Km 965 Alaska Highway Slope Stabilization

Northern, British Columbia

Golder Associates

GAIA CONTRACTORS

CANADIAN CONSULTING engineer

Project Summary

The Alaska Highway a pioneer road.

Twelve years of continuing instability along a 180 m section of the Alaska Highway has ended. The Golder/GAIA design-build solution using Cutter Soil Mixing (CSM) technology stabilized the embankment by providing economical cost effective barrette strengthening inclusions within the soil. The vital link that connects people, communities and access to the rich natural resources of northern BC is now secure.

Project Highlights

Innovation and New Applications for Existing Techniques

Since its completion in 1946, the Alaska Highway has been the main passage connecting people, communities of northern BC and providing access to the rich natural resources the area offers. The highway was originally constructed by the American Army as a supply route during the Second World War and stretches more than 2,000 kilometres (km) north from Dawson Creek, BC, to Alaska through some of the most mountainous terrain in the province. Slope movements and landslides are a recurring problem for several sections of the highway.

Golder/GAIA undertook an embankment stabilization assessment of a 180 m section of the Alaska Highway at Km 965. The historic instability and recurring slope movements and landslides along this section of the highway made repair a priority. We reviewed several options to stabilize the embankment which included stabilization methods such as; soldier piles, sheet piling, soil nailing, caissons, road re-alignment, deep soil mixed panels and other methods. Review of these options indicated that the most cost effective option with limited environmental and traffic interruption impact was *in situ* cement/soil barrettes.

The embankment stabilization works is a series of barrettes (panels), consisting of a mixture of soil and cement blended into a homogenous mixture using a Bauer manufactured deep soil mixing machine. The stabilizing barrettes are oriented perpendicular to the road alignment, approximately parallel to the direction of movement of the embankment. The panels have a minimum wall thickness (along the road alignment) of 1 m and a minimum length of 5.4 m (perpendicular to the road alignment). The spacing of the barrettes is dependent on several factors including; the strength of the embankment materials; the selected strength and modulus of the soil-cement; arching capability of the soil between the panels and compressive and tensile stresses mobilized within the panels resulting from loads imposed on the panels. We established the barrette spacing at 5 m by conducting detailed analysis. The barrettes extended a minimum depth of 1 m into competent bedrock to mobilize the resistance required to provide an overall minimum global factor of safety of 1.5 against continued sliding. We installed to depths varying from 10 m to 13 m thirty seven soil mix *in situ* shear walls using the Cutter Soil Mixing (CSM) technique over a 180 m length.

This method is new as it relies on the inherent stiffening that is achieved to a soil slope through the installation of strong inclusions into the soil mass. To our knowledge, this is the first time such a slope stabilization method has been used in western Canada.

Complexity

The use of inclusions as slope stabilization measures is not new technology but normally piles or drilled anchors have been used in the past. The effectiveness of such construction has been marginal at best and is generally not considered to be a method of choice. Generally some form of retention system is considered because of the effectiveness of the construction. In general these constructions are expensive and site intrusive. The use of soil mix barrettes is new in that the construction of *in situ* walls within the failing soil mass is to reinforce the soil. The design adopted for the Alaska Highway remediation required detailed finite element analysis of the deformation and effect of soil structure interaction within the embankment. Detailed analysis established the strength requirements that were necessary to be achieved in the barrettes to assure that the stabilizing reinforcement was satisfactory. Detailed sampling of the soil/cement mix was carried out during testing and extensive compression testing of the samples was carried out. In addition, following construction all panels were core drilled and the representative samples of the cored soil/cement tested. These test assured compliance to the compressive strength requirements established from the finite element analyses.

Environmental Impact

The location of the roadway above the Liard River was an environmental constraint on the project because the original road was built by excavating into the uphill slope and by end-dumping fill over the downhill side. This created an oversteep embankment that continually ravelled and was only nominally stable.

Because of the proximity of the river, we developed a construction methodology that would not aggravate the overall slope stability and would ensure that access road construction downhill would not result in slumping of soil into the river. Using a CSM process working from the shoulder of the road did not require access road construction and thereby was a more secure construction method and had no environmental impact.

