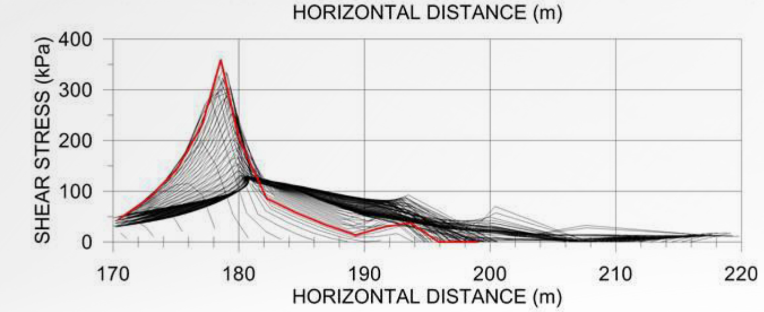
SITE LOCATION

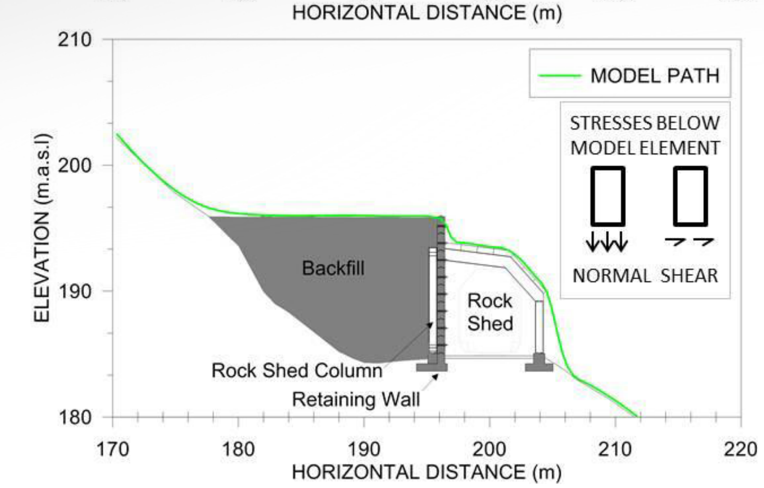


ANALYSIS

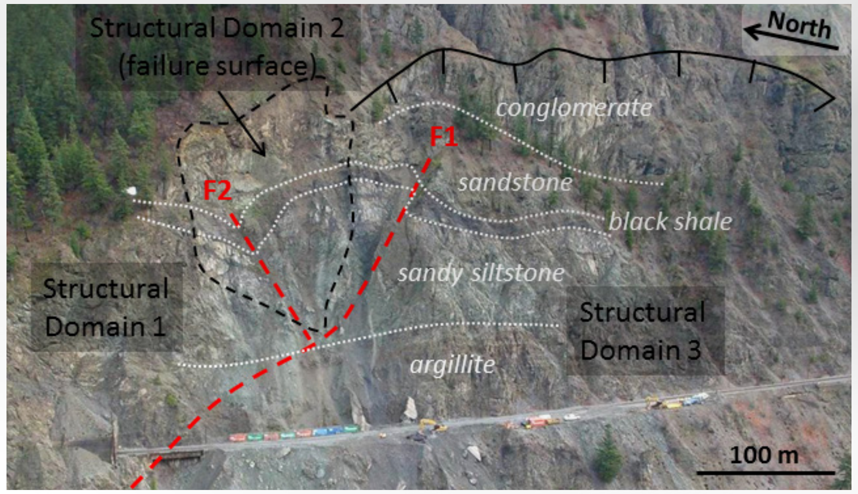
Numerical analysis was carried out using DAN-W software to derive impact loads for design of the new track protection structure.







POST-SLIDE GEOLOGY



ARTIST RENDERING

Klohn Crippen Berger