DEFORMATION OF CORRUGATED PLASTIC DRAINS BY SOIL SURFACE LOADS

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Static loads were applied at the soil surface to two types of corrugated plastic drains in two soil types at two depths of installation. Installation was in trenches and simulated mole channels. Results were evaluated statistically by analysis of variance. Soil surface loads which the drain tubes could support were significantly greater in sandy loam soil than in silt loam soil and when the drains were installed at greater depth. Placing the drains in simulated mole channels also allowed greater surface loads to be carried.

INTRODUCTION

The use of corrugated plastic tubing for land drainage is increasing. Fouss (1968) reported that the installation of corrugated plastic tubes with a drain tube (mole) plow was promising as a means for more effective and more economic field drainage. However, with increasing mechanization of farm operations, heavier farm machinery and equipment is being used. Also, the use of modern installation equipment has resulted in an increase in the depth at which drain tubes can be installed. Consequently, drain tubes are likely to be subjected to greater loads than they were in the past. The loads on these drain tubes include those caused by the weight of the soil and by concentrated loads due to the passage of vehicles or equipment.

Recently, some research has been done on the durability of plastic drain tubes. Drablos and Schwab (1971) made field and laboratory investigations of 4-inch (100-mm) corrugated plastic drain tubes which had been installed under different field conditions for at least 1 yr. The length of time that the tubing had been installed had some effect on the amount of deflection. Less deflection was found where care had been taken in properly placing the blinding and backfill soil.

Negi and Broughton (1971) carried out field loading tests and laboratory investigations on corrugated plastic tubing. The field loading tests, on drains installed in sandy loam soil, consisted of passing loaded wagons and trucks over the drains which were installed with a trencher or trenchless plow at 2- and 3-ft (60- and 90-cm) depths. Deformations up to 10 and 20% of tube diameters were checked with plug gauges.

The laboratory tests showed that the load-bearing capacity of the plastic tubes continued to increase to deflections of greater than 40% of the original diameter (Negi and Broughton 1971). The investigators concluded that a field deflection of up to 30% of the original inside diameter of a tube could be allowed without substantial reduction of flow capacity and without reaching ultimate load-carrying capacity.

The objectives of the laboratory study reported here were: (1) to establish the soil surface load values at which there will be no deflection in 4-inch (100-mm) corrugated plastic drain tubes installed at two depths (95 and 125 cm) in two types of soil (sandy loam and silt loam), and (2) to determine the magnitude of surface loads that produce a 30% (safe) deflection, and the loads that cause total failure of the drain tubes.

Deflections are taken to mean the percent reduction of the original inside diameter of the drain tubes with the application of a soil surface load. A failure load was defined as the maximum load reached after which the increase in deflection is rapid and the load starts decreasing.

MATERIALS AND METHODS

To investigate whether soil type is related to the load-bearing capacity of corrugated plastic drains installed at different depths by different installation methods, two soil types having different textures were used in the experiment. These soils are described by the Alberta Soil Survey (Reports No. 14 and No. 21) as a Peace Hills sandy loam and a Ponoka silt loam.

The two types of corrugated plastic drainage tubes used in the investigation were the “ADS”, previously manufactured by the Big “O” Drain Tile Co., and that manufactured by Daymond Ltd. (Figure 1). Both drain tubes were 4 inches (100 mm) inside diameter. The major difference was in the number of water entrance slots and the patterns of corrugations.

The shape of the corrugations is flat and square in the ADS tube whereas it is round and spiralled in the Daymond tube. The ADS tube has three rows of water entrance slots spaced equally around the tube circumference and the Daymond tube has eight rows of punched holes.

Two soil test boxes, 1.2 x 0.75 m, 1.8 m high, made from plywood, were used in the experiment (Figure 2). Two holes, 41 cm above the bottom of the test boxes, were made on the 0.75-m side through which the test sections of plastic drain tubing were laid. The soil was placed in the test boxes in 10-cm layers and packed with a standard 4.5-kg tamping rod. The tamping was done on a steel plate placed and moved over each soil layer. The plastic tubing was installed in simulated mole channels as well as trenches.