Social and Economic Benefits

The The Alaska Highway is a critical roadway connecting BC to the Yukon and local communities require a well-maintained road to ensure safe passage. The slope instability at Km 965 was ongoing for many years and a continual maintenance problem. In 2009, a sinkhole appeared in the pavement structure directly associated with the slope movement. A solution was necessary as the safety of the road was compromised and the risk for vehicle damage and potential loss of life due to traffic leaving the road embankment was high. The construction of the barrette stabilization measures eliminated these risks.

Increasing the stability of the slope makes the road a safer passage for both present and future users and ultimately benefits tourism and businesses. In turn, this helps to develop the northern communities as well as provincial and national economies.

The highway requires continual maintenance to ensure safe passage of travelers along its route, especially after the annual spring break-up when thawing temperatures cause an easily eroded and rutted soft road bed. The maintenance was an ongoing burden for the government. The deterioration of the road appeared to be accelerating, which resulted in rising maintenance costs and a growing need to find effective cost-reduction measures. The CSM-treated remediation of the slope was compared to other techniques and found to be the most economical option. The construction resulted in more than $1 million savings compared to alternative measures.

Safety to the traffic over this section of the road is assured and pavement maintenance will be reduced allowing concentration of funds in more severe areas.

Meeting and Exceeding Owner's / Client's Needs

The CSM option presented a solution that addressed all the stabilization requirements and delivered cost savings of more than $1 million, over 55% less than any of the other options considered. The design-build contract was effectively completed to the design specification, within budget and to the satisfaction of the client.

Introduction

The Alaska Highway a pioneer road.

The Alaska Highway Slope Stabilization Project was a Design Build project carried out to stabilize a problem slide area at Km 965 on the Alaska Highway above the Liard River and east and south of Watson Lake, BC.

The Alaska Highway is a critical roadway connecting BC to the Yukon. The road is a major artery and local people require that the road be well maintained to ensure safe passage. Approximately 180 m of highway had been affected by slope movements. The highway is situated over a steep embankment which descends into an inside corner of the Liard River. The movements have generally manifested themselves as tension cracks within the embankment slope (down slope from the highway). These tension cracks have extended upslope and into the highway structure while exhibiting both transverse and vertical movements, an indication of a progressively deteriorating condition of the embankment.

The slope instability which was ongoing for many years was a continual maintenance problem and in 2009 a sinkhole had appeared in the pavement structure directly associated with the slope movement. This situation was becoming critical to road maintenance and needed to be stabilized and repaired for continual road performance. If such a situation were to continue the safety of the road would be impacted and the risk for vehicle damage and potential loss of life due to traffic leaving the road embankment was high.

Stability calculations were carried out to determine the best methodology for the remediation works. Various options for stabilizing the slope were considered. As a result of a detailed assessment and comparison of the options, a Cutter Soil Mixing (CSM) retention system to provide stability to the active slide area was adopted. The work was carried out using a soil mixing technique by the construction of barrettes in the soil and thereby reinforcing the soil mass to provide the shear strength necessary to resist the instability.

Objectives and Solutions

The team's primary objective was improving the safety of the highway users. The main design goal addressed the long-term slope instability that was occurring at Km 965 on the Alaska Highway and avoided the need for ongoing maintenance. This stretch of the highway is now a safe passage for commercial transport, tourism, and residents. Due to the northern climate, the team faced a very tight construction window, which was a determining factor in completing the work on schedule. The team's experience of working in winter conditions was a benefit, as project work needed to advance quickly to achieve the target date. Overall, the solution offered the best project management and value for money.

Golder/GAIA developed a design using CSM, a new technology that would provide the solution required. The team met the overall objective of finding a solution for the 12 years of instability at Km 965 on the Alaska Highway. The completed work provided a safer, more efficient passage and eliminated the need for frequent maintenance required to keep this section of the highway safe and open to the public.

