Procedures and Problems of Highway Soils Engineering on Loessial Terrain in Alaska

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This paper describes current procedures used in performing soils investigations and developing design recommendations for highways on loessial terrain. It explains investigation procedures from the reconnaissance phase through the most detailed study and discusses the occurrence and character of Alaskan loess relative to surface transportation routes. Design practices are outlined and their relative success is described using examples from the Fairbanks area.

•THE sources for most of the loess in subarctic Alaska were the flood plains of the major rivers and the glacial outwash plains that generally surrounded the Alaska Range during the Pleistocene. Since the major transportation routes often follow the course of the larger streams and in many cases are near the base of the mountains, loess is encountered on many highway projects in interior Alaska. The thickest deposits have been encountered in the Fairbanks area, and the examples discussed here are drawn from that locality.

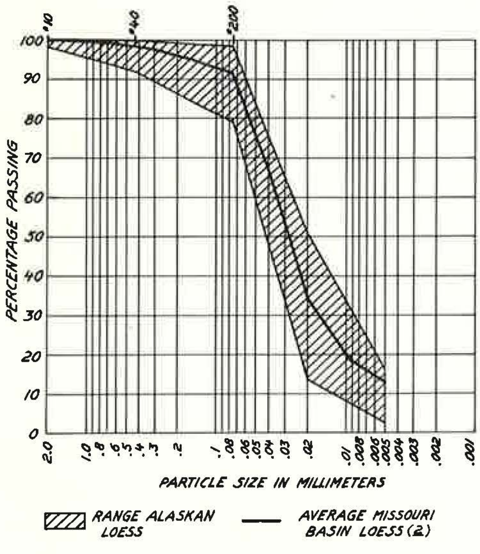

Figure 1. Loess gradation curves.

The gradation of loess from interior Alaska is compared with the gradation of loess from the Missouri River Basin area in Figure 1. In Table 1, other parameters are compared between the two areas. Most of the Alaskan retransported eolian silt shows extensive change from its original properties and cannot be properly termed "secondary loess." Retransported silt that accumulates on lower terrain is usually frozen and contains considerable moisture in the form of ice. The engineering properties of this material may be properly discussed in a permafrost context, not in a loess

TABLE 1

ATTERBERG LIMITS AND MOISTURE COMPARISON

	ALASKAN LOESS			MISSOURI BASIN LOESS (2)		
	AVG	HIGH	LOW	AVG	HIGH	LOW
LL	25.3	31.8	21.8	30.	34	25
PI	3.4*	7.3	1.1	8	12	4
NAT. MOIST.	23.5	48.7	11.1	8.0	—	—

* AVG OF 40% OF SAMPLES, 60% WERE NON-PLASTIC

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Figure 2. Shelby tube modified for frozen silt coring.

context. Loess, in interior Alaska, is seldom permanently frozen.

The purpose of this paper is to describe the procedures used by the Alaska Department of Highways in materials investigation and soils design in loessial terrain. Examples are presented to illustrate the effectiveness of these techniques and to point out some of the problems that have been encountered in dealing with Alaskan loess.

INVESTIGATION METHODS

The reconnaissance phase of a materials investigation begins with a study of topographic maps and aerial photographs. If the route in question is near major streams or areas of probable outwash fans at the edge of mountainous terrain, the occurrence of loess is expected. Erosion on loess covered hillsides often produces topography consisting of closely spaced alternating ridges and swales. This pattern is obvious on air photos and, if well developed, produces a crenulated contour pattern on topographic maps. In a field reconnaissance, observation is combined with a limited amount of shallow hand drilling.

Standard methods of detailed soils investigation require extensive observation, drilling, test pit excavation, sampling, and testing. Test holes are usually made by boring with a 6-in. diameter continuous flight auger or a 6- to 24-in. diameter bit on a kelly-type auger. Dozer trenches and backhoe pits are also used.

