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STABILIZATION OF A SLIDE USING A TIEBACK PILE WALL

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Abstract

The use of drilled shaft concrete piles is generally not a widespread method of stabilizing landslides along the Alberta Highway Infrastructure as a result of perceived high costs, the uncertainty of performance of these structures in the long term and the ready availability of land for realignment, offloading and toe berm construction. This paper presents a case history of a roadway embankment slide which was stabilized using a tieback drilled shaft concrete pile retaining wall. Although the piles were not installed to the desirable depth, the wall has performed satisfactorily since its construction some 10 years ago with none or minimal maintenance to the surface of the roadway.

INTRODUCTION

Highway 33, a Provincial Primary Highway in the North Central Section of the Province of Alberta, Canada, was constructed during the1950s. The highway crosses a small creek located in between two ridges about 8 km north from the Town of Swan Hills and 250 km north-west of the City of Edmonton. The location of the project site is shown on Figure 1.

Since construction, slope instability conditions have been experienced in a short section of roadway embankment fill crossing a creek channel. Initial investigations indicated the existence of subsurface springs in the creek banks which were blocked by the embankment fill. Drainage improvements were made through the construction of subsurface and surface drains along the highway ditch in the backslope and the

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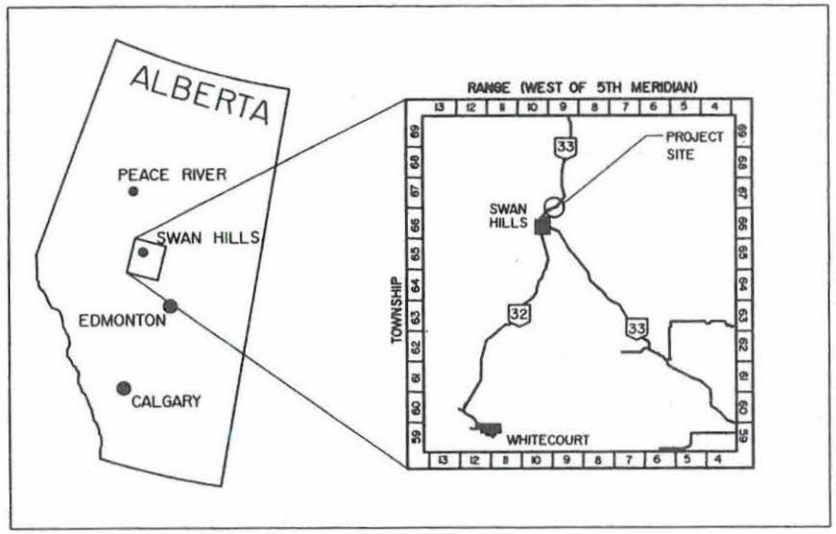

Figure 1. Project Location

installation of horizontal drains drilled through the slide area from the toe of the side slope. These measures, however, proved only partially successful in preventing further sliding of the embankment.

During the latter half of 1980, improvements were planned for this section of highway in a two stage process - grade widening in 1989, and a raise of grade in 1990. These improvements necessitated more permanent slide stabilization measures as any additional height of grade would require some form of lateral restraint.

This was accomplished by the construction in 1989 of a drilled straight shaft concrete pile wall consisting of 82 piles, each 760 mm in diameter, drilled at 1 m center-to-center spacing. Tieback anchors were subsequently installed through the pile wall in 1991 to enhance the stability of the slide area. The slope on the downhill side of the pile wall was reconstructed with wood chips, and capped with a silty clay soil. A gravel layer was installed at the bottom of the wood chips to improve the subsurface drainage downside of the pile wall. On completion of the wall and tieback installation, slope indicators were installed to monitor the immediate and long term performance of the pile wall.

The objective of this case history paper is to review the remedial measures implemented and to discuss their performance to date.

