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Plastic-Lined Mole Drains

Promising answer to low-cost subsurface drainage

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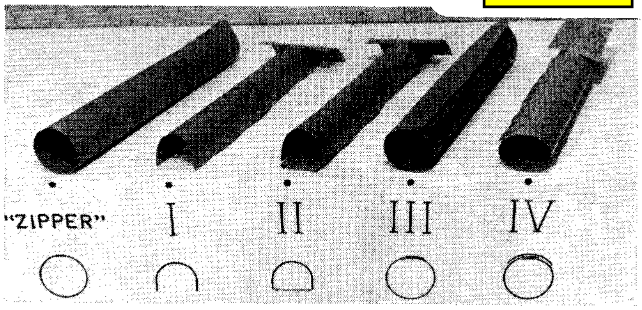

Fig. 1 Various types of PVC plastic mole drain liners under field test are: Positively closed "zipper" type, (I) Busch type arch, (II) arch type with 7½ mil plastic floor, (III) caterpillar-type overlap, and (IV) caterpillar-type overlap with "cap"

IN THE past fifteen years considerable research has been conducted to develop techniques for utilizing new materials to lower the cost of subsurface drainage. A new type of plastic mole drain liner and improved equipment for more accurately installing plastic-lined mole drains have been designed to provide a low-cost method of subsurface drainage particularly in slowly permeable soils and in soils with shallow impermeable strata requiring narrow drain spacings. Most of the research in this area has been centered around stabilizing a conventional mole drain channel with various types of lining materials and, to date, plastics have shown considerable promise.

Mole drainage has been attempted in the United States, but has not been particularly successful, except in certain organic soils where, at best, it serves only as a temporary drain. Stabilizing mole channels with shellaced metal tubes (16)[*], bitumenized fiber material (11), and various forms of plastic (12) have been investigated in Germany. Recently in England (8, 9), a method was developed to extrude a porous concrete lining within a mole channel. In the United States as early as 1948, Schwab (17) succeeded in pulling pre-extruded and perforated polyethylene tubing into a mole channel. Techniques have recently been developed for installing semirigid sheet plastic liners in mole drain channels (2, 13). Investigators in England have made considerable progress in developing an interlocked circular plastic mole liner.[‡] Each of these reports shows considerable success in reducing the cost per unit length of drain. However, durability of the various mole liners, problems of achieving uniform drain size and gradient, and equipment limitations all point to the need for more intensive study.

Busch (4) found in preliminary field studies that unlined mole drains tend to fail because of soil falling from the roof of the channel, thus plugging the drain, rather than because of the channel collapsing from surface loads. Therefore, the major function of the plastic mole liner is to resist those forces that cause the roof of an unlined mole channel to deteriorate. The mole liner also improves the drain's hydraulic characteristics and prevents sediment from entering the channel. Manley (14, 15) demonstrated that the "bridging" phenomenon of soil tends to transfer internal soil pressure caused by surface loads to the soil on the sides of the mole channel. He found that the tendency of a soil to "bridge" increases as the bulk density of the soil increases. He reported that lined or unlined mole channels were collapsed by surface loading only after considerable depression on the soil surface.

Types of Plastic Mole Liners

A semirigid sheet of polyvinylchloride (PVC) plastic, 15 mil in thickness, was used in this study for the mole lining material. It has a tensile strength of 7700 psi, modulus of elasticity of 450,000 psi and an Izod impact strength of 0.5 ft-lbs (all at 77F). It is a thermal plastic with high chemical resistance and good dielectric properties. The plastic material will withstand considerable bending, twisting, and tensile pull.

A method was developed to install within a mole channel a completely closed circular liner formed from a coil of sheet PVC plastic. A 3-in. diameter mole liner was formed from a 10-in. wide sheet of plastic that had interlocking tabs prestamped along both edges. A short section of formed "zipper" type mole liner is shown at the left in Fig. 1. It was nicknamed zipper mole liner because the interlocking tabs were fastened together with a zippering action by a special die mounted in the installation equipment.

