USE OF GEOFOAM FOR LANDSLIDE STABILIZATION-CTH "A", BAYFIELD COUNTY, WISCONSIN

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ABSTRACT: EPS geofoam was used as lightweight fill for remediation of a slow moving, creep landslide failure along County Trunk Highway "A", in Bayfield County, Wisconsin. The landslide movement persisted for over 25 years. Various stabilization schemes were reviewed before deciding to incorporate geofoam into the head of the slide mass, thereby reducing the driving moment, and successfully stabilizing the landslide movement. Two concerns with using the geofoam beneath the highway pavement were buoyancy and differential icing on the pavement surface. The geofoam was embedded within free-draining sand having internal drain pipes to transmit accumulated water out of the fill zone. The geofoam was also buried sufficiently deep to prevent uplift in the event of flooding of a nearby creek. This depth of burial also provided the necessary ground cover to reduce the risk of differential icing on the surficial pavement. Since construction in 1999, the remediation measures have performed as intended.

Keywords: Buoyancy, Differential icing, Embankment, Geofoam, Highway, Landslide, Stabilization, Wisconsin

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INTRODUCTION

A persistent, creeping landslide had been occurring along an approximately 45 m section of County Trunk Highway (CTH) “A” for over 25 years. Because the rate of movement was so slow, the landslide did not pose an immediate threat to the usefulness of the highway; however, it did present a continued maintenance problem requiring regular patching of the bituminous surface.

LANDSLIDE DESCRIPTION

CTH “A” is a two lane highway that is a main north-south thoroughfare within the north central portion of Bayfield County, south of Lake Superior, in northern Wisconsin (Figure 1). The topography of the area is a gently undulating, modified lake plain formed by the high water stage of glacial Lake Duluth. This lake was created toward the end of the Wisconsinan stage of glaciation, following the north and eastward wasting of the Superior Lobe of the Laurentide Ice Sheet approximately 11,000 to 9,000 years ago (Figure 2). The Ice Sheet had, during the advance, incised a deep basin within the soft, red, Precambrian sandstone bedrock. The meltwater drainage was blocked to the east by the ice of the Superior Lobe, forming the lake in the westernmost part of the Lake Superior region (Syverson, 1998). This allowed for the water deposition of clay and silt particles within the incised basin, which constitute the deep glacio-lacustrine sediments that currently overlie the site. These sediments at the landslide site are believed to be over 50 m thick. The lake water drained into the St. Croix River system through the Moose Lake and Brule Outlets to the southeast. This drainage caused the water level to drop and the shoreline to recede to the location of present day Lake Superior, approximately 12 km to the north of the landslide site.

The landslide had a width of approximately 45 m, and a head to toe length of about 25 m, with the embankment side slope forming an approximate 14 degree angle. The landslide developed within the approximately 5 m tall highway embankment constructed to cross Koln Creek, which flows beneath the embankment within a large corrugated steel culvert (Figure 1). Soil borings drilled within the landslide mass found the embankment fill to consist of a surficial layer of sand, forming the pavement subbase, overlying silty clay and sandy clay fill. Below the embankment fill, the borings penetrated naturally occurring, soft, red, highly plastic lacustrine silty clay. This clay was tested to have a liquid limit ranging from 88% to 105%, a plasticity index of 54% to 74%, and a natural moisture content of 39% to 80%. Figure 3 presents a generalized subsurface profile through the landslide. Rapid embankment construction is believed to have initially caused the slope movement by over-stressing the soft foundation soils.

It was reported that the slow, creeping slope movement had been occurring for over 25 years. To measure the movement and better define the subsurface geometry of the failure surface, an inclinometer was installed within one of the completed boreholes. The inclinometer casing also served as a standpipe piezometer for measurement of the prevailing groundwater conditions within the embankment soils. During the weeks following installation, sufficient creep movement had occurred to define the failure surface at a depth of about 6.1 m below grade at the inclinometer location. The landslide was calculated to be moving at a rate of about 7 mm per year.

REMEDIAL DESIGN AND CONSTRUCTION

A simple alternative for stabilization would seem to have been to completely excavate all of the soil within the slide mass and replace it with compacted granular fill; however, this approach would have meant temporarily closing the highway, which is a main thorough fare for the local residents. In addition, the excavation would have extended below the water table in order to reach the deep sliding surface, requiring extensive groundwater control and surface water diversion of the nearby Koln Creek.

To reduce the driving moment of the slide, it was decided to partly excavate the embankment fill from within the head of the slide and replace it with lightweight polystyrene geofoam. The relatively high strengths and very low densities available with geofoam led to the decision to use expanded polystyrene

(EPS) blocks on this project. Type II EPS geofoam was specified, having a nominal density of 24 kg/m^3 and a minimum compressive strength of 103 kPa at 10% strain.

The thickness and location of the geofoam installation were determined through a series of stability analyses. It was assumed that the landslide was moving along a continuous failure surface. Given the age of the landslide it was also assumed that sufficient movement had occurred to develop the residual shear strength along the entire failure surface. Therefore, for the stability analysis, an average, composite residual shear strength for the soils along the assumed sliding surface was calculated assuming a factor of safety of slightly less than 1.0 for the creeping condition of the landslide. Once defined, a sensitivity analysis was performed to determine the effect of varying widths and thickness of geofoam on the factor of safety in order to achieve a post-construction factor of safety of 1.5. The material strength of the EPS was neglected in the analyses; therefore, the results were based strictly on weight reduction and the effect on reducing the landslide driving moment.