The trenches were made by laying an aluminium pipe, having an outside diameter slightly larger than the outside diameter of the plastic tubes, in the soil box during filling and packing. Afterwards, the aluminium pipe was pulled out gently and the corrugated plastic tubes pulled into the mole channel thus formed.

The trenches were made by holding two plywood sheets 22 cm apart in the soil box during filling and packing. The plywood sheets were subsequently removed after the filling was completed thus leaving a trench. A 150° bedding angle was simulated by placing a cut section of 12.5-cm diam aluminium pipe at the bottom of a trench. The plastic
tube was laid on this cradle and the soil carefully packed around it. When the soil box was filled, the aluminium pipe was pushed horizontally through the side hole.

During the packing of the soil in the test boxes, the bulk density of each layer was measured using a hand-held gamma ray bulk density meter. At the same time, core samples were taken for the determination of the moisture content of each layer by the gravimetric method.

An average dry bulk density of 87 lb/ft³ (1.4 g/cc) was maintained in both soils used in the experiment. The bulk density of the soil measured around the mole channel in the experiment was 3 - 6% greater than that of the surrounding soil. This was in accord with Irwin's (1971) findings of an approximate 5% increase in dry bulk density immediately below and at the sides of drain tubings laid with a Badger mole drain plow. The bulk density of the earthfill in trenches in the experiment was kept at 7 - 12% less than the surrounding soil. An analysis of the bulk density data obtained in each test run showed that the average variation of bulk density in the experiment was 9.1% of the field bulk density cited above. This variation seems to be close to that expected under field conditions.

A steel frame was designed for application of loads from the soil surface in a test box. All loads applied to the soil surface were taken by the steel frame and no load was transmitted to the floor except the dead load of the test box and the steel frame itself. A 50-ton (45-metric ton) hand-operated hydraulic jack was used for applying soil surface loads through a 20 X 25-cm steel load plate in 90- to 113-kg increments. The load was held constant for about 2 min to permit the deflection to the drain tube to be measured.

A strain gauge mouse, similar to the "mechanical mouse" developed by Busch (1958), was constructed to record the deflections. There were two spring finger units (Figure 3), the front set for aligning the instrument and the rear set for measuring the deflections developed in the plastic drain tube. Each finger on the rear set had two strain gauges, an active and a compensating type. The two opposite fingers were considered to make one channel, and hence channel 1 measured the vertical deflection and channel 2 measured the horizontal deflection. The signal from each channel was amplified through a DC amplifier and recorded on direct print paper in a UV recorder. The deflection for each load increment applied was recorded by pulling the strain gauge mouse, attached to a long rod, through the plastic drain tube.

Data were thus obtained on load vs. deflection in the corrugated plastic drain tubings. Both vertical and horizontal deflections were recorded, but only the vertical deflection was taken as the basis for testing and comparing the drain tubings (P) and other factors such as soil type (S), installation method (I), and depth (D). Graphs of load vs. vertical deflection as a percent of the original diameter (similar to stress-strain diagrams) were drawn for each treatment combination. The deflections recorded did not include deflections due to earthfill loads.

### RESULTS AND DISCUSSION

An analysis of variance was computed (Ashraf 1974) for each deflection percentage, i.e. 0, 5, 10, 15, ..., 75%, including failure loads. The computed F values over all deflections showed that the main effects of installations (mole and trench), depths (95 and 125 cm), and soil types (sandy loam and silt loam) were highly significant (Table I). The interaction between depth and soils was highly significant, while the interaction between installations and depth was significant only for deflections greater than 35%.

The analysis of variance for 0% deflection showed that only the effect due to installations and to depths was highly significant, while the effect due to soil type was not significant. On this basis, the mean surface loads for 0% deflection are reported (Table II).