The additional types of plastic mole liners shown in Fig. 1 are being studied also. The earliest mole liner formed from a sheet of plastic was the Busch-type arch (I), which was merely a plastic roof in the mole channel. Through further study in Ohio a 7½ mil PVC plastic floor was placed in the arch type liner (II). Such a floor reduced soil erosion from the bottom of the mole channel and improved hydraulic characteristics of the drain. An overlap circular mole liner (III), and later an overlap type with a "cap" (IV) to prevent sediment from entering the overlap joint were developed and tested[†]. These liners were formed from sheets of plastic by merely overlapping the edges at the top of the drain. The overlapped edges were not bonded together.

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[*] Numbers in parentheses refer to the appended references.

[‡] Personal visit by A. N. Ede, Ministry of Agriculture, England, August 1960.

[†] Unpublished material supplied by the Caterpillar Tractor Co.

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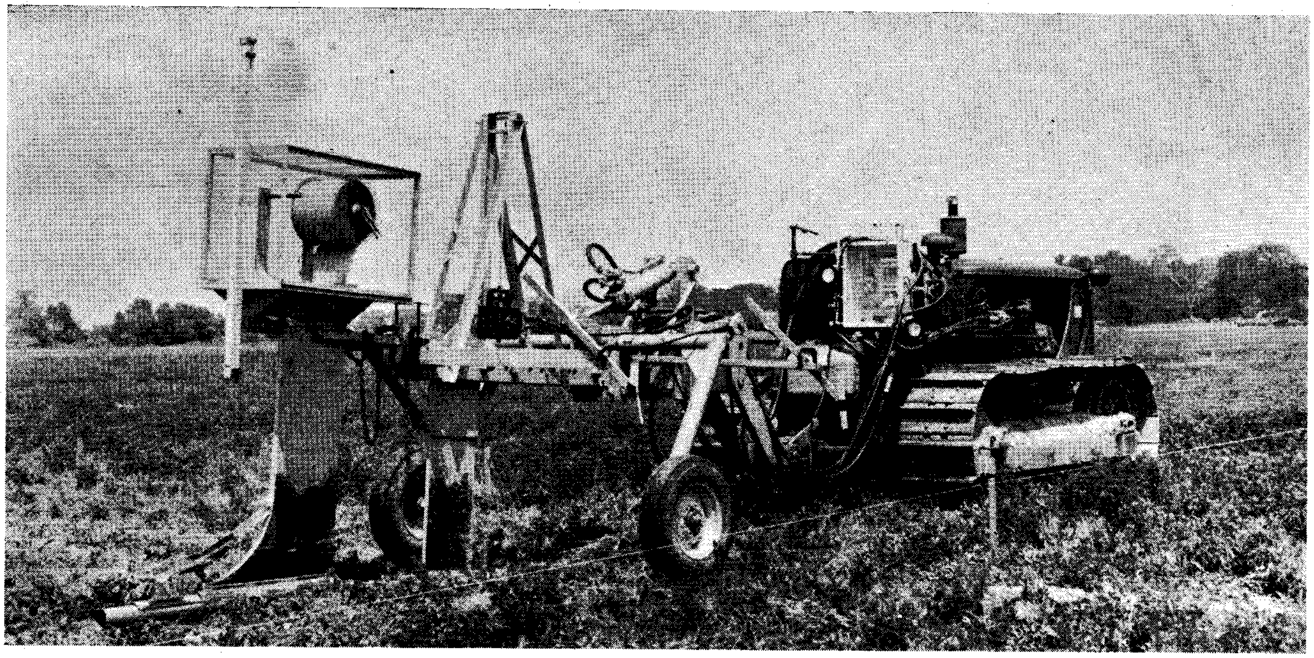

Fig. 2 Mole plow and attached mole-lining implement developed to install plastic lining in a mole drain channel. Completed "zipper" mole liner is shown at the lower left

Installation Equipment

Fig. 2 shows the mole plow and equipment developed for installing the plastic lining in a mole drain channel. Fig. 3 illustrates the progressive transitional forming of the zipper mole drain liner by the mole-lining implement. As the plastic material unwound from the 600-ft supply roll (A), it was folded into a tight U (B) and pulled down a vertical chute to the tubular base of the mole-lining implement; there it was pulled around a specially designed 45-deg directional change roller (C); then the interlocking tabs were fastened by the "zippering die" between (D) and (E), and the plastic liner emerged from the machine in a circular shape (F). The soil slit left directly above the mole liner by the plow blade was closed by a soil displacement device attached to the mole lining implement, shown at the lower left in Fig. 2. This initiated "bridging" of the soil over the mole liner. To prevent brittleness of the plastic during cold weather operations (35 to 50F), the supply roll was maintained at a 75F temperature in a heated chamber on the installation equipment.

