Anchors, Micropiles and GRS – 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 pilot project involved 7 Ministry of Transportation and Infrastructure sites on Vancouver Island. There was a common theme for the locations: remote, steep, and each were along critical access routes to the towns or communities they served with no easy solution for repair.

Road closures were not an option, and traditional methods proved to be too expensive to entertain. Due to these constrains the necessary repairs could not be completed in a traditional fashion and over years and decades caused maintenance work to be more frequent at an ever increasing cost.

Through extensive research and a collaborative effort, the above-mentioned techniques successfully mitigated every site with minimal traffic disruption and at a fraction of the time and cost associated to traditional approaches.

RÉSUMÉ

Une nouvelle approche de la route et à la stabilisation de glissements de terrain à l'aide de petites inclusions, et beaucoup d'entre eux, non seulement se sont révélés être une solution efficace et permanente, il a également été livré rapidement et le budget qui était de 50 % moins que les méthodes traditionnelles . L'approche combinée exécution des projets de conception / construction, sol / technologie d'ancrage de roche et géosynthétique sol renforcé (GRS) avec micropieux . Cette combinaison produit à plusieurs reprises, de haute qualité, des solutions efficaces à long terme qui étaient auparavant inaccessibles.

Ce document met en lumière un projet pilote sur l'île de Vancouver, en Colombie-Britannique qui a embrassé ces concepts . Il s'est avéré tellement polyvalent dans une variété de terrains qui a été utilisé sur d'autres autoroutes et a attiré l'attention de la Colombie-Britannique Premier qui l'a accordée le Prix de l'Innovation des premiers ministres de 2013.

Le projet pilote, qui consistait 7 Ministère des Transports et des sites d'infrastructure sur l'île de Vancouver. Il y avait un thème commun pour les emplacements: à distance, raide, et chacun d'eux était le long des routes d'accès critiques vers les villes ou les communautés qu'ils servent avec pas de solution facile pour la réparation.

Les fermetures de routes ne sont pas une option , et les méthodes traditionnelles se sont avérées trop coûteuses à entretenir . En raison de ces contraintes les réparations nécessaires n'ont pas pu être effectuées dans un mode traditionnel et au fil des ans et des décennies ont causé des travaux d'entretien à être plus fréquent à un coût de plus en plus.

Grâce à des recherches approfondies et un effort de collaboration, les techniques mentionnées ci-dessus atténués avec succès chaque site avec une perturbation minimale de la circulation et à une fraction du temps et les coûts associés aux approches traditionnelles.

1 INTRODUCTION

Fill slope failures along roads, rail, pipeline, and trails are common and frequently extremely challenging issues. Excavating the failed material out and either replacing it with higher quality soil and construction or retaining structures are the common or “traditional” methods of mitigation. Unfortunately these techniques are laborious, take time, and due to the excavation component are challenging to construct while maintaining traffic.

These types of failures are small but frequent; they also repeatedly prove to be technical but are generally under funded for traditional repair methods. This paper describes recent innovations that not only proved to be very efficient, they successfully mitigated multiple sites in a twelve month period and caught the attention of the BC Premier Awards committee who granted Peter Bullock, P.Eng., M.Eng. and his team the 2013 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.

2 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.

3 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 canvased 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 soutwest coast of Vancouver Island from Victoria to Port Renfrew.

4 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 off 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, micopiles and GRS followed the following publications:

FHWA0-IF-03-017, “Geotechnical Engineering Circular No.7”

FHWA – NHI-05-039 (Dec 2005) “Micropile Design and Construction”

FHWA-HRT-11-027, “Geosynthetic Reinforced Soil Integrated Bridge System Synthesis Report”

5 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.

5.1 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 colluviam. 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.

Figure 1 - Kennedy Hill West Slide

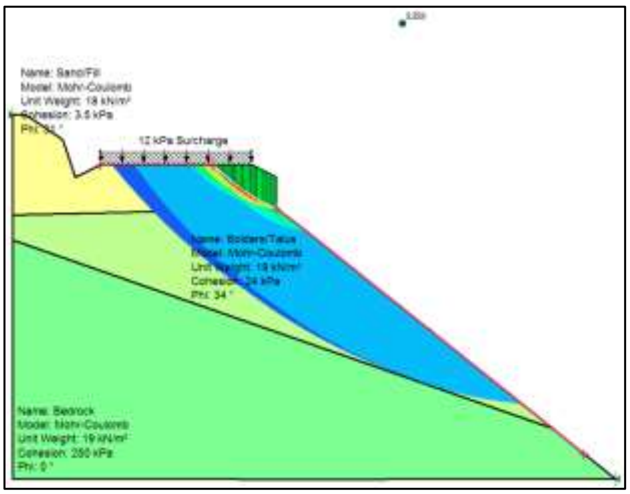

Figure 2 - Preliminary modeling to calibrate the soil anchor design work.

