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STABILIZATION OF MEIKLE RIVER SLIDE ON HIGHWAY 35

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Abstract

Stabilization of an unstable section of roadway along a major river valley experiencing deep seated movements was effected through the construction of a pile wall, simple drainage measures and a gabion wall. Since the construction of the pile wall in 1997, the effectiveness of these remedial measures has been evaluated through instrumentation monitoring and observation. So far the roadway is performing well.

INTRODUCTION

Northwestern Alberta has many geologically young river valleys which are very well noted for landslide activity along their valley walls. The Meikle River valley, one of such valleys, is located along Provincial Primary Highway 35 and situated as shown in Figure 1, about 900 kms north-west of the City of Edmonton, Alberta, Canada, in the geographical area of the Province known as the Peace Region. The area between the upper edge of the Meikle River valley wall and the flood-plain on the north side of the river has been affected by landslides at some time in the geologic past. As determined from aerial photographs, almost the entire stretch of highway between the Meikle River Bridge and the Canadian National Railway (CNR) tracks is within landslide terrain. The general opinion is that these slides have occurred as a result of the river cutting into the bank at the toe of the slope (Nasmith, 1964).

As shown on the aerial photograph, Figure 2, the highway follows a curved side hill alignment on the north side of the Meikle River, crossing the CNR tracks at the top of the valley which is located about 1.2 km north of the Meikle River Bridge. The highway has three lanes within this 1.2 km distance, one lane for the south bound travel and two

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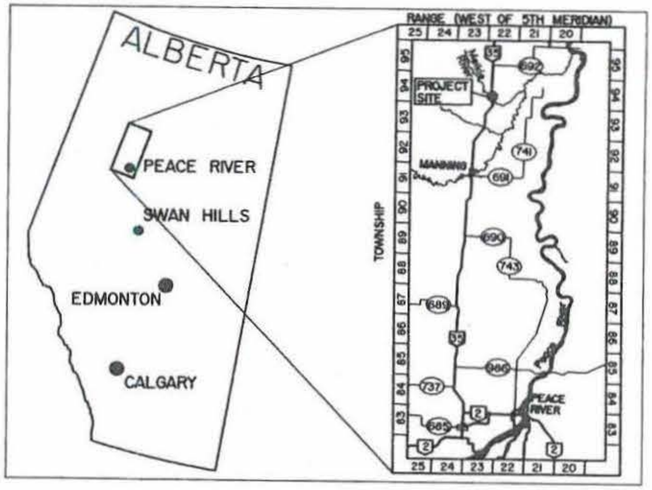

Figure 1. Location of Project Site

lanes for the north bound travel, with one of these being a climbing lane. The highway grade between the Meikle River Bridge and the CNR tracks is about 6 to 7% with an elevation difference of about 60 m from the top of the valley at the CNR tracks to the river at the bridge location.

Slide conditions and pavement distress were reported for the first time in 1991 at two sites (Site 1 and Site 2) identified in Figure 3 and located 0.5 and 0.9 kms, respectively, north of the Meikle River Bridge. At Site 1, sideslope failure occurred over a 30 metre stretch of the highway resulting in 4 to 5 slumped terraces towards the river. At Site 2, settlement of the roadway resulted in a sag at two locations within a distance of about 30 metres. The second site is located at a cut/fill transition of the highway at the top of the valley.

As an immediate short term response, drainage measures were carried out at the two sites by the Regional Maintenance Staff of Alberta Transportation & Utilities(AT&U), now Alberta Infrastructure. At Site 1, the surface water was diverted away from the slide location to minimize ingress of surface water into cracks in the slide area. At Site 2, a perforated pipe subsurface drain was installed in the backslope ditch with the outlet daylighted in a centreline culvert downhill of the slide area. This subsurface drainage measure was implemented based on the evidence of seepage on the sideslope which was inferred to be travelling through the highway from the backslope.

The primary objective of this case history paper is to review the remedial measures implemented at Site 2 and their performance to date.

