Use of Launched Soil Nails to Stabilize Shallow Slope Failure on Urban Access Road 172

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Abstract

In the transportation industry there are many methods of slope and embankment stabilization. Traditional soil nailing is one such method, which employs inserting nails into pre-drilled holes, then grouting them into place. A variant of this procedure, Launched Soil Nails (LSN), uses compressed air to accelerate a 6 m long 40 mm diameter steel nail or rod into the ground at over 350 km/hr. Research has indicated that at this high velocity a shock wave is generated ahead of the nails that elastically deforms the soil which subsequently rebounds and bonds to the nails (i).

LSN was used on an Alberta Transportation (AT) project site near the village of New Sarepta about 40 km southeast of Edmonton on Urban Approach Road 172. The failed area was a shallow slope failure approximately 130 m^2 in size. The LSN solution was ideal for site specific considerations such as a nearby high pressure oil pipeline, fibre optic cables crossing the failed area, 1200 mm diameter culvert immediately beneath the failed area, high road fill, and limited access.

LSN is not a broad replacement for traditional methods of slope stabilization. However, in cases where slope failures can be compared, LSN has its advantages over traditional methods of slope stabilization. LSN reduces cost, saves time, reduces public disruptions, reduces environmental concerns, and is a flexible and viable option for stabilizing slopes.

Purpose and Scope

The selection and design of launched soil nails is described in this paper. The LSN technique was used to stabilize a shallow slope failure at a site designated by Alberta Transportation as a Geohazard Risk Management Program (GRMP) site NC47, located in the North Central Stony Plain region. The geographic location of the site is about 40 km south east of Edmonton, on Urban Approach Road (UAR) 172 to the Village of New Sarepta (Figure 1).

Soil nailing is already a well known method of stabilizing embankments and vertical soil faces. However, using high pressure compressed air to launch soil nails to stabilize slopes is still a relatively new concept in Canada.

Background and Site Information

The NC47 site is a 6 m high road fill embankment through a seasonally swampy area. The sideslopes are steep, the right-of-way is narrow, and there are a number of buried services in the immediate vicinity of the site. The shallow slope failure was threatening the eastbound lane of UAR 172 and the notable impacts to the roadway were a parallel longitudinal crack in the eastbound lane about 2 m from the edge of pavement, a sag in the guardrail and roadway (Photo 1) and a back scarp associated with the unstable slope right up to the guardrail posts near to the edge of the pavement (Photo 2). This slope failure was identified at an initial site visit made in June 2005.

Features associated with this site include:

- A steep 2 H : 1 V sideslope, with the right-of-way boundary at the base of the slope
- A vertical scarp approximately 2 m high immediately to the south of the guardrail posts
- A w-beam weak post guardrail system

There were also a number of buried services and structures which are listed as follows:

- A TELUS telecommunications cable passing through the slide area on the south side
- A nearby high pressure oil pipeline crossing north to south
- A slope inclinometer installed through the centre of the eastbound lane
- 1200 mm diameter corrugated steel pipe (CSP) culvert directly under the slide area crossing north to south

The slope inclinometer was installed through the eastbound lane to monitor for deep seated movements and retrogression of the slope failure. To date there has been no evidence of retrogressive movements (ii). This may suggest the slip plane is shallow, localized to the guardrail and sideslope area, and has not retrogressed to the road surface.

Soil Conditions

Based on field observations, the road fill was mainly clay with moderate to low plasticity. The fill was originally brought onsite during initial road construction and it could be assumed that the fill was compacted to about 97% of standard proctor density. In general the long term water table onsite was at the base of the road embankment fill.

The embankment appears to have been constructed on a low-lying poorly drained area with possible soft lacustrine alluvial and organic soils.

Potential Slip Plane

The slip plane was estimated to be at a depth of 1.5 m to 2 m based on the locations of the scarp and toe.

Selection of Launched Soil Nails

Based on a 2006 annual site visit, a repair assessment (iv) was made by another consultant consisting of the following two options:

- Construct a toe berm along the distressed section with slight slope flattening
- Rebuild the distressed section of the embankment with pit run granular fill

The initial estimated cost of the work, excluding land, pipeline relocation and engineering cost was estimated at $150,000 to $200,000 for the first option, and $200,000 to $250,000 for the second option (2006 dollars).