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### TABLE I ANALYSIS OF VARIANCE OF LOADS (LB) ON THE LOAD PLATE

<table>
<thead>
<tr>
<th>Source of variation</th>
<th>df</th>
<th>Mean squares ( \times 10^6 )</th>
<th>F values</th>
</tr>
</thead>
<tbody>
<tr>
<td>I (Installation)</td>
<td>1</td>
<td>38.86</td>
<td>14.23**</td>
</tr>
<tr>
<td>D (Depth)</td>
<td>1</td>
<td>81.36</td>
<td>29.80***</td>
</tr>
<tr>
<td>ID</td>
<td>1</td>
<td>18.58</td>
<td>6.81*</td>
</tr>
<tr>
<td>S (Soil type)</td>
<td>1</td>
<td>156.05</td>
<td>57.16***</td>
</tr>
<tr>
<td>IS</td>
<td>1</td>
<td>1.52</td>
<td>0.56</td>
</tr>
<tr>
<td>DS</td>
<td>1</td>
<td>34.49</td>
<td>12.63**</td>
</tr>
<tr>
<td>P (Drain tubing)</td>
<td>1</td>
<td>0.328</td>
<td>0.12</td>
</tr>
<tr>
<td>IP</td>
<td>1</td>
<td>3.55</td>
<td>1.30</td>
</tr>
<tr>
<td>DP</td>
<td>1</td>
<td>0.446</td>
<td>0.16</td>
</tr>
<tr>
<td>SP</td>
<td>1</td>
<td>0.783</td>
<td>0.28</td>
</tr>
<tr>
<td>Error</td>
<td>16</td>
<td>2.73</td>
<td></td>
</tr>
</tbody>
</table>

* Significant at 0.05 probability level.
** Significant at .01 probability level.
*** Significant at .001 probability level.
For the 30% deflection (safe loads), the analysis of variance showed that the effects due to installations, depths and soils, and the interaction between depth and soil (DS) were highly significant. The surface load values for these factors are shown (Table III). The average soil surface load values are higher for the mole installations than for trench-installed tubes, for the same tube deflections. Also, these values were higher for the sandy loam than for the silt loam soil, and are higher for greater depths of installation. Such conclusions confirm the interpretation of results obtained from an analysis of variance of single deflection percentages.

The soil surface loads which caused failure (as previously defined) in corrugated plastic drain tubes are shown (Table IV). The deflections for these “failure loads” ranged from 35 to 50% of the original diameters of the tubes. The analysis of variance showed that the effects due to methods of installation and the interactions between depth and soil (DS) were significant. The effects due to depth and to soils were highly significant. These are the same factors that were significant for 30% deflections and for the overall data. The failure load values are not likely to be exceeded in the field with the present day farm machinery and equipment. However, such values are a useful guide for heavy machines or equipment that may be used in the future.

The strength requirements for corrugated plastic drain tubes installed in mole channels are significantly lower than for drain tubes installed in trenches. This is most likely due to additional support provided by the arching effect of the soil in the mole channels. Although the arching effect is also produced in trenches when the soil settles, this seems more pronounced in mole channels. Also, as confirmed by Fouss (1968), the curved bottom of the mole channel gives better bedding conditions to the drain tubes and hence lessens the strength requirements of drain tubes installed in mole channels as compared to those installed in trenches.

The differences in the two types of corrugated plastic drain tubes were not significant (Table I). Both types are about equal in load-bearing capacity.

### SUMMARY

Static loads were applied at the soil surface to two types of corrugated plastic drain tubes installed in two types of soil (sandy loam and silt loam) at two depths of installation (95 and 125 cm). The tubes were installed in simulated mole channels and in trenches. The soil surface loads were increased in 200- to 250-lb (90- to 113-kg) increments and the corresponding tube deflections were recorded with a strain gage “measuring mouse.” The effects on the load-bearing capacity of the corrugated plastic drain tubes due to soil type, depths of installation and method of installation were evaluated statistically by analysis of variance.

The strength requirements for the corrugated plastic drain tubes were less when installed in sandy loam soil than when installed in silt loam soil. The soil surface loads that the drain tubes could support were significantly greater when the tubes were installed at a depth of 125 cm than when installed at a depth of 95 cm. The strength requirements for the tubes installed in mole channels were significantly less than when installed in trenches. Both types of drain tubes were equal in load carrying capacities.

Loads of 698 and 678 kN/m² for mole- and 680 and 623 kN/m² for trench-installed drain tubes at the 95-cm depth in sandy loam and silt loam soils, respectively, were the safe soil surface loads (30% deflection). The load values for drain tubes installed at the 125-cm depth in sandy loam and silt loam soils, respectively, were 837 and 725 kN/m² for mole and 791 and 604 kN/m² for trench installation, respectively.

### ACKNOWLEDGMENTS

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