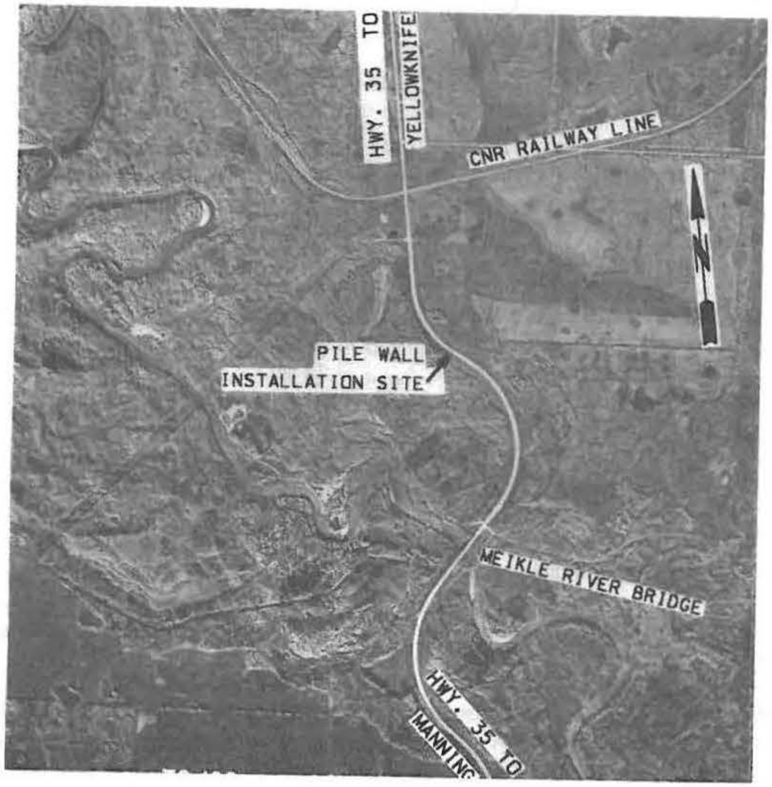

Figure 2. Aerial Photograph Showing Roadway Alignment

GEOTECHNICAL EVALUATIONS AND MEASURES IMPLEMENTED

Between 1991 and 1995

As a first step in identifying the depth of movements, five slope indicators (SI #1 to 5) were installed at both sites in 1992. The location of these slope indicators are shown in Figure 3. While the monitoring was still in progress, a sideslope slipout encroaching the south bound lane occurred at Site 1 in October 1993. Since the slide movements were noticed to be well below the toe of the side slope, a pile retaining wall was constructed as an emergency measure. The construction of this wall was undertaken by the Regional Maintenance Staff on recommendations from the Geotechnical Services Section of AT&U.

Eleven (11) slope indicators (SI #21 to 31) were installed during 1994 on both sides of the road to assess the global nature of the slide activity (Figure 3). Based on a visual observation of accelerating pavement distress and a review of the latest slope monitoring data, an internal AT&U recommendation was made in March 1996 by the Geotechnical Services Section to explore the feasibility of a realignment of the highway on the north side of the bridge without incurring relocation of the bridge.