Challenges

Geotechnical Challenge

Geological investigation indicated that the surficial geology of the area consists of glacial and glaciofluvial deposits. The Alaska Highway to the south of the site is located on an old glaciofluvial terrace. North of the site, the highway skirts an area of glacial moraine which ascends onto a glaciofluvial outwash plain. From the site northward, the Liard River is located within a steep canyon. The rock types present are primarily dark grey to black shale, siltstone and argillite with minor limestone which are prevalent along the lower portions of the embankment slope bounding the shoreline of the Liard River. The following soil conditions existed in the slope.

- An upper layer of inferred road way embankment fill comprising 0 m to 4.5 m of very loose to dense silty sand with gravel;
- A lower layer of inferred native soil comprising 0.5 m to 8.0 m of loose to very dense sand and silty sand with gravel;
- Underlying the native sandy soil is a very dense zone of bedrock weathered to soil estimated to be approximately 1 m to 2 m thick;
- Groundwater levels in the slope were regionally controlled and consequently variable depending on precipitation and snow melt, but in general were approximately 7 m below the crest of the highway embankment.

The design and construction challenge was to come up with an effective design to prevent continual movement. The slope movement failure plane was estimated to extend some 12 m below ground surface. Applying more conventional construction would be difficult because of the location above the Liard River and the depth of soil that had to be resisted.

Alignment Challenges

The slope stabilization works required consideration of access, maintenance of traffic flow by ensuring the road remained open, the precipitous nature of the embankment situated above the Liard River, and environmental issues to prevent material loss in to the river. The window available for the construction was restricted due to the northern climate affecting time of frost thaw in the ground, and limited good weather winter conditions. This restriction required creative thinking and the decision to utilize a Design Build (DB) contract was made realizing that the design would need to be implemented and issues resolved after construction began.

Economic Challenges

There was a limited budget for the work and if construction costs were exceeded it meant that the scope of the project would be reduced to maintain the overall cost within the monies available. Of the several alternatives reviewed for the works, the CSM construction was deemed to be the most competitive.
All construction problems and issues under the DB contract were completed entirely within the monies available for a cost of less than $1million.

Innovation and New Applications for Existing Techniques

New Applications for Existing Techniques

An emerging technology in other parts of the world, this project represents possibly the first ever North American application for this design approach used for a slope reinforcement applying *in situ* soil mixing to stabilize a landslide in steep terrain.

Several options to stabilize the embankment were reviewed which included stabilization methods such as soldier piles, sheet piling, soil nailing, caissons, road re-alignment , soil mixed panels and other methods. Review of these options indicated that the most cost effective option was the use of *in situ* CSM barrettes. This option not only was the least expensive but could be expedited rapidly. It also had the advantage that the highway did not need to be closed or traffic flow diverted, and excavation of downslope fill was not required. By adopting the CSM stabilization, the work was completed in the available limited time period of slightly over 1 month and demobilization occurred after the first snow fall.

Innovation

The embankment stabilization works is a series of barrettes (panels) consisting of a mixture of soil and cement blended into a homogenous mixture using a Bauer manufactured deep soil mixing machine. The stabilizing barrettes were oriented perpendicular to the road alignment, approximately parallel to the direction of movement of the embankment. The panels had a minimum wall thickness (along the road alignment) of 1 m and a minimum length of 5.4 m (perpendicular to the road alignment). The spacing of the barrettes was dependent on several factors including; the strength of the embankment materials; the selected strength and modulus of the soil-cement; arching capability of the soil between the panels and compressive and tensile stresses mobilized within the panels resulting from loads imposed on the panels. This barrette spacing was established by detailed analysis at 5 m. The barrettes extended a minimum depth of 1 m into competent bedrock to mobilize the resistance required to provide an overall minimum global factor of safety of 1.5 against continued sliding. The barrettes were situated between the existing highway and the Liard River to optimize the stabilizing benefit of the panel (i.e. located as close as reasonably accessible to the initial failure area) as well as limiting the amount of disturbance to the existing highway and lower portions of the existing embankment.

Thirty seven (37) Cutter Soil Mixed (CSM) *in situ* Barrette Shear walls were constructed with a minimum completed dimension of 5.5 m by 1.0 m in plan, and extended through overburden soils comprising silty sands and sandy silts with gravel and cobbles to depths of between 10 m and 13 m. Completed soil mixed shear walls had a specified design minimum 28 day unconfined compressive strength of 1.5 MPa over the bottom 8.0 m of constructed wall, and a minimum 28 day unconfined compressive strength of 1.0 MPa over the remainder of the wall.

