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Vertical movement of houses No 162 and 160 from middle of September to beginning of November 1947, as compared with variation of air temperature.

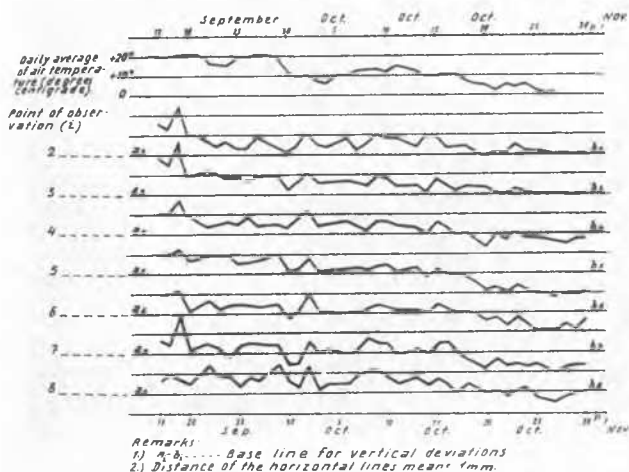


FIG.20

tubes here generally used for such purposes have been 15, 18, 22 cm. Wider drillholes would furthermore facilitate taking samples for proper shearing tests, the normal boreholes being too narrow for such samples.

After collapse of the houses Nr. 166 and 168 the behaviour of still standing houses nr. 162 and 160 has been observed with extraordinary care. The results of precise levelling of fix points on front walls of these houses (see figure 20) show distinctly a perfect stability of the flats and a rather synchronous character

of their little vertical movements with variations of air temperature.

In order to exclude for the future any danger by groundwater, the project on reconstruction of the shore-wall has been completed by a plan providing security against imbuing the clay-soil with artesian water. Ground water level is intended to be controlled by an outlet tube, discharging into the "Wienfluss"-creek, so that it cannot rise above the highest admissible horizon of soil-water behind the new retaining wall. In cases of floods in the "Wienfluss" the mouth of the aforementioned tube is to be closed up automatically and groundwater to be pumped into the creek. From the upper horizon of groundwater (above clay surface) drainage is secured by a channel at the wall-back. By that way protection of the retaining wall against any harm coming from groundwater may pass as guaranteed.

SUMMARY, (CONCLUSIONS).

Investigation of clay ground with respect to safety-computation against sliding should since be made -if possible- by means of carefully excavated and secured shafts instead of boring narrow drillholes to that purpose. By that way thin lubricating layers are easier to be found. When taken "undisturbed" samples of soil, diameters of sampling cylinders should be essentially wider than those having been till now generally used.

By that way not intended disturbances of "undisturbed" samples and errors in determination of soil resistance can surely be avoided. Such an increase of dimensions of samples supposes of course a corresponding increase of drillhole diameters. Wider drillholes furthermore enable the soil-mechanist to draw undisturbed samples for proper shearing tests.

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TREATMENT OF FROST SLOUGHING SLOPES

KENNETH S. LANE

Chief, Soils & Geology Br., Garrison Distr., Corps of Engineers,
Bismarck, N. Dakota

SUMMARY

Sloughing of slopes during frost melting often requires expensive maintenance for removal of soil which has moved down to partly cover the area at base of the slope. Examples are given and movement explained as a flow of loose and wet soil. From successful experience in New England, surfacing such frost reactive slopes with a thin blanket of pervious soil or cinders is considered an adequate preventive.

Sloughing of slopes during the frost melt period is a frequent source of annoyance and maintenance in regions experiencing frost action. The movements considered here are generally shallow and are most pronounced under highly frost reactive conditions. In the usual form of a frost slough, the top 6 to 30 inches of surface soil moves down the slope and develops to a flow, filling any ditch present and spreading over the ground at toe of the slope. In central New York State such flows have covered highways to a depth of several feet, often with an annual frequency; whence, one of the treatments adopted has been expensive widening of cuts to provide a 15 to 25 foot shoulder to partially contain future flows. The fol-

lowing two cases are good examples; pictures of others have been presented by Mullis 1).

Fig. 1 shows a frost sloughing slope on the access railroad to Westover Airfield, near Springfield, Mass. This cut is about 30 feet deep through approximately 5 feet of sand underlain by varved silt (silt, fine sand and lean clay in thin interstratifications). It was originally constructed in 1940 with a 1 on 1½ slope from back of the ditch. During its first spring melt period, the silt sloughed down to fill the ditch. One or two years later a more extensive slough flowed about 2 feet thick across the tracks. At time of the photograph, in the Spring of 1946, the cut had been widened considerably by further sloughing and mainte-



FIG. 1

nance excavation on a nearly annual basis. Severity, of course, decreases with age and the slough of 1946 did little more than fill the ditch and gravel ballast as shown in Fig. 1. An underdrain is present beneath the ditch shown, but has been of no value in reducing sloughing.