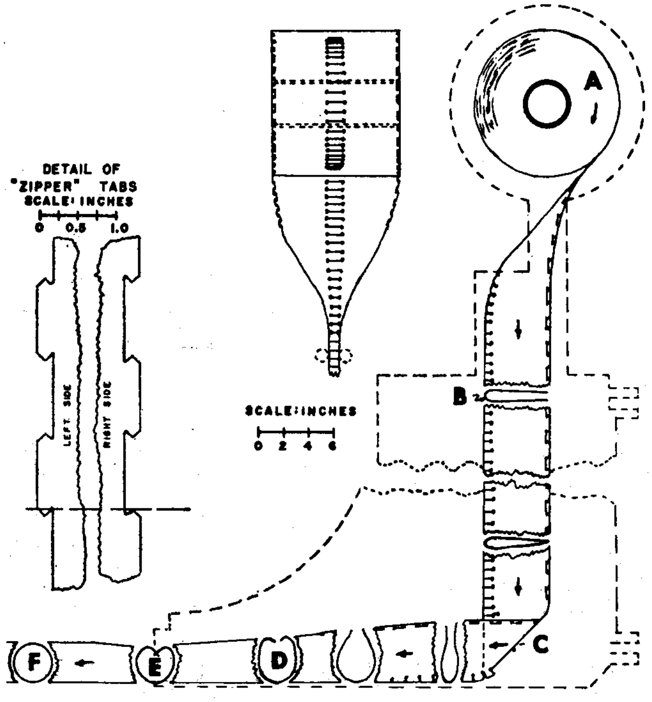

Fig. 3 Progressive transitional forming of the "zipper" plastic mole drain liner by special guides in the mole-lining implement

An operating speed of 100 to 125 fpm and a penetration depth of 28 in. were successfully used in heavy clay soil. At that depth a track-type tractor capable of developing 15,000 to 24,000 lb of drawbar pull (varied with soil and moisture content) was required to pull the machine. By interchanging parts and devices in the mole-lining implement, it was possible to install the various other types of liners shown in Fig. 1. With this versatility, only one basic machine was required to install the various types of mole liners for comparison in replicated field tests.

A floating-beam type of mole plow was adapted to pull the mole-lining implement. The two-wheel dolly shown on the plow in Fig. 2 was used only for lifting and transporting the machine. The wheels were allowed to "float" during field operation. The mole plow operating depth was adjusted by hydraulically changing the angle between the hitch linkage and the plow beam.

An automatic, grade-control system was developed and tested for the floating-beam mole plow. It operated similarly to an automatic leveling device in that it maintained the plow beam at a constant slope (parallel to the drain gradient) regardless of ground-surface irregularities the tractor and machine passed over. A fluid-dampened pendulum (mounted on an A frame on the plow beam, Fig. 2) was used to maintain a vertical reference from which changes in slope of the plow beam were "sensed" as the machine moved forward. The pendulum activated electrical switches that controlled hydraulic cylinders for raising or lowering the front of the plow beam. This maintained the beam at the desired slope. In preliminary field tests the automatic grade-control system worked satisfactorily at flat gradients of 0.2 percent and at speeds of 80 to 100 fpm. The performance of the system was evaluated by taking level readings on the rod attached to the machine as it traveled across the field (Fig. 2). The grade string stretched alongside the machine and the string pointers attached to the plow beam were used for visual reference. A few design modifications are being made on the automatic grade-control system, and further testing will be conducted in 1962.