SITE CONDITIONS

As indicated earlier, the highway crossed a small creek at the slide location. The terrain adjacent to the highway formed a basin which gently sloped towards the creek. The slopes of the basin were littered with fallen and tilting trees which indicated a generally progressive slope movement pattern towards the creek. The formation of ice blocks in the winter time over much of the slopes indicated the existence of possible seepage paths. A centreline culvert under the highway at about 120 m north of the slide area handled the creek flow across the highway from the east to west.

A major backslope was located at about 30 m from the south end of the pile wall. Ice build up was noticeable during the winter months at several locations along this backslope indicating the existence of active springs within the slide area.

SUBSURFACE DRAINAGE MEASURES INSTALLED PRIOR TO PILE WALL INSTALLATION

Prior to the installation of the pile wall in 1989, horizontal drains were installed at the toe of the sideslope in the slide area on the west side of the road to improve the stability of the embankment fill. These drains flowed free for a year or two and eventually became silted up, broken, or non-functional. Five horizontal drains and three shallow trench drains with perforated pipes were installed in 1988 as an immediate response to sliding instability occurring during that period. These horizontal drains, drilled through the embankment fill under the road to reach the backslope, yielded an average groundwater flow of about 1.5 to 2 litres/min.

PILE WALL INSTALLATION - 1989

Installation of drilled straight shaft concrete piles was undertaken in July 1989 ahead of the proposed grade re-construction schedule. In view of the slide conditions, it was agreed to undertake the grade revision work in the slide area over the 1990 and 1991 construction seasons.

A pad was prepared on the side slope about 2.5 m below the elevation of the road as an access for the drilling equipment. In total, 82 piles, each 760 mm in diameter, were installed from Sta. 9+620 to 9+700 at an average center-to-center spacing of 1 m. Although these piles would be conventionally anchored into bedrock or hard shale in typical piling projects, the depths of piles in this project were constrained by the location of horizontal drains installed within the slide area in the previous years. The location of the pile wall in relation to the roadway embankment is shown in Figure 2.

The piles were extended 2.3 m above the drill pad by using cardboard forms (sonotubes), which were subsequently removed after the concrete was cured. The piles were extended above the pad elevation to facilitate reconstruction of the roadway after the completion

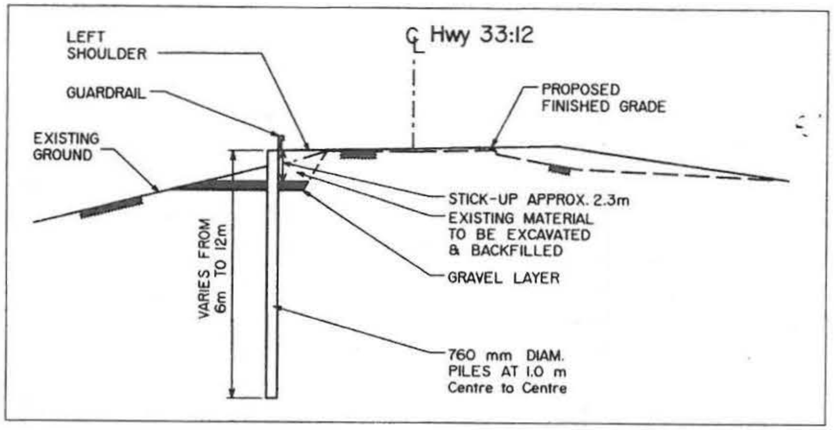

Figure 2. Location of Pile Wall along Roadway

of pile wall installation. The pile holes were nominally reinforced and backfilled with 25 MPa strength, Type 10, Portland Cement Concrete. The pile wall installation was carried out by North American Construction Ltd of Edmonton, Alberta.

Following the completion of the pile installation, the areas on the downslope side of the pile wall and between the piles and the west shoulder of the road were backfilled with native soil that had been excavated earlier. The road grade was brought back to match the elevation of the adjacent roadway surface. Two slope indicators (SI #A and B) installed adjacent to the pile wall in the reconstructed shoulder area of the roadway indicated movements at depths of 14.5 and 17.5 m, respectively, along the contact with stiff clay till and shale. These slope indicators were subsequently destroyed during the winter of 1989/90 by maintenance equipment. A general layout of the slope indicators installed is shown on Figure 3.