For both options the nearby oil pipeline company would have to be contacted to realign their line or to confirm that the additional earth loads and associated settlements were within the allowable limits for the pipeline. A nearby TELUS line would have to be realigned prior to construction. The first option would extend into private land and, therefore, right-of-way negotiations would also be required before the work could commence.

The decision was made by AT to repair the NC47 site in the fall of 2008. AT's Maintenance Contractor could not mobilize the resources needed to carry out either the toe berm or slope reconstruction options in a timely manner due to the robust economic conditions in Alberta in the fall of 2008. LSN presented a good opportunity and was recommended by EBA for the slide repair due to the shallow nature of the slide and because it offered the following advantages over the two traditional methods of repair:

- Much cheaper repair method than traditional methods
- Quicker installation
- No need for access road and work bench for equipment
- Improved ability to work around buried services, structures and instruments
- Fewer road user disruptions as a result of the shorter construction period and closure of a single lane
- LSN is a greener method as a result of reduced carbon footprint created by only one piece of heavy equipment
- Sedimentation would be reduced because there is no requirement for borrow fill material

Soil nails would be launched using compressed air from an auxiliary air compressor mounted on the rear of the excavator and fired through an air cannon mounted on the end of the excavator's articulated boom. As this is proprietary technology, its use is restricted to a limited number of contractors globally and its service is offered in Canada by one contractor, Morsky Industrial Services Ltd. (Morsky). AT retained the services of Morsky to provide an estimate to perform the work needed to stabilize the NC47 site.

Mechanics of Using Launched Soil Nails

The depth of nail penetration is dependent on air pressure and soil resistance. For this project site, the nails were launched at over 350 km/h using compressed air pressure of approximately 18 MPa. The nails typically are "shot" normal to the potential slip plane. See Figure 2 for the forces acting at the slip surface. The nails are installed by pulling the nails from the tip. This pulling action and launch velocity puts the nails into tension immediately.

There are certain conditions under which LSN may not work effectively:

- Soils which contain high occurrences of cobbles or boulders (i)
- Situations where the depth to slip plane, perpendicular to the slope surface is greater than 4.5 m when using a 6 m nail (iii)
- In very cold air temperature, as this limits the efficiency of the air compressor on the launching equipment

However, the above factors were not applicable to the NC47 site.

Design

The design that was used for construction was submitted by Morsky and consisted of installing nails in a standard 1 m^2 grid with each row offset by 1 m. The Morsky design was checked by EBA using a simplified wedge design method described by Steward (1994). Use of this method indicates using 90 nails and a nail spacing one nail every 1.4 m^2 which would provide a factor of safety of 1.2.

Construction

Based on a price of $600 per nail, in addition to other costs, Morsky estimated that it would cost $70,050 to launch 80 nails spaced in a one meter grid. This price excluded any work involving hydro seeding, backfilling, culvert removal or replacement, nor any work associated with the high pressure oil pipeline and any work associated with the TELUS cable.

The depth of penetration of each nail during construction varied and was apparent from the length of nail sticking up above ground after a launch (stickup). As mentioned earlier nail penetration is dependent on the compressed air pressure and the soil resistance. On this project site the compressed air pressure was kept constant therefore the stickup was dependent on the soil resistance. In a few situations the soil nails were launched fully buried into the soil and had no stickup.

The design required 80 nails to be installed onsite; however, seventy-one nails were eventually installed. The decrease in the number of nails installed was reduced because the spacing had to be altered around appurtenances, namely the 1200 mm diameter CSP culvert and the slope inclinometer, as each required a buffer zone of 1.0 m and 0.5 m respectively on either side in order to prevent a potential conflict. As a requirement from the pipeline company, nails were not installed within a 5 m exclusion (or setback) zone established on both sides of the high pressure oil pipeline. See Figure 3 for the final soil nails layout.

