Top Down Road Reconstruction, Slope Stability Solutions on a Budget

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Abstract

A new approach to road and landslide stabilization using small inclusions, and lots of them, not only proved to be an effective permanent fix, it was also delivered quickly and on budget that was 50% less than traditional methods. The approach combined design/build project delivery, soil/rock anchor technology and geosynthetic reinforced soil (GRS) with micropiles. This combination repeatedly produced efficient, high quality, long-term solutions that were previously unattainable.

This paper highlights a pilot project on Vancouver Island, British Columbia that embraced these concepts. It proved to so versatile in a variety of terrains that is was used on other highways and gained the attention of the BC Premier who granted it the 2013 Premiers Innovation Award.

The 7 sites across Vancouver Island, BC. each had some, or all, of the following attributes: steep ground, limited access, environmental constraints and/or limited right of way.

Design/build delivery with small inclusions, and lots of them, were the theme of this work. Soil and rock anchors, closely spaced micropiles and geosynthetic reinforced soil (GRS) were the tools. Small footprint, few resources, shortened construction timeline and reduced cost with a wide applicability was the result.

The Challenge

Unlike large jobs, the small, non-emergency, maintenance type work on secondary or rural roads have limited political pull, few resources, but all the technical challenges. Every site was unique and every site had challenges. This resulted in the need for specialized engineering and/or expensive investigations and logistical considerations.

The following few examples were all long standing challenges that the BC Ministry of Transportation and Infrastructure had been repairing, studying and routinely maintaining for years, even decades at an ever increasing cost to the taxpayer.

The Test

After years of watching traditional methods either consume budgets or simply prove to be too expensive to proceed, a test project was entertained. In 2011 the South Coast Region took on a new venture that captured multiple projects under one design/build contract on Vancouver Island.

The Vancouver Island District was canvassed and suitable projects were highlighted for cost and priority. The list identified 12 challenges with a combined construction cost estimated at over $10 million using traditional methods.

The Region allocated $500,000 for the preliminary work. The intent was to mitigate 5 sites: Ford Cove Hill on Hornby Island, and 4 sites on Highway 4: Kennedy Canyon, Kennedy Lake East and West Slides and Kennedy Lake Pinch point. Highway 4 travels across mid Vancouver Island between Qualicum Beach and Tofino.

These projects proved so successful that additional work was completed under a different contract on Highway 14. Highway 14 travels up the southwest coast of Vancouver Island from Victoria to Port Renfrew.
Design Methodology

The design/build process is best completed when there are synergies between the designers and construction crews. The flexibility of a system and process are critical to allow for field alteration as required.

The preliminary design was based on basic site measurements, observations, experience, and past studies (when available). The assumptions made in the initial design work were verified through the construction process and alterations were made as warranted.

Design methods for the soil anchors, micropiles, and GRS followed the following publications:
- FHWA0-IF-03-017, “Geotechnical Engineering Circular No.7”

Project Overviews

The following case studies are highlights from the initial design build contract and the additional work completed on Highway 14.

Both Highway 4 and Highway 14 traverse extremely steep and rugged coastal terrain. The routes were initially pioneered in the 1950’s as forestry and mining roads carved out of the slopes and wilderness as single lane dirt tracks. Much of the road length was cut fill construction with frequent rock cuts and log cribbing to cross the steeper ground and gully systems.

The routes were further challenged with high rainfall, up to 4m/year, and limited width due to cliff bands, streams and lakes.

Highway 4, Kennedy Hill West Slide

Kennedy Hill West Slide was a shoulder fill area that was impacting the westbound lane for decades. During wet weather events it was not uncommon for the slide to move several cm’s/day and 100-300mm annually causing frequent need for asphalt patch repairs. The road width as also very narrow constrained by large boulder (5-8m diameter) colluvium on a steep slope above and Kennedy Lake below.

In 2008 the Ministry made some improvements through the area with a road widening project using concrete blocks and geogrid. The project was initially successful at gaining the desired width, however the additional loading only exacerbated the slope movement (Figure 1).

Geotechnical investigations found the soil to be a boulder colluvium. Bedrock was not intercepted by the drilling but could be found as an outcrop 15m below the road. The preliminary engineering suggested complete road reconstruction using retaining walls founded on the bedrock. Unfortunately the preliminary estimates made the project cost prohibitive and maintaining traffic through the work zone could not be guaranteed.

The preliminary engineering by GeoStabilization International (formerly Soil Nail Launcher based in Colorado) was completed and the construction work through their Canadian contractor was completed (Figure 2).

The work involved soil anchors varying in length from 6 to 18m through every concrete block and a third row above on an offset pattern. The anchors were all grouted into the boulder colluvium and bedrock was not intercepted (Figure 3). Torsional stiffness and corrosion protection was gained with a shotcrete shell (Figure 4).
The work was completed late 2011 and the site has performed exceptionally well ever since. The MoTI Road Area Managers comment when the work was completed “It is interesting, driving across it now “feels” solid.”. The last inspection in March 2014 found no reflective cracking or settlement.

**Highway 4, Kennedy Hill East Slide**

Kennedy Hill East Slide was only 40m east of the West Slide (Figure 5), but the morphology of the slide was completely different.