The highway grade was raised by about 1.0 m during the summers of 1990 and 1991. Prior to the construction of the grade raise, a site inspection was done in May 1990 to check the performance of the pile wall. This inspection revealed that little or no lateral movement was evident in the roadway embankment fill in the area of the concrete piles, but the road had settled considerably south of the pile wall close to Sta. 9+560.

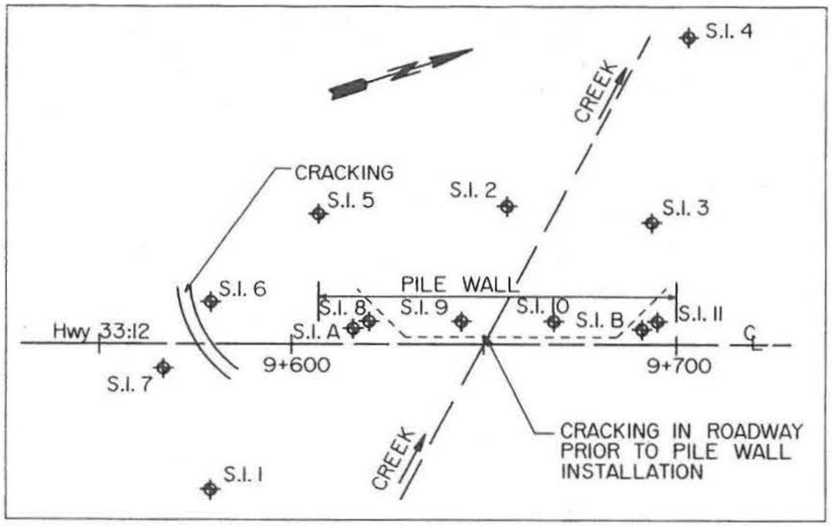

Figure 3. Layout of Slope Indicators and Crack Patterns

During the time interval between the phases of the pile wall installation and the grade raise construction, four slope indicators (SI #1 to 4) were installed in March 1990 along the creek banks on either side of the roadway embankment to monitor subsurface movements occurring therein on either side of the highway. Readings from these slope indicators indicated that progressive movements were occurring along the creek banks on either side of the highway. No slope indicators were installed to replace SI #A and B in the pile wall area in view of the grade raise construction scheduled for the summer of 1990.

TIEBACK INSTALLATION - 1991

Based on the indication that slow movements were still occurring and the fact that the piles were not drilled into bedrock, it was considered more appropriate from a long term stability consideration to strengthen the free standing piles by installing a tieback system. The tieback system was installed in September 1991 by Beck Drilling and Environmental Services Inc. of Calgary, Alberta.

The design of the tiebacks was undertaken using laboratory obtained shear strength parameters of c'=12 kPa and ϕ'=25° for the native soil behind the pile wall. The design called for two rows of tiebacks consisting of 28 tiebacks in each row installed at 1 m and 3 m depth, respectively, below the top of the piles. Each waler beam was designed to be a composite section consisting of two of C380 x 60 kg channels laid back to back