Conclusion

Lower project costs, shorter construction times, fewer road user disruptions, the ability to work around obstacles, and the greener environmental by-product are some of the benefits realized by using LSN for the NC47 New Sarepta project. It is important to realize that using the LSN technology is not a broad replacement for stabilizing slopes as there are certain limitations to its application. In this case, LSN provided an economical solution compared to traditional slope repair methods, which permitted rapid repair of the NC47 slide before it retrogressed into the driving lanes.

When work was completed, the construction cost for slope stabilization was approximately $500 per m^2. When compared to the toe berm and cut and refill methods, the LSN method cost between 56% and 74% less and the time to complete the project was 70% shorter. Six months after installation, no observable movements have been noted. The site will continue to be monitored for at least the next year.

Acknowledgements

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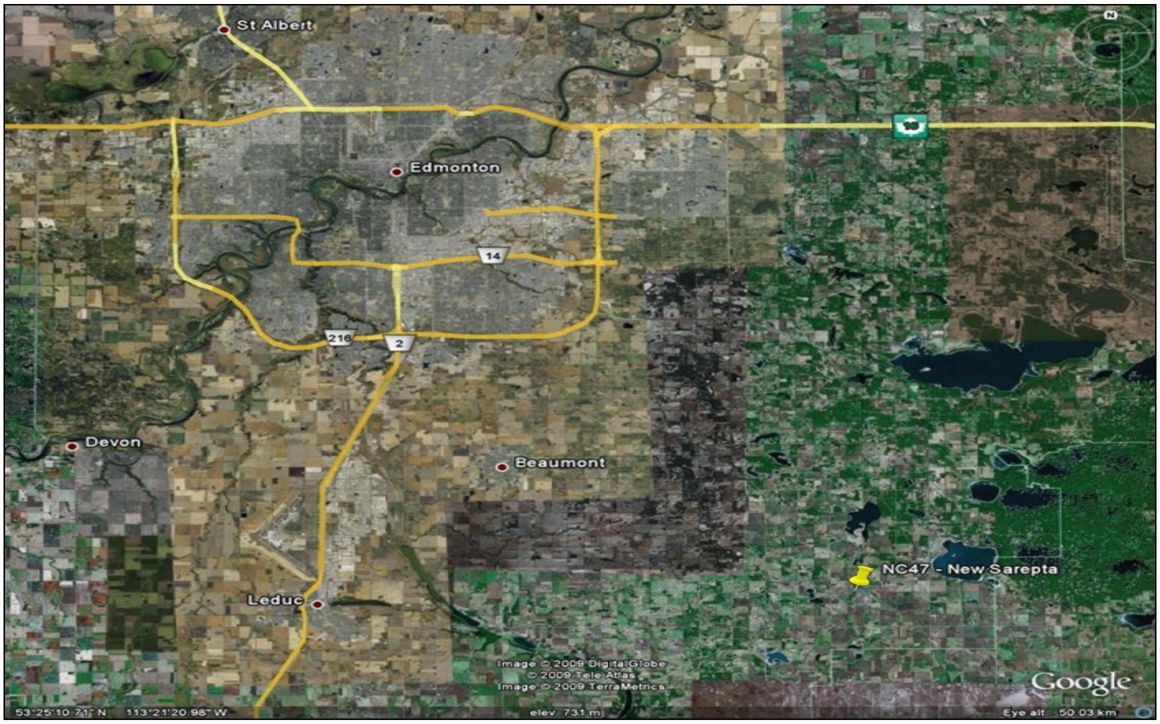

FIGURE 1: Location of NC47 – New Sarepta slide location. Courtesy of Google Earth 2009