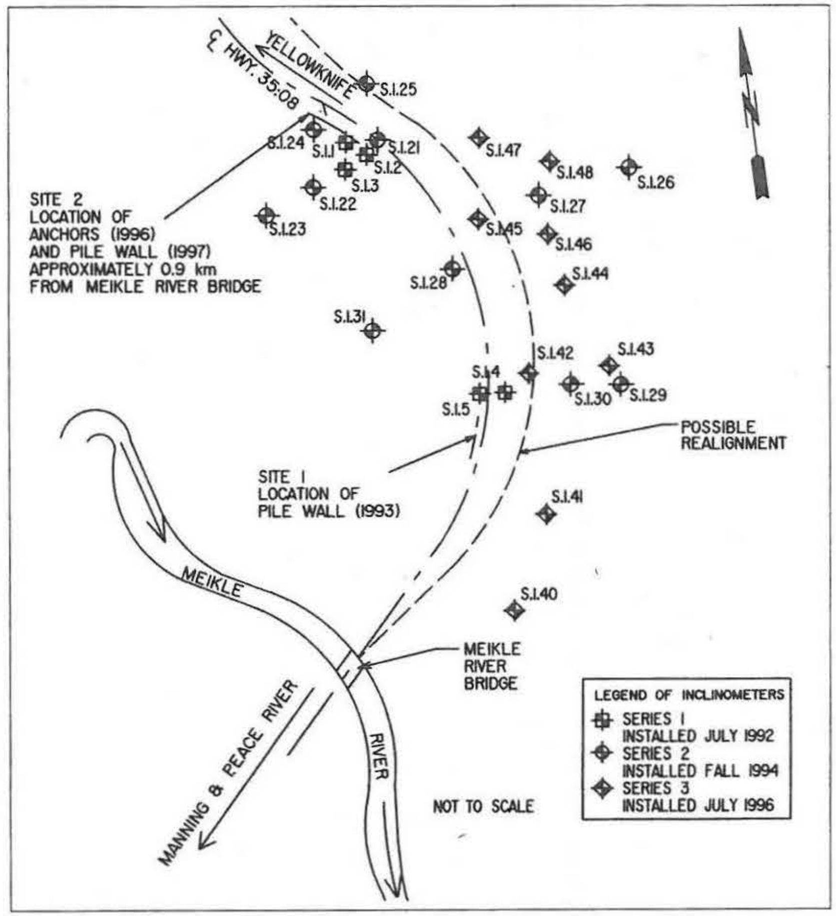

Figure 3. Plan of Instrumentation Locations

In May 1996 and Later

While the realignment feasibility was under study, differential settlement and pavement cracking started to re-appear in the south bound lane in May 1996 over a 120 m stretch of the highway at Site 2. This created an unsafe situation especially for the downhill traffic coming from the north. GAEA Engineering Ltd, a consulting civil engineering firm providing geotechnical services to AT&U on landslide problems in the Peace Region, was requested to inspect the site conditions and design appropriate remedial measures. Based on a visual inspection of the site conditions, screw anchors were installed in the south bound lane in July 1996 as a temporary remedial measure to improve the stability of the highway.

Installation of additional slope indicators, especially in the uphill side of the highway, was also recommended since any realignment option on the north side of the bridge would involve substantially deep cuts. Accordingly, nine (9) additional slope indicators (SI #40 to 48) were installed covering a wider area of the uphill portion and to depths varying between 30 and 60 m in few holes (Figure 3).

The generalized stratigraphy of the subsurface soils encountered consisted essentially of gravelly clay varying from soft to stiff in the upper 8 m and stiff to hard to a depth of 24 m. Very hard clay shale was encountered below a depth of 26 m.

INSTALLATION OF SCREW ANCHORS

As mentioned previously, screw anchors were installed in the south bound lane in July 1996 as a short term measure to improve the stability of the roadway in the south bound lane. The projected advantage of the screw anchors was two fold: (i) to allow traffic to utilize the existing roadway, and (ii) to avoid the possible widening of the highway towards the backslope.

Widening was considered as an option to shift the highway into the backslope to maintain the three lanes in the event of a closure of the southbound lane by the slide activity. The construction of this widening would have resulted in substantial costs, since a much longer length of highway than the length affected by the slide would have to be constructed to allow for proper horizontal geometrics, sight distances and stable cut slopes. In addition, this scheme would have necessitated the acquisition of private property which would have been time consuming and not in the best interests of the travelling public. As a result of these constraints it was decided not to pursue the widening option.

Fifty (50) helical screw anchors each consisting of a 7.6 m long by 114 mm diameter shaft and two 300 mm diameter helixes, were installed in the slide area by Alberta Anchors Inc. of Fort Saskatchewan. For the installation of the anchors, two notches were made in the road by excavating the asphalt and base course to a depth of about

1.5m below ground to facilitate the insertion of the anchors and to ensure that they were buried below ground. The anchors were installed in an inclined direction towards the backslope of the road at an angle of approximately 30° to the vertical (Figure 4). After the installation of the anchors was completed, the notches were backfilled with gravel and the surface was repaved.