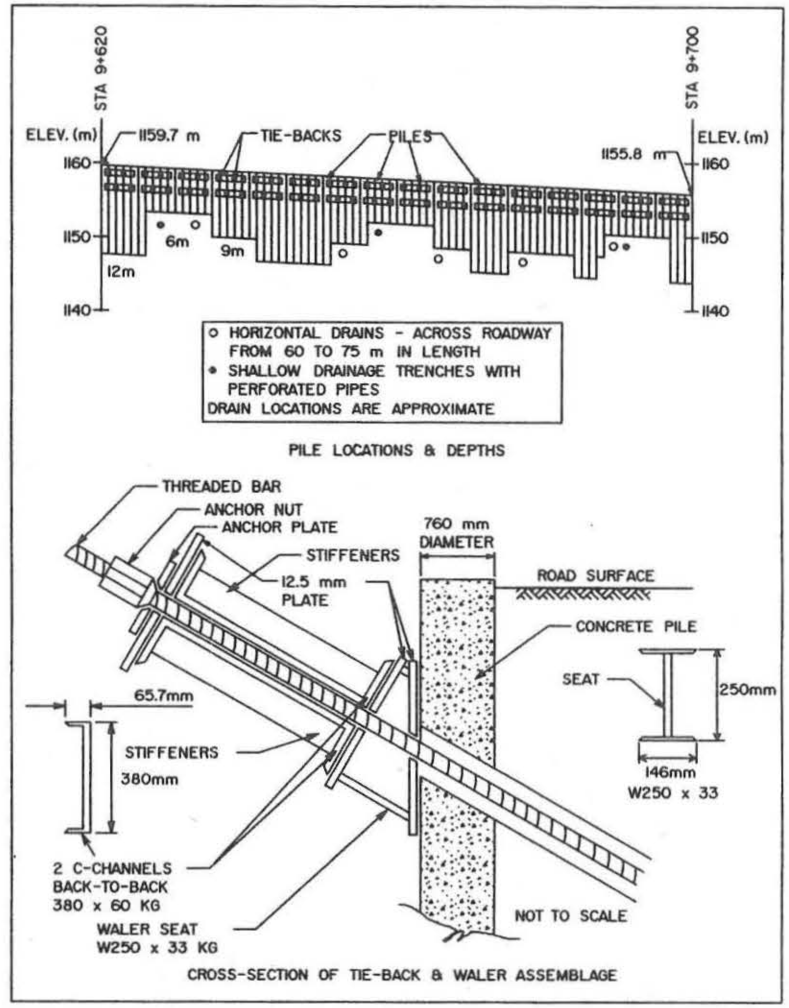

Figure 4. Details of Tieback Installation

and covered both at the top and bottom by steel plates of 12.5 mm nominal thickness. Typical details of the tieback installation are shown in Figure 4.

Two anchors were installed in each beam at an angle of 30° to horizontal. Each anchor consisted of a 36 mm diameter Dywidag Grade 150 steel rod inserted in a 125 mm predrilled hole and grouted for a length of 7.5 m into the intact shale zone. The length of each anchor in the native silty clay zone was about 36 m. Each anchor was designed to resist a tensile force of 600 kN. Fifty (50) MPa strength cement concrete was specified for the grout.

The top row of tiebacks was installed at 1 m below the top of piles. For the purpose of installing this row of tiebacks, a working bench was cut on the downslope of the pile wall to a depth of 2 m below the top of concrete piles to allow for access of equipment and machinery. After completion of the top row of tiebacks, excavation was done to a further depth of 2 m below the first bench and the lower tiebacks were installed at a depth of 3 m below the top of the piles.

In the process of the tieback installation, about six (6) anchors failed to achieve the desired strength, probably due to variable quality of rock. The failed anchors were replaced by new ones at an additional cost. Grout pipes were also placed in those failed holes and multi-stage grouting was done as necessary.

After the completion of the tieback installation, a gravel layer was placed on top of the lower drill pad to allow quick drainage of any seepage coming through the roadway embankment fill. The downslope of the pile wall was reconstructed in the summer of 1992 with wood chips and a silty clay cap.

PAVEMENT CRACKING SOUTH OF PILE WALL LOCATION

Cracking of the pavement at about 60 m south of the pile wall location (Sta. 9+560) was observed even before the installation of the wall in 1989 and became more pronounced in the summer of 1990. This cracking was almost diagonal to the centreline of the road and can still be observed today (Figure 3).