Disturbed samples are dug from the sides of trenches of pits. When the highway auger is used, samples are taken from the loaded auger. When using the continuous flight auger, disturbed samples are taken from the pile of material raised to the surface. A split-spoon sampler is occasionally used. Undisturbed loess samples are taken in a hole bored with the continuous flight auger by using a Shelby tube. It has been necessary occasionally to take undisturbed samples in frozen silt. A special tool was constructed for this purpose by cutting teeth in a Shelby tube and case-hardening the toothed end (Fig. 2). This modified Shelby tube has been very successful.

Loess samples are tested for gradation, Atterberg limits, disturbed unit weight, natural moisture content, and, in some cases, for maximum density and optimum moisture. These data allow establishment of the AASHO classification and the Corps of Engineers frost susceptibility values. (The frost susceptibility of a soil is an indication of its tendency to segregate ice on freezing and lose strength on thawing.) The values for the general soil types are determined empirically and are listed in Table 2 in order of increasing frost susceptibility.

TABLE 2

FROST SUSCEPTIBILITY VALUES

FSV	KIND OF SOIL	% FINER THAN 0.02 mm BY WEIGHT
F-1	GRAVELLY SOILS	3 TO 10
F-2	a) GRAVELLY SOILS b) SANDS	10 TO 20 3 TO 15
F-3	a) GRAVELLY SOILS b) SANDS c) CLAYS PI > 12	OVER 20 OVER 15 —
F-4	a) ALL SILTS b) VERY FINE SILTY SANDS c) CLAYS PI < 12 d) VARVED CLAYS AND OTHER FINE-GRAINED, BANDED SEDIMENTS	— OVER 15 — —

(5)

DESIGN PRACTICES AND EXPERIENCE

Overlay Design

For overlay design the Corps of Engineers design procedure for frost conditions is used. Application of this technique involves consideration of the terrain, the freezing index, the frost susceptibility of the embankment foundation, the moisture content of the embankment foundation and subbase material, and the type and amount of traffic. Climatic conditions require the use of the reduced strength of subgrade method. High freezing indices make it impractical, in most of Alaska, to prevent the freezing isotherm from penetrating the embankment foundation. Therefore, design thicknesses of select material are those required to prevent excessive deformation of the embankment foundation when it is weakened by excess water during thaw. Loess possesses a range of properties that call for a select material overlay of 2.0 to 3.0 ft in interior Alaska. Roads built to these specifications have exhibited satisfactory performance. Roads constructed with less select overlay have demonstrated a greater degree of distortion and have shown an increased tendency to develop pronounced dips where contraction cracks occur.

Embankment Design

As standard procedure, the Department utilizes dry excavated loess as unclassified fill wherever possible. Loess fills are constructed with side slopes no steeper than 1½:1 and compaction to 95 percent of the maximum density (AASHO T-180) is required. When economics dictate the use of loessial silt in poorly drained areas, a layer of granular material may be provided at the embankment base to cut off capillary rise. Completed examples of this type of "sandwich" embankment are too recent to have provided information on their performance. However, the behavior of a substandard example is illustrated by a road built by the University of Alaska near Fairbanks. This temporary road was built during the winter of 1962-63 by placing a 3- to 4-ft thick "loess" embankment on the natural ground surface. It crosses low terrain with a gentle cross-slope and was provided with few cross-drains. Initially it was topped with less than 1 ft of granular material. Subsequent lifts, placed in an effort to maintain a smooth riding surface, have increased the thickness of the granular layer to the 1- to 2-ft range. This road has exhibited severe differential settlement and slumping of the shoulders. Large frost boils are common in the spring and early summer. These phenomena result from the triple failing of poor drainage, no capillary cutoff, and insufficient granular topping for load distribution.

Backslope Design

The Department has used two types of backslopes in loess. These are the so-called conventional slopes and vertical or near-vertical slopes.