An example of maintenance expense from frost sloughing is the cut on Highway C-1 at Orient Heights near East Boston, Mass., see Fig. 2. Here a cut was made about 100 feet deep through a strong formation of compact glacial till, partly cohesive and well graded from 18 inch boulders to clay sizes. It is understood this cut was made around 1935 with about a 1 on $1\frac{1}{2}$ slope and that during most subsequent spring melt periods sloughs have flowed down to nearly cover the four lane highway at the base. Maintenance excavation to create a shoulder, while removing the sloughed material, has been an unsuccessful remedy, as have likewise been various constructions of rock retaining walls and the chain link fence shown in Fig. 2. At the time of this photograph, in September 1946, construction was under way to flatten the slope to 1 on 2 with two mid-slope berms, each equipped with a gravel and pipe underdrain 2)

From observation of numerous frost sloughs the mechanics of the movement are visualized as shown in Fig. 3. When the rate of penetration of cold drops below the rate at which heat is supplied from the earth's interior, thawing begins at bottom of the frozen zone and progresses upward. As the melt period advances, thawing also starts from the surface and progresses downward, the middle zone remaining frozen as noted in Fig. 3. During freezing the soil has been expanded by formation of ice lenses, approximately equaling the amount of heave. Melting converts this to a very loose and very wet soil approaching a semi-fluid. With drainage from the surface thawed zone trapped by the impervious frozen layer directly below, the surface material retains its melt water and as a semi-fluid creeps down the slope, accelerating to a flow at the base. Evaporation from the surface retards the movement; erosion from surface run-off accelerates it. The soil below the frozen layer AA is more stable, from drainage of melt water downward during the longer period of upward thawing and from restraint supplied by the frozen layer AA.

That heaving from frost action and subsequent melting can convert a soil to a very loose state, with a corresponding large reduc-



FIG. 2

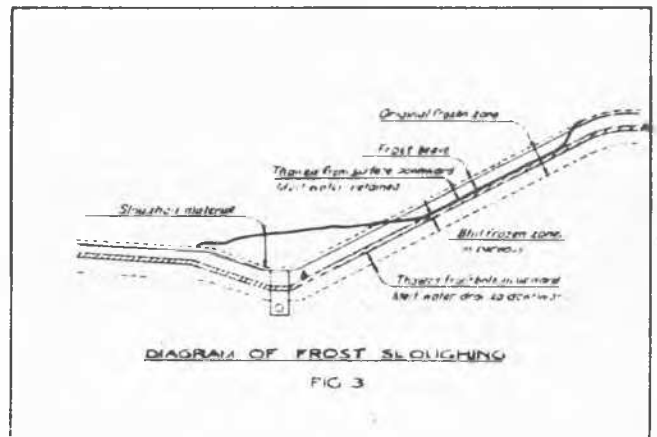


FIG. 3

FIG. 3

tion in shear strength, is illustrated by Table I. In view of laboratory results obtained by Winn and Rutledge 3) (up to 60% heave and quadrupling of initial water content), the assumptions of 40% heave for a uniform silt and 25% for a graded glacial till are considered reasonable for illustrative purposes. These laboratory results were based on behavior of the entire specimen 7 inches high; but in nature lower percentages of heave should be expected in the upper part of the frozen zone than in the lower part where the greatest concentration of ice lenses has usually been found. 4)

The tendency for frost sloughing is most pronounced with soils of high frost susceptibility and low shear strength - in the humid climate of New England varved silts, uniform silts and cohesive glacial tills being about the worst offenders. It also varies with the percentage of heave in the upper part of the frost zone which, in the Fall, is accentuated by a sustained slow freeze and minimized by a very rapid severe freeze. A major factor is the speed of surface thawing in the Spring. Such conditions as bare soil without insulating vegetation, snow insulation removed or blown away and a slope exposed to a maximum of sunlight combine to increase the rate of melting and the tendency toward sloughing.

Nature has developed several remedies, including: (1) bonding the surface to underlying soil with deep roots; (2) covering with an in-

ulating layer of vegetable matter (some observations show hardwood forest litter as particularly effective 5); and (3) creating a more pervious surface layer as from soil creep carrying down a pervious soil from a cap deposit or from weathering making the top horizon more pervious than the parent soil. An insulating layer acts to retard thawing from the surface, ideally until bulk of the frozen zone has thawed from below. It is felt the value of a pervious cover comes from its weight consolidating the melting soil below back to normal density and shear strength and, from its drainage ability, removing the excess water expelled by such consolidation.