INSTRUMENTATION

General

Slope indicators were installed at this site periodically after the installation of the pile wall in 1989 to monitor the long term performance of the pile wall. The instrumentation is currently being monitored twice a year. Visual inspection of the site is also undertaken periodically to determine any unusual features which may affect the integrity of the roadway.

As described earlier, the first set of slope indicators, SI #A and B, was installed in the pile wall area in August 1989. The second set, SI #1 to 4, was installed in March 1990 to monitor slide movements along the creek on either side of the road. The third set, SI #5 to 11, was installed in September 1991 after the grade was raised to the design

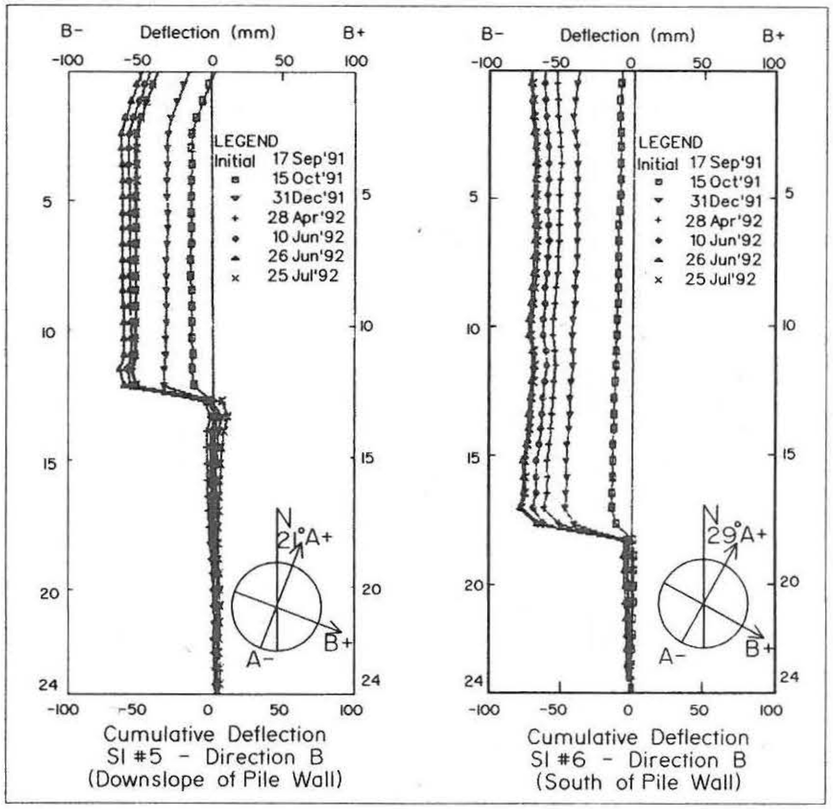

Figure 5. Typical Slope Indicator Plots Outside of Pile Wall

elevations and the new pavement completed. Of these, SI #5, 6 and 7 were installed on either side of the road at the crack location while SI #8 to 11 were installed between the outer edge of the south bound lane and the pile wall.

Unfortunately, many of the slope indicators have sheared or have been destroyed. SI #8 and 10 were destroyed by road maintenance equipment or by animals. Only two (SI #9 and 11) are currently functional.

Inference From Instrumentation Monitoring

Well-defined failure planes are indicated in the plots of the slope indicators located by the pile wall and south of the pile wall, as shown in the typical plots of Figures 5 and 6.