Field Evaluation of Plastic-Lined Mole Drains

Experimental field installations for comparing the various types of plastic mole liners under varying soil types were made in Minnesota, North Dakota, Ohio and Indiana during 1960 and 1961. Results were not available from all these sites in 1961. The experiment discussed in this paper was installed at the North Central substation of the Ohio Agricultural Experiment Station at Vickery, during November, 1960, to compare the zipper, overlap with cap, and plain overlap types of mole liners. The experimental site is on a slowly permeable Toledo silty clay soil, a typical "lakebed" soil, which is very sticky when wet and difficult to till when too wet or too dry. A second-year meadow was in the site at the time of installation, and soil moisture was about 28 percent.

Experimental design. The experiment included three 400-ft drains for each type of liner tested, or a total of nine experimental lines. Two plastic-lined boundary drains and two unlined mole drains were used as controls. The drains were spaced 15 ft apart and were installed 25 to 27 in. deep on a 0.2 percent gradient. All drain outlets discharged into a canal. A stainless steel wire was pulled into each drain during installation to facilitate pulling cross-sectional and grade-alignment measuring equipment through the drains. The inside diameter of each plastic-lined mole drain was measured periodically with a strain-gage "measuring mouse", similar to the one developed by Busch (3). A grade-alignment probe (1) was used to determine the uniformity of the drain gradients.

Results. The diameters of the plastic-lined mole drains were measured nine months after installation and the results are shown in Fig. 4. These results are for only one replication in the experiment, but they are considered typical. The partially collapsed section of the drains shown at 290 ft from the outlet, for all three types of liners, was located at a field surface ditch. The mole liners were approximately 12 in. deep at that point. The plastic mole liner wall irregularities observed in September 1961 were unchanged from those observed in March 1961. The plastic drains flowed for the first time in March 1961. The "mouse" could not be pulled through the unlined mole drains because they were almost completely closed with loose soil.

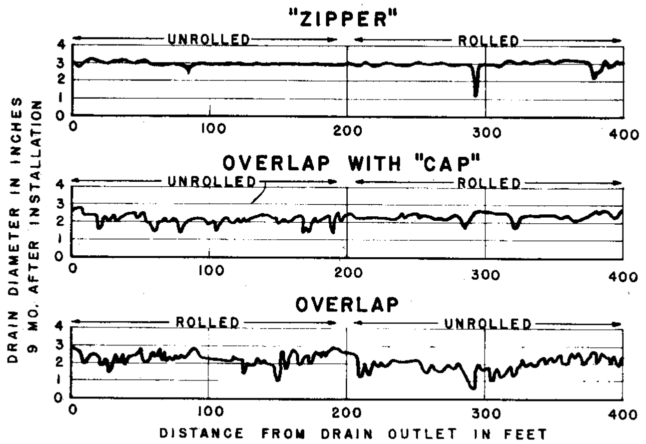

Fig. 4 Diameters of three types of plastic-lined mole drains nine months after installation (Ohio)

Fig. 4 also shows the effect of surface "rolling" one-half of each drain immediately after installation to close the vertical soil slit left by the machine. One track of a large track-type tractor (7-psi unit pressure) was used to "roll" the slit closed. In general, the rolled sections of the overlap with cap and the plain overlap types of plastic-lined moles were larger in cross section than were those sections not rolled. Surface rolling did not show a significant effect on the zipper-type liner.

The experiment was irrigated in September 1961 with 5.25 in. of water at a rate of 0.25 in. per hour. Immediately after irrigation 0.8 in. of rain fell at a rate of 1.2 in. per hour. Although considerable variations in the diameters of the various types of plastic-lined drains were found, significant differences were not found in the outflow rates or volume of flow from all the plastic-lined drains, including the lined boundary drains. The flow rate from the plastic-lined moles during irrigation was compared with that from 4-in. tile drains in a very similar soil type on the same farm. Under the same application rate of irrigation, the outflow rates per unit length of drain from plastic drains and tile drains were essentially the same.