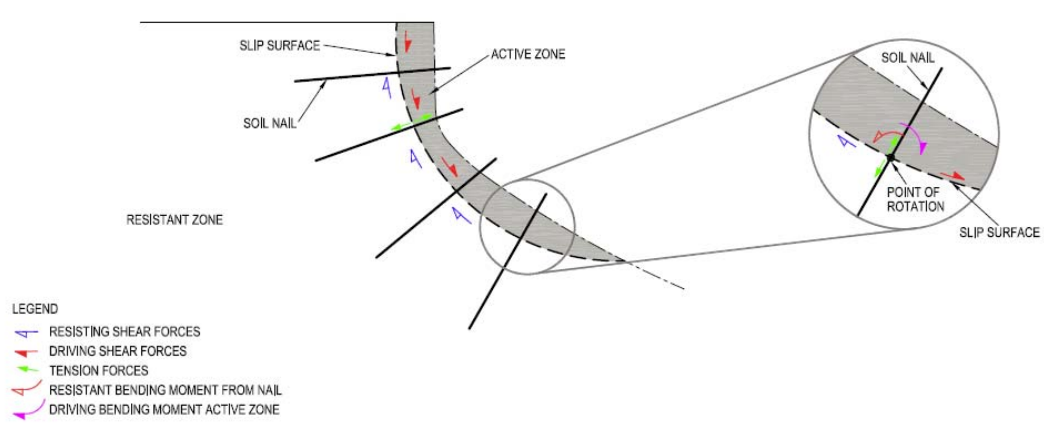

FIGURE 2: Force diagram of soil nails at the slip surface

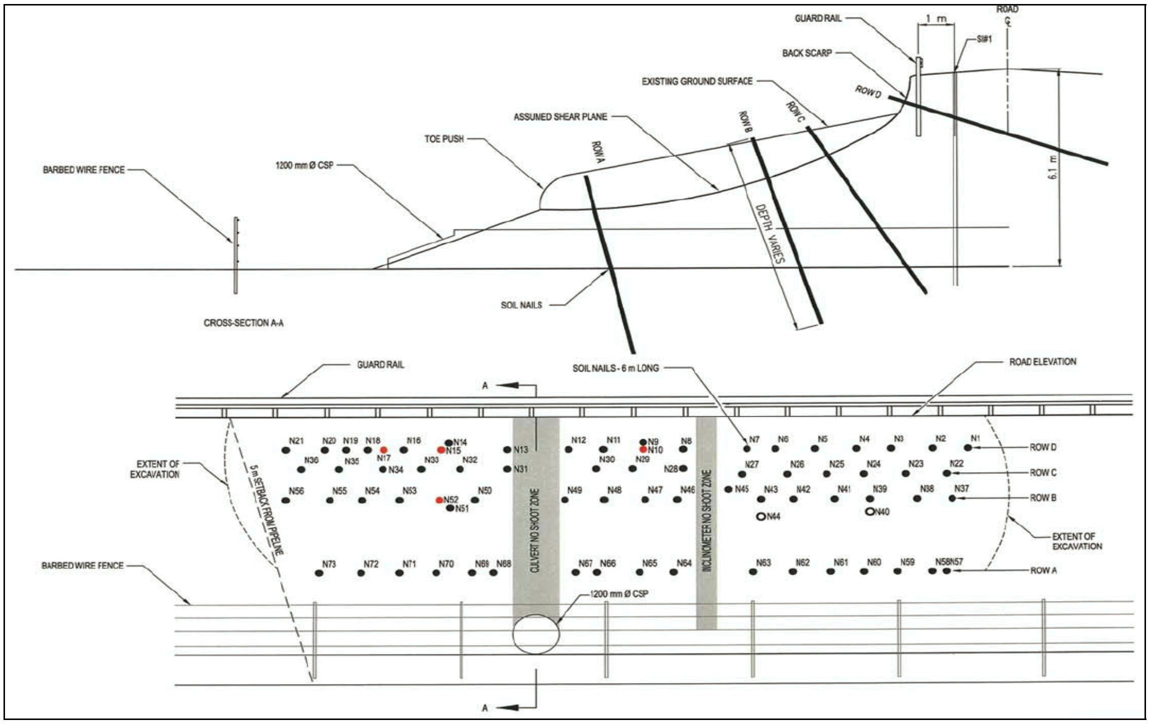

FIGURE 3: As-built of NC47 showing launched soil nails layout (not to scale)

PHOTO 1: Looking west along the eastbound lane; notice the sag in the guardrail & roadway

PHOTO 2: Looking eastbound; notice the vertical scarp close to the guardrail posts

PHOTO 3: Advantage of using soil nailing is that only a single lane closure is needed and this reduces road user disruptions

PHOTO 4: Closer look at the launcher's ability to reach around obstacles and utility services to install nails