PERFORMANCE OF SMALL-BORE SLOTTED PLASTICS PIPES AS VERTICAL DRAINS IN PEAT SUBGRADE

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ABSTRACT

This report describes a pilot-scale experiment which was carried out to determine whether the use of vertical drains consisting of small-bore slotted plastics pipes can accelerate the consolidation of a peat subgrade under a road pavement or embankment. The experiment consisted of loading with gravel four areas measuring 14.0 m x 14.0 m, in three of which the vertical drains were installed, and measuring the amount of consolidation occurring in each area. The experiment was designed to study the effect of spacing (0.6 m and 1.2 m centers) and the size of the slotted plastic pipes (1.25, 2.5, and 5.0 cm diameter) on the consolidation of the peat. The settlements which occurred after the areas were loaded show that the use of the plastic pipe as vertical drain led to an acceleration of the consolidation of the peat. The largest settlement occurred in the section with the pipes at the closest spacing. There was no significant difference in the performance of the three sizes of pipe.

INTRODUCTION

In many parts of the world, use has been made of vertical sand drains to accelerate the settlement of compressible soils under road embankments. Their use is based on the principle that, by reducing the length of the drainage path, they enable water expelled from the soil under the weight of the embankment to escape more readily so that the majority of settlement occurs fairly rapidly. There is considerable conflict of opinion concerning the effectiveness of vertical sand drains in accelerating the settlement of peat subgrades.

Experiments carried out by the Road Research Laboratory have indicated that vertical sand drains do not appear to have marked effect in accelerating the settlement of road embankments constructed on peat. Vertical sand drains are normally installed at minimum spacing of about 3.00 m centers and this appears to be the closest spacing at which they can be installed having consideration to their cost. It is possible that vertical sand drains have not shown a marked advantage because of the presence of natural drainage paths at spacing of 3.00 m or less; if this is so, vertical drains would need to be installed at spacings closer than provided by the natural drainage path in order to have a significant influence on the rate of settlement.

It has been proposed that small-bore slotted plastic pipes could be used as vertical drains in peat subgrades. It is possible that they might provide a comparatively cheap method of installing vertical drains at closer intervals than practical with sand drains. With this in mind, a pilot-scale experiment was carried out to study the effectiveness of small-bore slotted plastic pipes when installed as vertical drains in a peat subgrade.

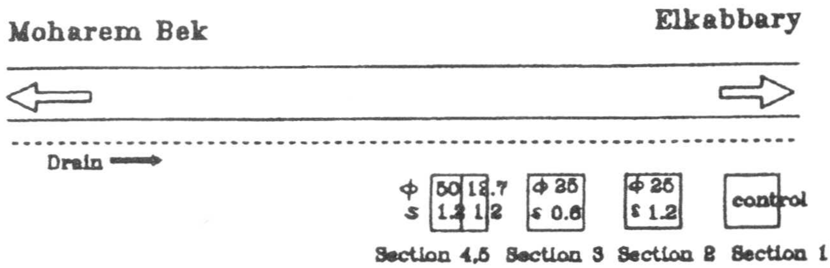
EXPERIMENT

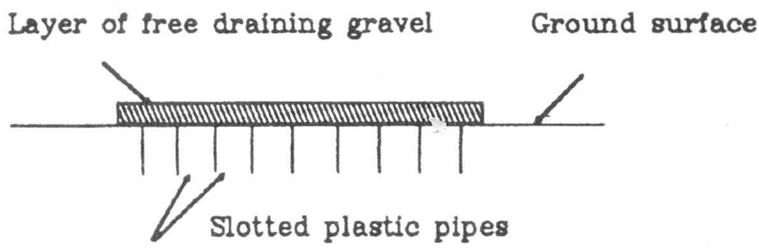
The experiment was carried out at El-Kabbary - Moharem Bek road. The general layout of the experiment is shown in Figure (1). There were five sections. Section 1, 2, and 3 were 14.00 m x 14.00 m in area. Section 4 and 5 each covered an area of 14.00 m x 7.00 m. the sections were located about 12.00 m from the edge of the road.

The slotted plastic pipes were installed in four sections and one section without pipe acted as a control. Details of sizes and spacings of the pipes are given in Table 1. The pipes were installed vertically in a triangular pattern.