Equipment

Cutter Soil Mixing (CSM) equipment consisted of a system capable of cutting and blending the *in situ* soils using cutter wheels which rotate about a horizontal axis and which introduces a suitably designed and controlled cement slurry through a nozzle situated within the cutter head. The equipment was capable of recording applied cutter wheel torque, cutter wheel speed, slurry volume delivery per increment of depth (such increment not to exceed 0.5 m), and cutter head position in all three planes to an accuracy of at least 0.1 m, in real time.

Social Economic and Environmental Impact

Economic Impact

The continual maintenance requirements to ensure safe passage on the highway were a continual economic burden on the operation of the highway. This maintenance was necessary on an annual basis especially after spring breakup. The deterioration of the road was becoming more of a concern as costs of maintenance repairs were increasing since the deterioration seemed to be accelerating and the need for effective cost reduction became more apparent. The adoption of a CSM treated remediation of the slope was compared to other techniques and found to be the most economical. The construction resulted in more than $1 million saving compared to other alternatives.

Environmental Impact

The adoption of the CSM remediation option for the stabilization had the least impact on the existing environmental conditions. Equipment on site was maintained at a minimum and the use of minimal excavation, and the need for extensive access road construction resulted in a minimum footprint at the site. An effective completion of the construction of the barrette inclusions with minimal clean up requirements or disturbance to the area was testimony to the effectiveness of the option adopted.

Meeting and Exceeding the Clients Needs

The CSM option presented a solution that addressed all the stabilization requirements for a total cost of less that $1 million substantially less than other potential stabilization measures. The CSM option was selected by Public Works Government Services Canada, and was successfully completed in the fall of 2010.

Another unique aspect of the project was the ability of Golder to provide all the necessary expertise from design through to construction, in-house. GAIA Contractors (a wholly owned subsidiary of Golder) developed and provided the DB CSM solution. Golder geotechnical engineers carried out detailed analysis on the design and GAIA contractors staged the construction. QA/QC was carried out by Golder.

The DB contract was effectively completed to the design specification, within budget and to the satisfaction of the client.

Successes

The Alaska Highway in this region has provincial and national significance. The Km 965 Alaska Highway Slope Stabilization project supports the main objective of providing better access to northern communities; a vital link for tourists, residents, and commercial vehicles alike and provides a safe passage for all. Our involvement in the Alaska Highway slope stabilization project earned recognition by the Consulting Engineers of British Columbia and received an Award of Merit.