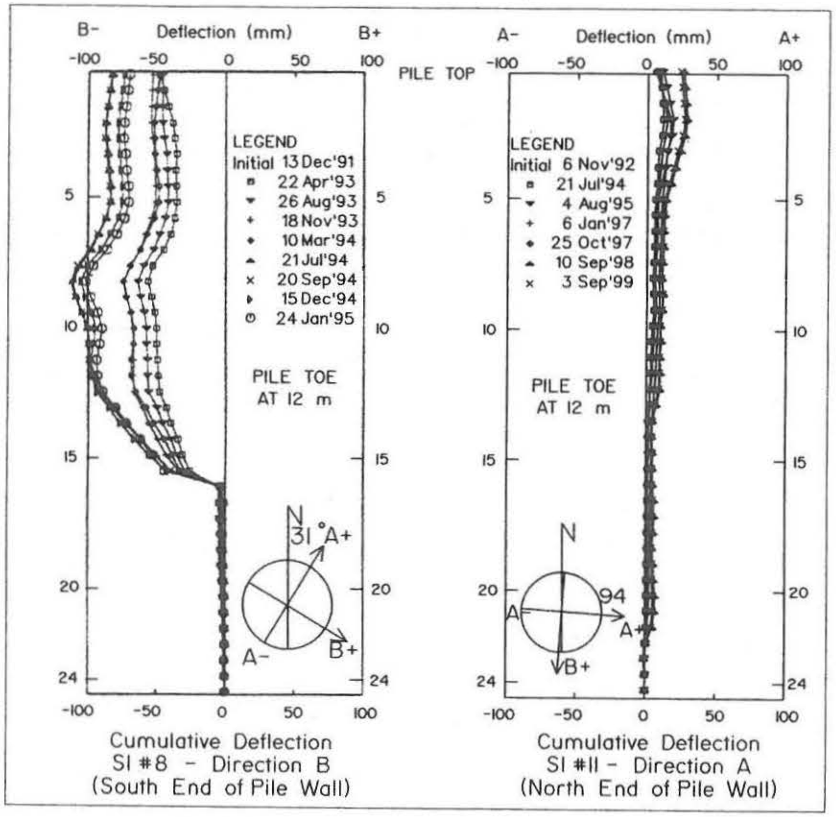

Figure 6. Typical Plots of Slope Indicator Within Pile Wall Location

Pile Wall Area

It is interesting to note from the plots of Slope Indicators (SI #8 and 11) within the pile wall area that slide movements are occurring in the roadway embankment at more than one depth. The depth of deepest failure plane varies from about 16 m at the south end (as shown by SI #8) to about 22 m (as shown by SI #11) at the north end. From this observation, it is clear that slide movements are occurring well below the tips of the deepest piles. A cross section of the roadway embankment showing typical soil stratigraphy and the ground movements is presented in Figure 7. As far as the rate of ground movement is concerned, the time-movement plots typically indicate continuing slow creep movements and no evidence of dramatic changes was noticed either in the plots or visually on the ground to date.

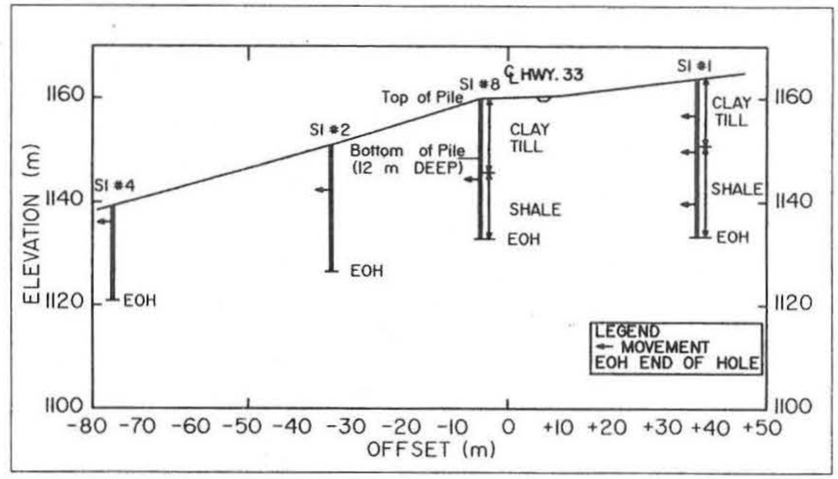

Figure 7. Cross-Section showing Stratigraphy and Movement Depths (Sta. 9+650)

A set of typical time- movement plots of SI #11 is presented in Figure 8. It is further noticed that the sub- surface movements are more restrained below the 12 m depth mark in comparison with the movements between the road elevation and the bottom of the piles.