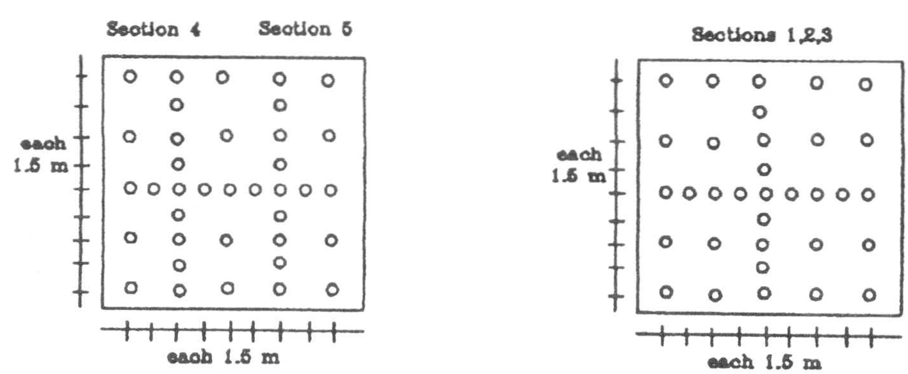
Table 1: Sizes and spacings of plastic pipes in experimental section

Section No.	Diameter of Pipes (mms)	Length of Pipes (ms)	Spacing of Pipes (ms)
1	-	-	-
2	25.4	3.00	1.20
3	25.4	3.00	0.60
4	12.7	3.00	1.20
5	50.8	3.00	1.20





Cross section of experimental section with slotted plastic pipes installed



Location of level gauges for measuring settlements in experimental sections

Figure 1. Layout of experimental sections.

A 0.3 m thick layer of free-draining gravel was placed on each section after the pipes were installed. The load on each section was increased to a total of 53.4 cm thick of gravel after about 8 months.

Measurements were carried out at regular intervals to determine the settlement occurring in each of the sections, changes in the moisture content and changes in the shear strength of the underlying peat.

PEAT SUBGRADE

The depth of the peat, including the mattress of vegetation on the surface which was about 30 cm thick, ranged from 6.4 to 7.0 m. There was a layer of silty clay, about 0.6 m thick, underneath the peat. Hard material, which could not be penetrated by a sampling tool, existed below the silty clay.

Samples were taken 0.6, 1.5, 3.0, 4.5, and 6.0 m below the surface to determine the range of moisture contents of the peat throughout its depth. The moisture content of the peat varied considerably, ranging from 460 to 800 percent. The mean moisture content for the upper 4.5 m of the peat ranges from 600 to 715 percent; the mean moisture content at a depth of 6.0 m was rather lower, ranging from 463 to 670 percent.

Measurements of the in-situ shear strength of the peat at depths of o.6, 1.5, 2.4, 3.3, and 5.1 m below surface level were made with a hand vane apparatus, using 15 cm x 7.5 cm vane. The shear strength of the peat tended to increase with depth. The average value of each section at a depth 0.9 m ranged from 0.072 to 0.10 kg/cm^2.

The height of the free water-table appeared to be very near to the surface of the bog in winter and 10 to 25 cm below the surface in summer.

CONSTRUCTION OF EXPERIMENTAL SECTIONS

The pipes were plastic pipes with longitudinal slots cut through the wall at regular intervals. Three sizes of pipes were used, with nominal diameters of 1.25, 2.5, and 5.0 cm. Each pipe had four rows of slots located at 90x intervals around the circumference. The manufacturer specification concerning the number and dimensions of the slots was :

- Maximum number of slots per 1 ft run of pipe, 19.
- Minimum number of slots per 1 ft run of pipe, 17.
- Maximum length of each slots, 28 mm.
- Minimum length of each slots, 22 mm.
- Maximum width of each slots, 0.70 mm.
- Minimum width of each slots, 0.55 mm.

It was possible to push the pipes by hand down into the peat, but installing them in this fashion was likely to cause the slots to become smeared and blocked up. The following technique was adopted for placing the pipes in order to avoid the possibility of this occurring. A gas pipe having an internal diameter of about 5 cm was fitted with a disposable end-cup to plug the lower end and pushed by hand down into the bog to a depth 2.7 m below the surface. The end-cup, which consisted of a plastic cup three-quarters filled with concrete, fitted over the end of the pipes and prevented peat from being forced into the gas pipe as it was pushed down into the bog.

A slotted plastic pipe was then lowered into gas pipe until it came into contact with the end-cup the gas pipe was then lifted out of the bog, leaving the slotted plastic pipe in position. The vertical drains were placed in a triangular pattern with the distance between pipes being 0.6 m or 1.2 m as required.