Over a period of years several of the New England railroads have gradually developed a practice of covering sloughing slopes with a blanket of pervious material similar to Nature's remedy. The common material has been cinders, largely because of a readily available supply. Most cinder blankets have been only 6 to 12 inches thick, although one 3 feet thick has been observed at West Caanan damsite (near Lebanon, N. H.) where the Boston and Maine Railroad passes through a cut about 40 feet deep in glacial till. This type of treatment has been quite effective as, for example, a slope on the Boston and Maine Railroad relocation around Birch Hill Dam (near Athol, Mass.) with a 6 inch cinder blanket has stood well, while sloughing has occurred in an adjacent untreated highway cut in similar soil (semi-impervious sandy till, cohesionless). The more frost reactive conditions require thicker blankets, as illustrated on the Boston and Albany Railroad at West Brookfield damsite (near West Brookfield, Mass.). Here a 6 inch cinder blanket has not been sufficient to eliminate sloughing in a 15 foot cut through semi-cohesive glacial till, although considerably reducing it in comparison with adjacent untreated slopes.

In addition to protecting against frost sloughing, such pervious blankets are also a proper treatment against sloughing from seepage emergence - another type of sloughing where the pervious cover acts as a filter blanket by allowing drainage while weighting the soil against movement from seepage forces. As a treatment for sloughing from seepage, from frost and from a combination of both causes, the author has had good success with pervious slope blankets on several projects designed and constructed by the Providence (R. I.) District, Corps of Engineers.

In 1939 relocation of the State highway

TABLE I

Effect of Heave on Soil State			
Soil	Dry Weight Pcf	Void Ratio ^x	Water Content ^x
<u>Silt</u>			
Normal	100	0.66	25%
Assume Heaved 40%	72	1.33	50
<u>Glacial Till, Cohesive</u>			
Normal	135	0.23	9
Assume Heaved 25%	107	0.54	20

^x) Based on 100% saturation, specific gravity 2.65.

across a diversion canal for Mill River at Northampton, Mass., encountered varved silt in a cut about 25 feet deep just west of the canal drop structure. As treatment against seepage and frost sloughing combined, the uphill slope was covered with approximately 12 inches of sand plus 6 inches of topsoil and equipped with an underdrain at the toe. Keene Airport at Keene, N. H., was constructed in 1942 - 1943, in part founded on an extremely soft varved silt, too weak to support construction equipment. For protection against frost sloughing a 1 on 2 slope about 20 feet high was blanketed with bank run gravel, because of the weakness of this varved silt using 24 inches of gravel plus 6 inches of topsoil.

On the municipal airport at Rutland, Vt., a 10 foot high uphill slope (5 feet of fine sand over varved silt) was blanketed with 24 inches of sand and about 3 inches of topsoil to guard against both frost and seepage. On the east access road for Union Village Dam, now under construction above White River Junction, Vt., a 24 inch sand blanket has been included as frost sloughing protection on two 1 on 1½ slopes about 20 feet high in varved silt.

At Knightville Dam, completed in 1941, near Huntington, Mass., an underdrain alone seemed to the author sufficient for treating an uphill slope in cohesive glacial till. However, performance was otherwise as the drain has been able to control seepage emergence but not frost sloughing. This case and experience with the slope in Fig. 1 confirm experiences of others that drainage alone does not prevent frost action, except where it can drop the zone of capillary saturation below the frost line (a rare case in frost susceptible soils).

CONCLUSIONS

From this and railroad experience a pervious blanket is considered a satisfactory treatment for frost sloughing. Unless there is also a problem of seepage emergence, the additional use of an underdrain appears unnecessary. Where a cap deposit of sand or gravel is present, bulldozing this down over the underlying frost reactive soil is a simple method of constructing the pervious blanket. From present experience a blanket thickness of 6 to 30 inches has seemed adequate for Central New England, using the larger thicknesses for the most severe cases or for frost and seepage sloughing combined. For frost sloughing alone, cinder fill appears slightly more effective than sand or gravel as its lower thermal conductivity 6) also gives an insulation effect. For seepage sloughing alone, sand or gravel are considered preferable to cinders, their greater unit weight offering greater resistance to seepage forces.

REFERENCES:

- 1) "Illustrations of Frost and Ice Phenomena," by Ira B. Mullis, Public Roads, U. S. Dept. of Agriculture, Bureau of Public Roads, June 1930, p. 68.
- 2) New England Construction Magazine, Oct. 1946
- 3) "Frost Action in Highway Bases and Subgrades" by H. F. Winn and P. C. Rutledge, Engineering Experiment Sta., Purdue Univ., Research Series No. 73, May 1940, p. 56-65.
- 4) "Report on Frost Investigation, 1944-1945," New England Div., Corps of Engineers, Boston, Mass., April 1947, p. 29.
- 5) "Soil Freezing and Forest Cover," by K. T. Belotelkin, U. S. Dept. of Agriculture, Northeastern Forest Expr. Sta., Technical Note No. 37, 1941.
- 6) Reference 4, p. 32.