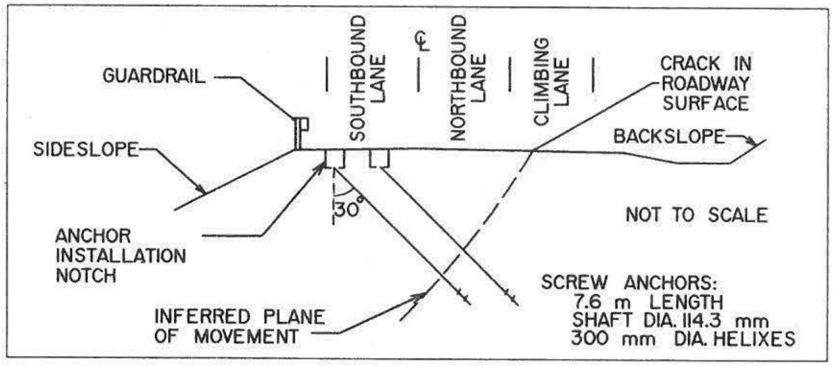

Figure 4. Installation of Screw Anchors

RENEWED SLIDE ACTIVITY IN THE SUMMER OF 1997

Following the installation of the screw anchors, the road surface did not exhibit any major distress through the winter of 1996/97. However, during the months of April to June 1997, the pavement surface started to show renewed differential settlements and sloughing of material on the sideslope on a more severe scale in the section where the screw anchors were installed earlier. These developments were considered to be the result of unusually heavy snow fall that occurred during the winter of 1996/97. As a result of this renewed activity, immediate remedial measures were considered warranted to avoid a total loss of the south bound lane. The realignment option was once again reviewed more closely in the light of the latest slope indicator data and rejected because of the following drawbacks:

1. A realigned section would still be exposed to slide terrain as may be inferred from the deep seated nature of movements shown by the slope indicators installed in the area considered feasible for realignment (Figure 5).

2. The realignment would have to be done through privately owned land and hence could be subject to long delays due to likelihood of expropriation measures to acquire the necessary right-of-way.

3. Shifting the alignment of the highway would also involve steeper grades, longer

realigned length of the highway and substantial cut volumes before reaching the top of the north valley. The disposal of excess material would also involve long haul distances leading to high costs.

4. The Meikle River Bridge could not be relocated any further to the east of its present location as a result of a massive slide, which was present along the north bank of the river only a short distance downstream of the bridge.

As a result of these observations and findings, it was considered more prudent and cost-effective to maintain the road along its existing alignment and implement appropriate remedial measures.

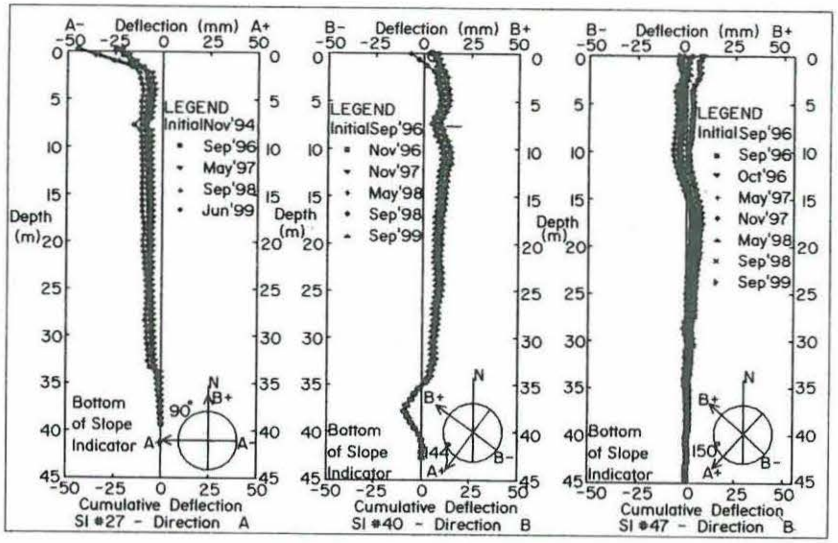

Figure 5. Typical Slope Indicator Plots on Possible Realignment Location

STABILIZATION CHOICE

A careful review of the site was undertaken to determine the most appropriate slide remedial measure. Two alternates were considered in principle, viz., (i) construction of a toe berm in the flood plain to provide the necessary lateral restraint to the highway and the valley walls, and (ii) installation of drilled straight shaft concrete piles.

Toe Berm

Construction of an earth toe berm in the flood plain would literally involve filling in the area that was scoured by the Meikle River in geologic past. While this was a possible solution to implement, this construction would entail the movement of a large volume of earth material. This concept was referred to Alberta Environment for formal approval as part of the procedure that is mandatory when construction activities influence land disturbance outside of the existing highway right-of-way.

From the referral, it was determined that the Meikle River valley is a prime habitat for a wide range of wild life and the river carries three important varieties of fish. Any highway construction in the valley will disrupt the wild life and increase the risk of erosion of valley slopes and siltation in the river which could be detrimental to the fish. The referral also pointed out that an Historical Resources Impact Assessment of the project would be needed since the physiographic features of the site were considered to have high potential for the discovery of archeological resources.