Layout of equipment on site

Cracks in pavement

Typical cement/soil mix core

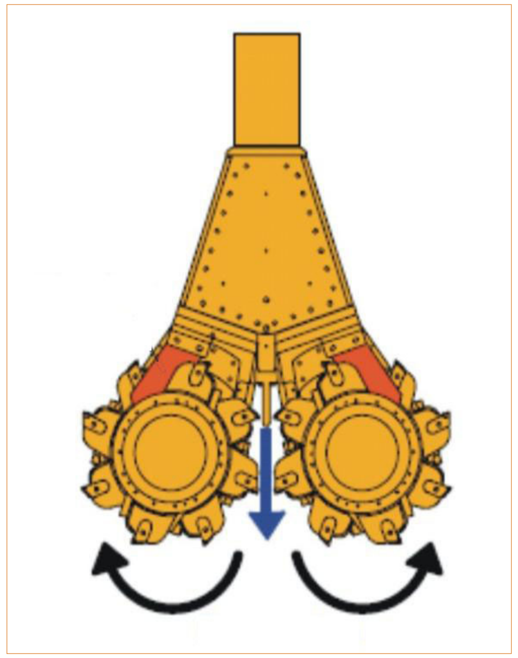
Cutter soil mixing equipment

Location of barrette construction

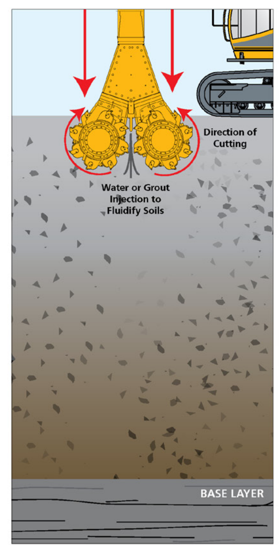
Cutter penetrating road embankment

Trench of cement mixed soil

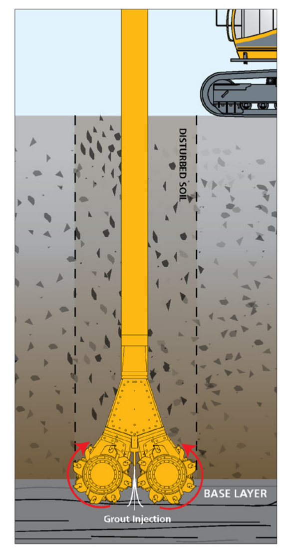
Barrette construction



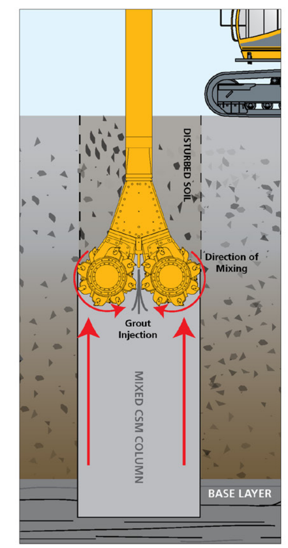
Frontal view of the cutting wheels on CSM.



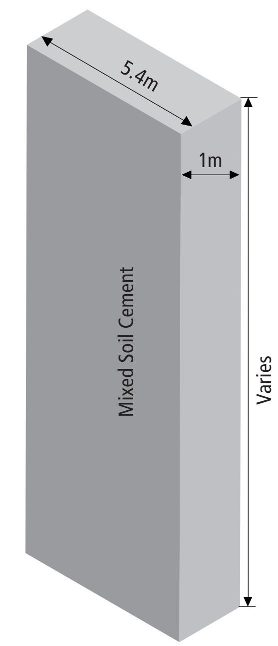
Cutting Phase



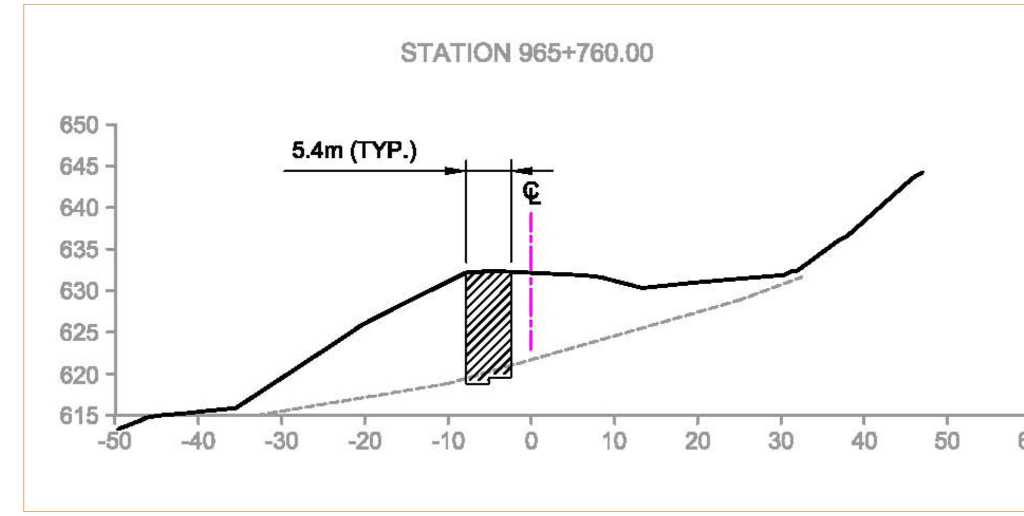
Socketing into Base Layer



Withdrawal & Mixing Phase



Single Barrette



Typical Section