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 colluviam 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.

Figure 3 - Tie back soil anchors through the 2008 concrete blocks and shoulder fill, pre shotcrete.

Figure 4 - Kennedy Hill West Slide complete.

5.2 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).

This site was also investigated and the mitigation cost was prohibitive and the gaining the desired road width was not guaranteed. Using tie back anchors, micro piles and GRS fill, an additional 3m of width was constructed at a quarter of the traditional cost estimate.

Figure 5 - Typical West Coast Terrain and the site of the Kennedy Hill East and West Slides

Figure 6 - Kennedy Hill East Slide pre 2011 construction

The site was excavated to competent material, the road was shored up and the micro piles constructed to gain global stability for the GRS fill (Figure 7).

Figure 7 - East Slide with shoring and micro piles constructed.

5.3 Highway 4, Kennedy Lake Pinch Point

The "Pinch Point" was a trafficablity 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).

Figure 8 - Kennedy Hill Pinch Point overview

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).

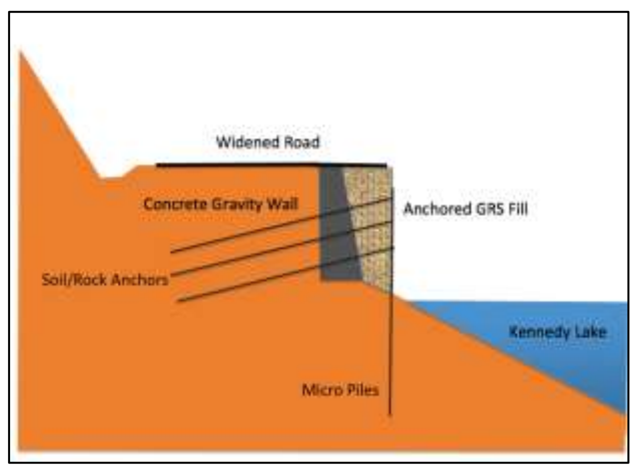

Figure 9 - Typical Cross Section

The final product gained the necessary road width allowing for enhanced road geometrics and additional shoulder width (Figure 10).

Figure 10 - Completed works with additional 2m of width

5.4 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.

Figure 11 - Hornby Island, Ford Cove Hill pre construction

Figure 12 - Preliminary grubbing completed. Barrier and logs exposed.

Figure 13 - Completed project using loose straw for revegetation, wire mesh facing with closely spaced soil/rock anchors.

5.5 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 Sombiro 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).

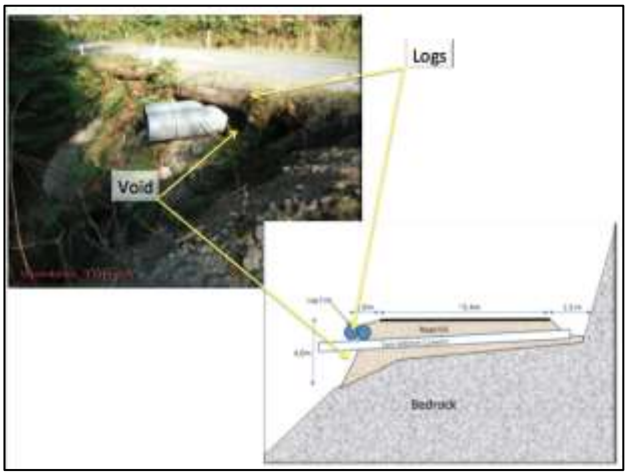

Figure 14 - Highway 14, Lost Creek Pre Construction.

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.

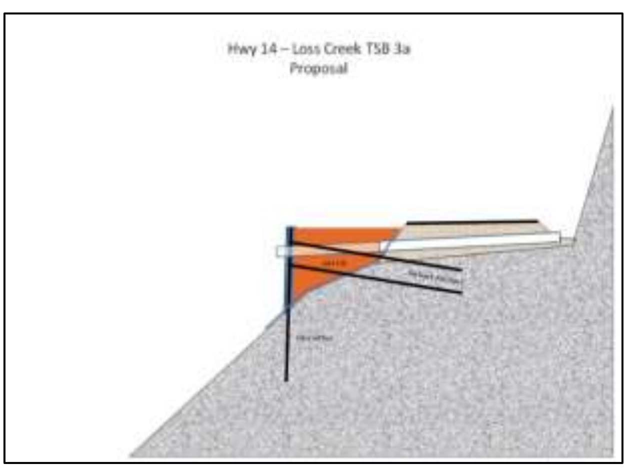

Figure 15 - Lost Creek Typical Cross Section


Figure 16 - Lost Creek wall complete with new asphalt ready for shotcrete.

6 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 fabiric completely alters the soil mechanics of the retained fill.

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