Since these investigations take a considerable amount of time, it was decided to utilize the pile wall concept which would allow construction activities to be undertaken close to the existing roadway and without any time delay, thereby minimizing the continuing and escalating public complaint of the danger posed to commuter traffic of an unstable highway with a steep gradient.

Drilled Straight Shaft Concrete Piles

The approach of using drilled straight concrete piles to stabilize slide areas has been successfully used on a selective basis within the last 10 to 12 years in a few problem areas along the Alberta Highway Infrastructure, especially in the Peace Region.

While the installation of drilled straight shaft piles was considered a feasible alternative in principle, it was also recognized that the slide activity along this 1 km stretch of roadway was deep seated, as inferred from Figure 5, wherein existence of multiple slide zones is generally noticeable at depths varying from 5 to 40 m. However, in the immediate vicinity of Site 2, the depth of slide zones vary from 8 to 28 metres. Figure 6 shows typical monitoring data of two slope indicators of Site 2.

The presence of multiple slide zones is typical at many sites in the Peace Region, where rivers are responsible for valley formation. The various slide zones would correspond generally to depths at which various stages of river down-cutting or toe cutting occurred as a result of the river progressing from a youthful to a mature stage. The overall picture is one of retrogressive sliding activity which, from an aerial photograph review, influenced the movement of land beyond the immediate top of the valley crest parallel to the roadway. This emphasizes the importance of a careful aerial photograph review of the valley slopes since, very often, realignments are taken just beyond the valley crest without recognizing that this area may also contain slide zones.

Based on the understanding of the sliding mechanism, it was determined that the installation of piles well below the lowest perceptible slide zone would be very costly. Hence, engineering judgement was exercised to limit the depth of piles to 24 metres, which was considered to be a reasonable compromise from a cost-effective point of view and the variation in depths of sliding observed.

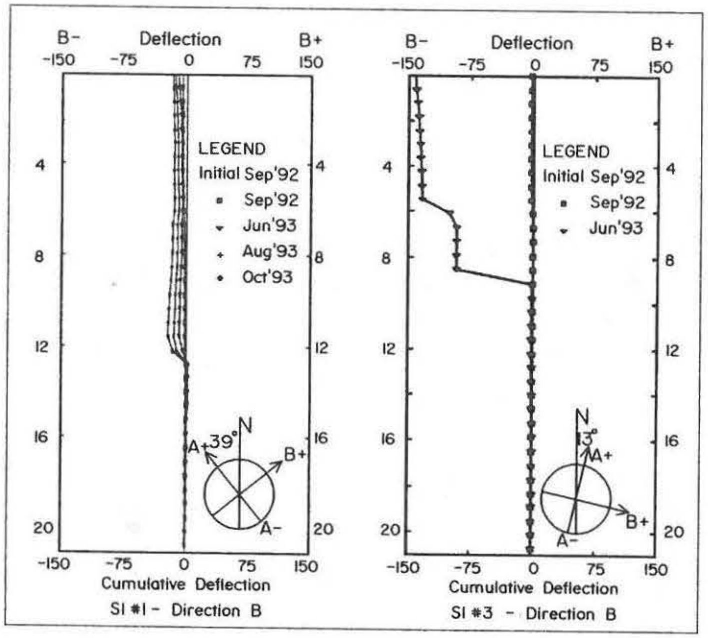

Figure 6. Slope Indicator Plots In the Vicinity of Site 2.

STABILIZATION SCHEME

The stabilization scheme proposed and implemented was the immediate construction of a row of drilled straight shaft concrete piles to allow the retention of the roadway and thus prevent the loss of the south bound lane. This was to be followed by the installation of a capping beam to provide rigidity to top of the piles, prevent rotation of the pile tops, and allow any lateral movement of the pile wall to occur with the piles acting as a unit rather than individually. Beyond the pile wall, the sloughing sideslope was to be retained by a gabion wall to prevent material from behind and in front of the piles from slipping out and exposing the piles thereby reducing the soil lateral restraint against the piles. Drainage measures were also proposed to remove the surface run off from the road and subsurface seepage within the roadway embankment to improve the over-all stability of the slide area.

Installation of tiebacks was also considered as an option to enhance the stability of the wall and the slide area. However, the tiebacks were not favoured since their installation costs would have been quite expensive and there was uncertainty about the performance of the site. Rather, it was decided to proceed with the less costlier option of the construction of a capping beam, gabion wall and surface drainage measures. Installation of tiebacks was, however, still a consideration should performance show that there was a need to preserve the integrity of the pile wall based on observations of site monitoring and that the site conditions would still support this as a feasible option.