The steepness of conventional slopes in loess is varied according to the slope height, and the ratio chosen is influenced mainly by economic considerations. That is, the backslope angles are varied to alter the amount of excavation so that quantities of cut and fill can be balanced as nearly as possible. Slumping or sliding of conventional loess slopes of any height has never been a problem in interior Alaska, and stability analyses are not normally made for these slopes.

The decision to experiment with vertical and near-vertical loess backslopes was a natural consequence of the economic basis of backslope design. Vertical slopes have the obvious advantage of decreasing excavation quantities. They should also lessen maintenance costs by reducing or eliminating erosion of the backslope.

Both conventional and vertical backslopes are in service in the Fairbanks area. Comparison of their performance provides some instructive information on loess slopes in the subarctic.

A project about 8 mi northeast of Fairbanks has cuts in loess that range up to about 40 ft in depth. Conventional backslopes (usually 2 to 1) were used throughout the job. Construction began in 1963 and was completed in 1965, and cuts of various ages were observed during the summer of 1965.

Some degree of gullying was found on all slopes of 1963 and 1964 vintage. When the top of the backslope was nearly at the crest of a ridge, gullying was minor as the amount of runoff was then limited. Moderate gullying developed in areas where an expanse of hillside above the backslope allowed accumulation of a significant amount of runoff. Severe gullying developed only at those locations where runoff was concentrated above the backslope. This occurred at natural drainage paths and at places where the backslope intercepted old access roads or other cleared areas. Gullies,

Figure 3. Moderate gullying.

Figure 4. Severe gullying.

pitlike in profile, up to 12 ft deep were observed in 1963 vintage slopes at these points. Illustrations of moderate and severe gullying are shown in Figures 3 and 4.

A project about 12 mi northwest of Fairbanks has cuts in loess up to about 20 ft high and also involves cuts in retransported silt. Vertical backslopes were used in all cuts up to 10 ft. Near-vertical slopes (about 76 deg) were used in all cuts over 10 ft. Construction was begun in 1964 and completed in 1965. This project provides an example of vertical and very steep loess backslope performance for comparison with the conventional slope example just discussed. Design plans called for the preservation of the organic mat at the top of the backslopes to provide protection against precipitation and runoff. This was not possible for several long stretches, since a preexisting dirt trail happened to lie along the top of the backslope.

Figure 5. Slabbing of vertical loess backslope.

Figure 6. Chunking of vertical loess backslope.

Figure 7. Erosion of vertical loess backslope due to runoff concentration.

In loess where the top of the slope was protected the steep slopes have performed very well. In all but the dryest areas, however, slabs from about 1 to 4 in. thick separated from the face of the slope (see Fig. 5). This "slabbing" was observed to be more severe in damper material and on the south-facing slopes. It is thought to be a result of the development of planes of weakness due to concentration of moisture by cyclic freezing and thawing. In some places irregular chunks of material have fallen out of the backslope (see Fig. 6). The occurrence of these features could not be correlated with moisture content, slope exposure or material variation. They are apparently caused by the intersection of joints (probably contraction cracks) a short distance behind the face of the slope.

Erosion occurred in both loess and retransported silt, but only where there was no protecting organic mat above the slope or where runoff was concentrated to some degree. Figure 7 shows a case where a small berm oriented approximately transverse to the roadway concentrated water and forced it over the face of the slope. Retransported silt occurs only in swales (where drainage could concentrate); so it was always eroded. In general, the erosion seemed to stop when a projecting "roof" of organic material had formed.

Seeding as a means of slope protection has not been widely used by the Department. The dry climate, short growing season, and near sterility of the loess combined with the high cost of hand dressing of slopes and conventional seeding methods have made it unfeasible. In 1963, however, the Alaska State Division of Lands initiated a test program of seeding of loess slopes hydraulically. This method, which involves spraying a slurry of peat, grass seed, fertilizer, and water on the slope, overcomes the principal objections to seeding. In general, the planting was successful and has prevented erosion. However, these test slopes are rather low and in areas where little runoff flows over them. Although this cannot be considered a definitive test of seeding, it has caused a renewal of interest in that method of slope protection.