Pavement Crack Location South of the Pile Wall

Slope indicators #5 to 7 installed in the crack area have sheared at different depths varying from 8 m in SI #7 to 18 m in SI #6. Generally, the average depth of movement is about 12 m below the road.

CURRENT STATUS OF THE SLIDE AREA

It is nearly 10 years since the pile wall was installed. Although the slope indicators show slow creep movements in the order of 30 to 50 mm at the road level over this time, the pile wall seems to be holding well, and there is no distress observed in the two driving lanes. Only a small settlement is visible in the shoulder area adjacent to the piles. A photograph taken recently of the road and the piles is shown in Figure 9.

Mixed success has been reported in the literature regarding the use of pile walls in slide stabilization. However, in the opinion of the authors, this form of stabilization has proved to be a successful solution for this site, considering the complex ground conditions and site constraints.

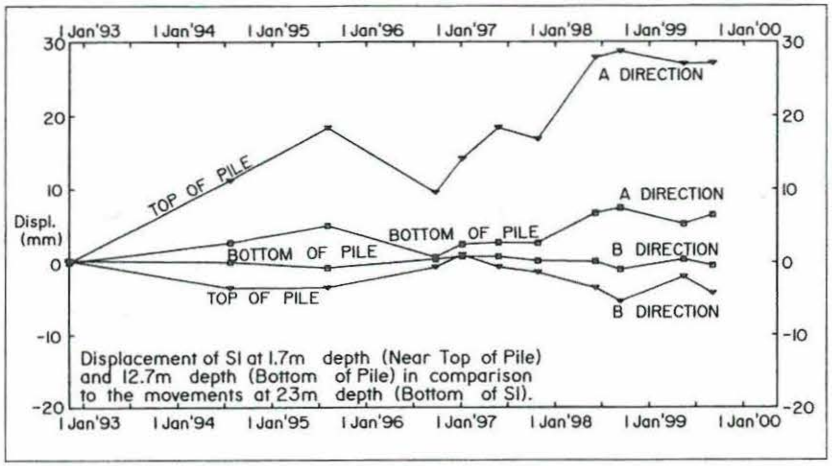

Figure 8. Time-Movement Plots For SI #11

The cracking south of the pile wall continues to be a matter of concern. Since the depth of movements are in the order of 12 to 18 m, a recommendation was made to extend the pile wall southward to encompass the pavement cracking location. However, no specific measures have been implemented to date. It is likely that the pile wall system may be extended sometime in future if continued maintenance of the roadway surface by patching is no longer considered to be a cost effective approach in keeping this section of roadway functional.

CONCLUDING REMARKS

The approach of using drilled straight shaft concrete piles to stabilize slides has not been the norm for stabilization of slope stability problems along the Alberta Highway Infrastructure. In many situations, relocation or the use of earthwork methods such as berms, slope flattening etc, has been utilized as a result of the availability of adjacent land. It has been noted, however, that many highways are located in what can be described as the "best alignment" routes, and very often the use of earth work methods of solution to slide problems is not feasible.

The stabilization approach described herein was the first of its kind to be used on the Alberta Highway Infrastructure. Since then, this approach has been adopted over the last 10 to 12 years in a few areas where site constraints and other factors precluded the use of other forms of stabilization.

Figure 9. Recent Photograph of Pile Wall and the Highway

In reviewing the infrastructure, we see that this type of remedial measure is probably very suitable to the resolution of many similar instability problems. The long term performance of this and other similar projects would no doubt be of importance to the utilization of this method of stabilization.

Over the last three (3) years, this and other sites have been placed on a twice-a-year monitoring schedule with an annual inspection undertaken in the spring of each year. This monitoring schedule will allow the performance of the stabilization measures to be evaluated and, where necessary, the implementation of additional measures to preserve the integrity of the highway.

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