To accommodate the availability of funds, installation of drilled straight shaft piles was first undertaken in the fall of 1997 to retain the road in position for the convenience of the travelling public. The construction of the capping beam, gabion wall and drainage measures was done later in the summer months of 1998.

PILE WALL INSTALLATION

The pile wall installation was undertaken by North American Construction Inc. of Edmonton, Alberta, during the fall of 1997. Seventy seven (77), 760 mm diameter by 24 m deep piles were drilled with a Texoma 900 drill at 1.5 m centre to centre spacing along the location of the guardrail. H-piles, 310 mm x 96 kg in size, were installed with their flanges parallel to the roadway centre line and the pile holes backfilled with 30 MPa strength concrete. The settled portion of the south bound lane was then brought back to grade with native soil to match the level of the asphalt pavement of the north bound lanes and left unpaved to check for any settlements during the spring/summer of 1998.

Selection of the size of the piles, their spacing and depth, was done based on a general interpretation of the slope indicators monitoring information in the neighborhood of the slide area, overall cost implications, past experience and engineering judgement.

Three slope indicator tubes were installed along the length of the pile wall, one at the centre and the two near the ends of the pile wall. The slope indicators were embedded in the piles by affixing these tubes to the H piles at the junction of the web and flange of the H piles through a rectangular slot running along the length of the pile.

CAPPING BEAM CONSTRUCTION

As explained earlier, a reinforced concrete capping beam was utilized on this project to provide fixed support conditions for the pile tops. The cross sectional dimensions of the capping beam were maintained as 1.5 m wide by 1 m deep for about 20 m length of the beam at the outer ends of the pile wall, and 1.75 m wide by 2 m deep for a distance of 70 m in the middle of the pile wall. The 2 m depth was designed to prevent movement of roadway embankment material in between the piles, due to seepage and internal erosion occurring in the middle part of the pile wall. Weep holes were also provided in this section to prevent the build up of pore pressure behind the wall.

The capping beam design was considered as a cost effective approach as the massive size of the beam used on this project was expected to provide an equally satisfactory rigidity to the top of piles. Another indirect advantage of the capping beam was that the guardrail could be positioned on top of the capping beam.

The capping beam construction contract was undertaken between August 20 and September 5, 1998 by Ruel Concrete Ltd of Peace River, Alberta. Concrete was supplied by Szmata Concrete and Aggregates Ltd, of Grimshaw, Alberta. The guardrail was mounted on top of the capping beam after its completion, Figure 7. The traffic lane adjacent to the pile wall was restored with an additional gravel base course and paved with new asphalt concrete pavement.

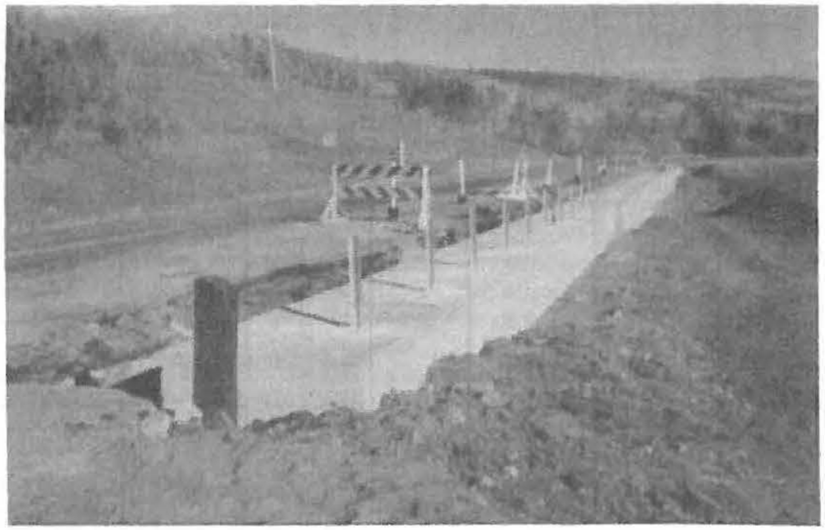

Figure 7. Completed Capping Beam Installation

GABION WALL INSTALLATION AND DRAINAGE MEASURES ON SIDESLOPE

The gabion wall installation and drainage measures were undertaken on the sideslope during the month of November 1998. The work was carried out by Kauri Contracting Ltd of Grimshaw. These measures were instituted to preserve the integrity of the sideslope on the downhill side of the pile wall.