Ditch Design

One of the most serious problems that has been encountered in road building in loess areas is that of ditch erosion. In the Fairbanks area a fairly large percentage of the annual runoff normally occurs during a short period of time in the spring. Under these conditions flow velocities sufficient to cause extensive erosion are attained on ditch gradients as flat as 0.3 percent. Artificial reduction of ditch gradients by use of structures has not received serious consideration because of the tendency of loess to develop "pipes" around or beneath such features.

For any given discharge a flat-bottomed (trapezoidal section) ditch permits a shallower depth and lower velocity of flow than a V-section ditch. However, a trapezoidal ditch requires a greater volume of excavation, and excavation of a more complicated shape. It is felt that, in most cases, the extra capacity of a wide, flat-bottomed ditch is not required. For this reason a wide V section with some form of erosion control is normally used for ditches in loess. At present the only means used to prevent loess ditch erosion is to armor the ditch with gravel. Specifications are being developed for seeding ditches as well as cut slopes, and vegetative erosion control methods may be used in the near future. Of course, ditches in loess are made as flat as possible, and frequent cross-drains are provided to minimize concentration of water.

Runoff during the spring breakup can cause very dramatic erosion. Gullies as deep as 22 ft have formed in a very few days where the initial ditch gradient was about 5 to 7 percent. On occasion, spring flow in excessively narrow ditches has undermined backslopes and caused their failure.

Design Trends

In territorial days, narrow V ditches were the standard. Erosion and excessive maintenance costs caused this to be changed to a wide trapezoidal ditch section after statehood. It has been found that the high efficiency of the flat-bottomed ditch section is not required in many areas. The current standard procedure is to use a wide V ditch (4:1 foreslope) in most areas and a wide trapezoidal ditch when problems of backslope stability, drainage, or snow storage are evident.

Initially, conventional backslopes were the standard. Erosion problems led to the use of vertical and near-vertical slopes. The steep slopes may become the standard in true loess, but hydraulically seeded conventional slopes appear more favorable in unfrozen retransported silt. Conventional slopes will continue to be used in frozen retransported silt when cuts in that material cannot be avoided.

Initially, excavated loess was placed in fills without using a granular capillary cutoff at the base. In wet areas differential heaving due to ice segregation resulted. Frost boils and shoulder slumping occurred during thawing. Current standard design procedure is to use only granular material for embankment construction in poorly drained areas. Where economics dictate the use of loess fills in wet areas, a capillary cutoff of gravel or crushed rock is provided at the base.

The only research pertinent to loess problems currently in progress deals with the prevention of ice segregation during freezing of silty soils. The study is being conducted by the Arctic Environmental Engineering Laboratory at the University of Alaska. The purpose is to evaluate the effectiveness and economic feasibility of various methods of treatment of silty soils to prevent or reduce ice segregation on freezing. Laboratory testing is currently in progress. According to the principal researcher, the most promising techniques seem to be (a) the addition of a soil dispersant chemical (Tetra sodium pyrophosphate); and (b) placement of an impervious boundary (polyethylene membrane) between the silt and the source of water. If laboratory tests continue to show promising results, test sections may be considered.

SUMMARY AND CONCLUSIONS

The major problems encountered by the Department in designing and building highways on loessial terrain result from frost action. The subarctic climate produces very deep seasonal frost penetration and, given a water source, allows segregation of a great deal of ice. A large percentage of the total runoff occurs in the spring when frost prevents percolation into the ground and when culverts may be clogged with ice. Frost action is a direct cause of some of the types of failures of near-vertical slopes discussed here. The short growing season complicates the establishment of vegetative slope protection. Design practices are in a state of evolution. The present techniques are successful and economical, but are continually being refined to provide improved performance at lower costs.

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