The plastic-lined drains removed water at a rate of 4.8 in. per day (12.5 gpm for a 400-ft drain) once equilibrium conditions were reached during irrigation. Immediately after the rainfall ceased, an average peak flow rate of 8.5 in. per day (22 gpm for a 400-ft drain) was measured from the plastic-lined drains. Only one of the two unlined mole drains in the experiment flowed, and it was at a much lower rate — 0.2 in. per day (0.5 gpm) during irrigation, and 0.3 in. per day (0.7 gpm) following the rainfall. The total 400-ft length of unlined mole drain probably did not contribute to the outflow since loose soil plugged most of the channel.

Only preliminary field results on the arch types of plastic mole liners were available for this report. Arch-type liners installed in Ohio during June 1961 were more irregular in cross-sectional size than the other types of liners studied.

Field Studies of the Plain Overlap Mole Liner

In the spring of 1959, the plain overlap-type plastic-lined mole drain was installed at eight different locations in California, Nevada, Utah and Colorado. The plastic drains were installed 27 to 29 in. deep in several soil types represented in the various sites. In one installation on a rice plot, an average of 15 tons of salts per acre were removed through the plastic-lined moles by 120 days of flooding. This trial demonstrated that this type of drainage can be employed successfully in a leaching and reclamation program.

Following two seasons of observations it was concluded that the plastic-lined moles were successful in the heavy clay types of soils, partially successful in the silty clay and loam soils, and unsuccessful in the sandy soils. The most critical problem in clay soils appeared to be the management practices immediately after installation. Flooding disintegrated the clods and hastened the repose of the soil around the mole liner. The earlier machine (13) used for these installations did not employ a soil-displacement attachment to close the soil slit directly over the mole liners. The most critical problems in sandy soils appeared to be the prevention of sand entry into the drains through the perforations or along the top overlap, and/or their collapse because of sand entry or hydrostatic pressure of the saturated sand. In general, it was concluded that an installation depth of 42 to 48 in. would have resulted in better performance of the plastic drains in the fine-textured soils.

Laboratory Sand Tank Studies

The field tests in sandy soils led to an investigation in California to study the thin-walled plastic mole liners in laboratory sand tanks. The objectives were to determine stability of the zipper-type mole liner against collapse in saturated sand, and to obtain an opening for water entry into the drain that would exclude the sands but would not appreciably restrict entry of water. Preliminary results indicate that almost any size hole used in the fabrication or conformation of the plastic mole liner will admit some sand into the drain. It was found, however, that the small opening resulting from the interlocking tabs on the zipper mole liner excluded the sands. Further studies will be made prior to field testing the zipper-type mole liner in sandy soils.

Comments and Interpretations

Experience with the mole-lining machine during 1960 and 1961 showed that the zipper plastic mole liner could be installed with as much ease and trouble-free performance of the machine as the simpler overlap or arch types of mole liners. After nine months of field testing, the zipper mole liner had maintained its cross-sectional size and shape better than the overlap types. However, to make a sound evaluation of the various types of plastic mole liner, a long-term study of these drains under field conditions is needed, possibly four to six years.

This application for plastic may have an extremely important function in future drainage developments. Costs for installing the zipper mole liner 28 in. deep in a heavy clay soil are estimated at 10 to 12 cents per linear foot, 8 cents of which is for the plastic material. With further improvement in equipment, grade-control devices and plastics, it may be possible to install 3-in. diameter lined moles up to 4 ft deep in many soils. As depths increase, installation costs increase, but probably not to exceed 17 to 18 cents per linear foot.

If this method of subsurface drainage proves successful, it will have many applications. Probably its most important application would be in heavy clay soils, since the lower cost of installation would permit closer lateral drain spacings resulting in better water-table control. Because the drain size is limited to smaller diameters, these plastic drains would be applicable only for laterals and not mains. They may have extensive use throughout much of the West for leaching saline soils. Their use in the distribution systems of subsurface irrigation in the West may be another application. Many other applications are apparent, such as interceptor drains on hillside seeps, drainage of long narrow waterways, random drains to depressional areas in a field, drainage and water table control of muck soils, etc. Another desirable characteristic of such subsurface drainage systems is that they can be installed in many areas without disrupting normal farming operations or disturbing the crop.

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