Four shallow gravel filled finger drains with perforated pipe were installed in the slumped material of the sideslope between the pile wall and the gabion wall. These were installed

perpendicular to the centre line of the roadway to tap into the seepage below the road elevation coming from the uphill terrain. These finger drains were then connected to a longitudinal collector drainage pipe system installed behind the gabion wall. A 150 mm diameter non-perforated corrugated plastic pipe was then connected to the collector pipe and daylighted away from the gabion wall further down the slope.

Following the completion of the gabion wall and the subsurface drainage system, the sideslope between the gabion wall and the pile wall was reshaped to a uniform slope using discarded tires and wood chips as part of the fill material to reduce the lateral pressure on the gabion wall. A non-woven geotextile was then laid on top of the tires/wood chips and then capped with clay material. A typical drawing related to the gabion wall construction and drainage measures is shown in Figure 8.

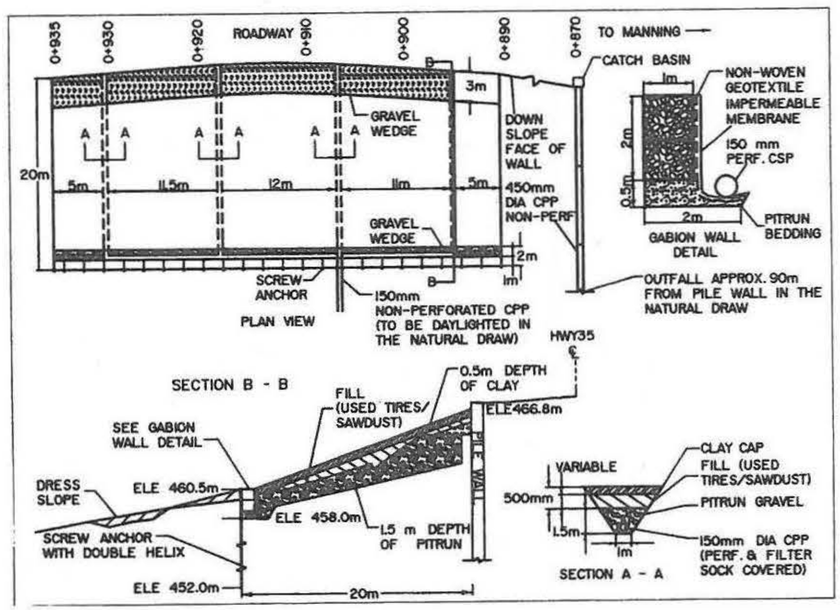

Figure 8. Gabion Wall Installation and Drainage Measures

As part of surface drainage improvement measures, a catch basin was constructed at the lower end of the pile wall to collect the surface runoff from the roadway. A 450 mm diameter non-perforated corrugated plastic downdrain pipe was connected to the catch basin and was laid along the sideslope to a distance of about 150 metres, where it was daylighted in a treed area. The purpose of the catch basin system and the downdrain was to minimize the seepage of surface runoff into the soil on the downhill side of the pile wall and to prevent the occurrence of shallow soil slipouts along the sideslope within the rehabilitated slide area.

CURRENT STATUS OF THE PROJECT SITE

To date, the roadway is performing well, except for minor settlement of the material downslope of the gabion wall. It should be noted that since the gabion wall construction and drainage measures were undertaken in winter months, compaction of the material might not have been perfect at that time. Hence, the settlement being observed currently may be the result of readjustment within the reshaped material.

The slope monitoring instrumentation is being read on a semi-annual basis. The three slope indicators installed in the pile wall are showing slow creep movements generally within the top 8-12 metre depth range (Figure 9). Below that depth, the movements are practically negligible. It is also interesting to note that there is a kink in the deflection plots at about 2 m depth below the road. This kink generally coincides with the depth of surficial sloughing, noticed prior to the pile wall installation, on the side slope of the highway. Typical time-movement plots corresponding to both A and B grooves of SI #50, which was installed in the middle of the pile wall, are shown in Figure 10. The rate of movement is generally in the order of 0.02 mm/day and there is no indication of drastic changes observed in the displacement plots.