The site crossed a rock cut and fill section that was also widened using similar techniques of concrete block and geogrid in 2008. Unfortunately the additional width was unknowingly placed over the edge of a subsurface rock cliff and over the next 3 years the work progressively slid down the slope approximately 7m and reduced the road width back to pre construction widths (Figure 6).

**Highway 4, Kennedy Lake Pinch Point**

The “Pinch Point” was a trafficability challenge for decades that became more of an issue with 2008 road improvements just to the west that widened the road and effectively increased the hourglass effect that pushed vehicles toward the inside cliff.

Eastbound, the highway closely followed the shores of Kennedy Lake and then steeply climbed to an upper bench across a steep cliff face. The “pinch” was created at the base of this hill with the construction of cast in place gravity wall from the 1950’s.

Additional width was needed but infilling into the lake was not an option and deconstruction of the wall would render the highway impassable during construction (Figure 8).

Due to numerous factors, the engineering and delivery was undertaken by the author, Peter Bullock, P.Eng., M.Eng. The design involved tie back support for the marginally stable gravity wall into bedrock, GRS fill supported by micropiles and a tie back anchor system to gain the additional width (Figure 9).

![Figure 5. Typical West Coast Terrain and the site of the Kennedy Hill East and West Slides.](image)

![Figure 6. Kennedy Hill East Slide pre 2011 construction.](image)

![Figure 7. East Slide with shoring and micro piles constructed.](image)

![Figure 8. Kennedy Hill Pinch Point overview.](image)

![Figure 9. Typical Cross Section.](image)
The final product gained the necessary road width allowing for enhanced road geometrics and additional shoulder width (Figure 10).

**Hornby Island Ford Cove Hill**

Hornby Island is a remote Northern Gulf Island just south of Comox, BC. Travelling there requires two ferries from Vancouver Island, via Denman Island. This trip takes time and logistical challenges for not only the locals but construction intent too.

The Island has one main access road from which the secondary roads connect to. Near the end of this road is a large cliff escarpment of conglomerate and sedimentary rock sequences. The road traverses down across the cliff face to the harbour below.

Near the top of the hill was a section that was built out onto a rudimentary log crib and a poorly constructed road side barrier “wall”. The challenge was the logs were rotten and no longer able to support the shoulder fills above. The consequential settlement was impacting the road surface, the cross culvert system, and increased the maintenance needs.

Unlike the other sites highlighted in this paper, bottom up construction was an option. The preliminary design to remove the shoulder fills and reconstruct with GRS founded on bedrock was completed, however the construction cost estimate was more than anticipated and the need to remove the protected Gerry Oaks from the work zone was not desirable so alternatives were investigated.

The result of the second phase investigation found that a “beam” of soil anchors across the top of the slope would adequately support the failing shoulder fills and off-load the soil below stabilize them as well. The overall construction cost was less than half of the original design and no trees were lost in the process.

**Highway 14, Lost Creek Culvert**

On August 30, 2012, the author sat in a pre construction meeting for a paving project along Highway 14 near Sombrio Bridge. During the meeting it became apparent that the cantilevered log section in Lost Creek had not been identified or highlighted to the contractor, nor had construction plans been investigated due to the technical challenges of the site. This was a problem as it would not address the maintenance issue of the site and the contractor was reluctant to cross the area with the heavy asphalt equipment.

The 15m wide segment crossed a natural steep gully system where the bedrock quickly fell away. The cliff below was approximately 40m high above Lost Creek with an overall slope angle of nearly 60 degrees. Shoulder loss was mitigated with the addition of several logs in the fill effectively bridging the gully and twin culvert system (Figure 14).
Timeline and budget were critical for this job. The pavers were scheduled passing through this segment within 3 weeks of the pre construction meeting. In that time a design had to be developed, a contractor secured and construction complete to allow for asphalt.

Through the successes of the previous work on Highway 4 enough experience was gained to develop a GRS fill supported by rock anchors and micropiles into bedrock (Figure 15).

The system worked and the paving schedule was unaltered.

Conclusions
Within a 12 month period 7 significant sites within the MoTI inventory had been mitigated with long term solutions and are now no longer maintenance issues. These repairs were extraordinarily efficient as the construction costs in terms of both time and money were repeatedly less than 50% of traditional approaches.

Much of the savings were due to the compressed investigation, design and construction sequence afforded by the design/build approach. The technical requirements were attained with the philosophy that “many hands make light work”. The close spacing of smaller anchors provides a more uniform loading and redundancy, while the close spacing of the geosynthetic fabric completely alters the soil mechanics of the retained fill.

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References


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Peter Bullock, Principal Engineer. Peter is a native of British Columbia, holds a Geological Engineering degree from the University of British Columbia, and has 20 years of experience within the earth science and engineering fields. His early days were spent primarily in the forestry and mining sectors both within the corporations and as a consultant. In 2006, Peter moved into the Public Sector as a Regional Geotechnical Engineer for the Ministry of Transportation in BC. Through the years Peter has been involved with hundreds of projects that ranged from routine maintenance to multi million-dollar legacy and capital works projects. Many of these projects were scattered across the globe and ranged from the African deserts to the ice of Antarctica. His earlier years focused on the natural hazard side of geotechnical engineering. These hazards included landslides, slope stability and rock fall challenges. As his career progressed he became more interested in the structural side of engineering, which led him to complete his Masters of Engineering at the University of Saskatchewan, gained him a nomination for the BC Premiers Award for Innovation and ultimately GSI.