Geofoam will absorb some water with time once placed below ground due to soil moisture and surface water infiltration. The ability for EPS geofoam to absorb moisture increases with decreasing material density (Negussey, 1997). The Norwegian Public Roads Administration (NPRA) has reported that exhumed samples of EPS that have been buried for almost 30 years have shown water contents below 1% by volume where the EPS was kept in a drained condition, that is, above the groundwater table (Aaboe, 2000). Periodically submerged EPS had water contents of up to 4% by volume. For the stability analysis on this project, the material density was increased slightly assuming a water absorption of 3.5% by volume for the type II geofoam.

Based on the results of the stability analyses, three layers of geofoam blocks were placed on top of the drainage blanket, with each layer stair-stepped upward and into the embankment (Figure 4). The geofoam was manufactured in block sizes of 0.81 m high by 1.22 m wide by 2.44 m long. The geofoam layers were orientated such that each successive layer was placed with the long axis of the blocks perpendicular to the previous layer. To reduce the potential for sliding and movement between the blocks and layers, each of the blocks and layers were fastened together with steel gripper plates. The blocks were shipped to the site by tractor-trailer truck; however, no special equipment was required for unloading and placing the blocks since each block was light enough to be handled manually (Figure 5).

Due to the insulating effects of geofoam, an important consideration when using geofoam beneath pavements, particularly in northern climates, is the potential development of differential icing on the pavement surface. This is defined as the formation of ice on the surface of an insulated pavement when neighboring, non-insulated pavement is free of ice. Bridge deck icing can be anticipated by motorists; however, differential icing along a normal stretch of highway cannot be anticipated, and therefore can pose a serious safety problem. The intent is not to eliminate icing, but to attempt to time the formation, and degree of severity, of ice formation to be nearly compatible with icing over non-insulated areas (Horvath, 1995). On this project the top of the geofoam was embedded at a depth of 1.5 m below final pavement grade to be consistent with the anticipated frost depth in the Bayfield County area.

Buoyancy is also a concern with geofoam. Prior to placing the geofoam blocks, a drainage blanket and leveling pad were constructed at the base of the excavation, consisting of a 0.3 m thick layer of free-draining sand conforming to WisDOT Sec. 209, Grade 1. Within this drainage layer a 200 mm diameter slotted plastic pipe was placed parallel to the road centerline at the back of the excavation. Additional perforated drain lines were installed extending out perpendicular from the centerline pipe at approximately 15 m intervals, which daylighted the final embankment face. The backfill surrounding and overlying the block layers consisted of compacted free-draining sand. Although the weight of the overlying fill was sufficient to counteract the buoyancy of the geofoam, the drain lines would insure that the geofoam would not be permanently submerged due to water collecting over time within the granular backfill.

To reduce the potential for deterioration of the geofoam by petroleum infiltration from possible spills or leaks from the highway vehicular traffic, the geofoam was covered with an impermeable high density polyethylene (HDPE) sheeting prior to placing the final fill over the top of the geofoam blocks.

PERFORMANCE

The remedial work was completed during the summer of 1999, and has performed as intended since that time. Figure 6 presents a photograph taken of the landslide site during the spring of 2001. No cracking or distress of the pavement surface was observed and the pavement appeared to be in excellent condition.

Natural degradation of the geofoam over time is not an issue since polystyrene is not biodegradable. Current research by the NPRA indicates that no degradation in material strength or physical properties is expected of buried EPS fill over a 100 year period, provided that proper allowance is made for buoyancy forces, protection from accidental spills of dissolving agents, and that the stress level from applied dead loads is less than 30 to 50% of the material strength (Aaboe, 2000).

The risk for long-term termite infestation is believed to be slight to moderate in the northern Wisconsin area. Termites and carpenter ants are not attracted to polystyrene insulation, but could tunnel into, or through it in search for food or as a nesting site (Hahn, 2000). Since these insects tend to forage within the upper couple of feet of the ground surface, it is believed that the risk for insect related damage to the buried EPS on this site is low.

SUMMARY

A number of considerations must be reviewed in deciding an appropriate remedial measure for landslide stabilization. The use of lightweight geofoam provides a viable solution particularly where the reduction of the landslide driving force is required without permanently lowering the grade at the head of the slide. The use of lightweight EPS geofoam on the CTH "A" project allowed for a rapid construction process, which reduced the amount of over-all excavation required, and minimized the impact of construction on the continued use of the highway. The work was completed during the summer of 1999, and the slope has performed satisfactorily since its remediation. In addition, two other landslides along CTH "A" were also remediated using geofoam, and they too have performed as intended.

REFERENCES

Aaboe, R. (2000). "Long-term performance and durability of EPS as lightweight fill." Nordic Road & Transport Research, Vol. 12, No. 1, p. 4-7.

Hahn, J.D. (2000). Personal correspondence. University of Minnesota College of Agricultural, Food, and Environmental Sciences.

Horvath, J.S. (1995). Geofoam Geosynthetic. Horvath Engineering P.C.

Negussey, D. (1997). "Properties & Applications of Geofoam." Society of the Plastics Industry, Inc.

Syverson, K.M., (1998). Glacial History of Western Wisconsin, *in* Syverson, K.M., and Havholm, K.G., eds., Geology of Western Wisconsin: Guidebook for 61st Annual Tri-State Geological Field Conference and University of Wisconsin System Geological Field Conference, p. 15-28.

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