CONCLUDING REMARKS

The total cost of the various measures described in this paper was about $1 Million Canadian dollars. Although this order of expenditure may seem high, the remedial measures implemented have proved quite helpful and cost-effective in maintaining the highway through this major river valley. Considerable engineering judgements had to be exercised to decide on the most logical and practically viable slide remedial measure, while at the same time to be cost effective.

The final choice of stabilization measure was governed not only by the technical appreciation of the problem, but as well, by social, economic, and environmental factors, and by constraints imposed by topography and geometrics of the alignment. Although it is often desirable to install piles well below the deepest slide plane with tiebacks to retain them, preference was given to the principle of observational approach and engineering judgement to make the project reasonably viable and cost effective in maintaining the integrity of the road for the convenience of the travelling public.

The installation of drilled straight shaft concrete pile walls in this project, is the third of its kind used along the Alberta Highway Infrastructure in the Peace Region to stabilize landslides in complex geologic conditions. The first installation was undertaken in 1988 to stabilize the Judah Hill landslide which has been previously reported in the literature

(Diyaljee, 1992). The second installation was done near the Town of Swan Hills. A detailed description of the second project has been reported in another paper submitted to this Conference (Diyaljee et al, 2000).

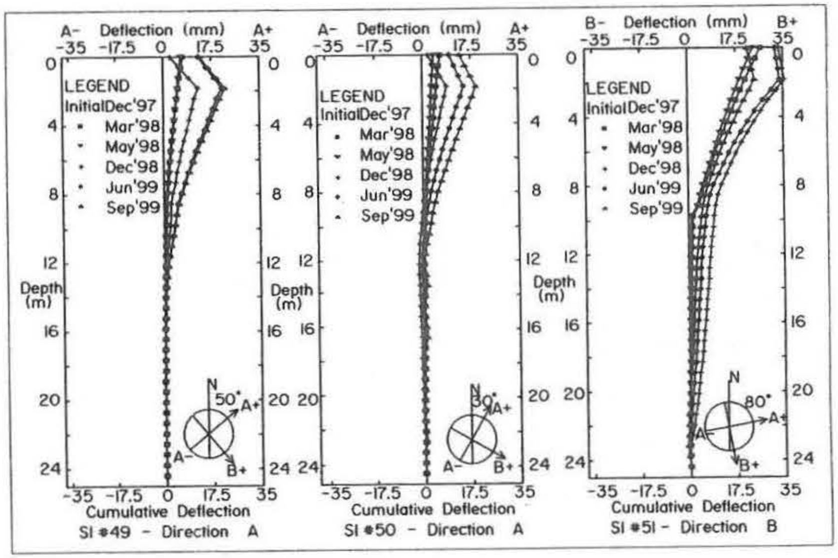

Figure 9. Typical Plots of Slope Indicators in the Pile Wall

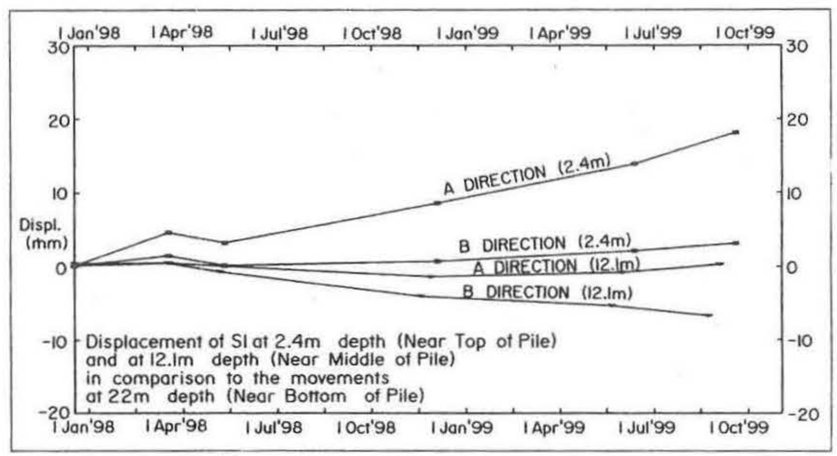

Figure 10. Typical Time-Movement Plots of SI #50

So far all of these installations are performing satisfactorily thereby allowing the highways to perform their intended function of providing safe, efficient and effective movement of goods and people within and through Alberta.

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 would 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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