Level gauges were placed in each section in the pattern shown in Figure (1). The gauges consisted of flat steel plates measuring 30 cm x 30 cm with a 10 mm diameter steel bar fixed perpendicular to the plate. The gauges were fixed in position so that the plate was at the interface between the surface of the bog and the gravel fill, with bar protruding above the gravel. The consolidation of the peat after the sections were loaded were recorded by making regular measurements of the level of these gauges.

Hanrahan states that creep settlement will occur in peat if it is subjected to a load greater than the shear strength of the peat as measured by a laboratory vane apparatus. A test on a sample of peat from the site, taken about 0.6 m below the surface, indicated that the shear strength of the peat was between 0.053 and 0.07 kg/cm^2. It was decided, therefore, to load the sections with a 30-cm thickness layer of gravel, which would impose a pressure of less than 0.07 kg/cm^2.

The gravel used for loading the sections was free-draining crushed gravel aggregate which would permit water flowing upwards through the vertical drains to flow to the site of the section and hence, to surface drains.

The gravel was placed in position in each section during the course of a working day. It was placed by hand with the aid of hand-barrows and timber barrow-runs. The loading of the section with 30-cm thickness layer of gravel took place in October, 1988.

Samples of peat were taken about 0.6 m below the gravel in each section in March 1989 and the shear strength of the peat was measured using the laboratory vane apparatus. The mean value of shear strength for the samples was 0.11 kg/cm^2, and it was decided to increase the loading on each section to a total of 52.5 cm of gravel. The extra thickness of gravel was placed on the section in May, 1989.

BEHAVIOUR OF EXPERIMENTAL SECTIONS

The relationship of settlement to time for each section from the time the sections were first loaded until October, 1988, a period of 18 months is shown in Figure (2); the settlements recorded for each section are the average of the settlements occurring at the five level gauges located at the center of each section. The settlements recorded are those which occurred in each section from the time that placing of the initial load of 30-cm of gravel was completed. Measurements of the settlement occurring while the initial loading was being placed in position were taken for section 4 and 5, but not for the other sections. The measured settlements which occurred at the centers of sections 4 and 5 during the placing of the first loading were 4.88 and 5.49 cm respectively.

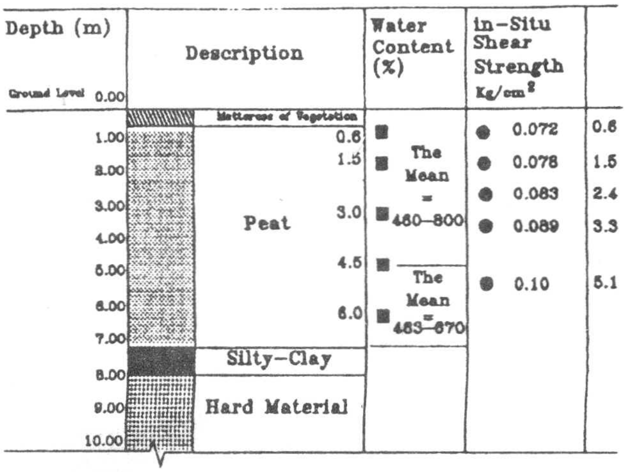


Figure 2. The relation between water content, shear strength and depth.

Some information obtained from the curves in Figure (2) are summarized in Table 2. Over the period of about 200 days when sections were subjected to initial loading of 30-cm of gravel, the total settlement ranged from 15.24 cm in the section without vertical drains to 29.21 cm in the section with 1.25 cm pipes spaced at 1.20 m centers. Larger settlements occurred in the sections with vertical drains than in the control section.

Rapid settlement occurred in all the sections immediately after second loading was imposed. After a total time of loading 550 days, the settlement ranged from 54.61 cm in the section without drains to 91.44 cm in the section with 2.5 cm pipes spaced at 0.6 m centers.

The settlement in the section with vertical drains ranged from 76.2 cm to 91.44 cm distinctly larger than the settlement in the control section. The largest settlement occurred in section 3, where the pipes were installed at the closest spacing.

Table 2: Summary of Settlement at Center of Each Section

Section No	settlement (cm)		Average rate of settlement over period from 380 to 550 days after initial loading (cm/year)
	200 days after initial loading	550 days after initial loading	
1	15.24	54.61	17.78
2	22.86	78.74	21.59
3	20.32	91.44	16.51
4	29.21	86.36	22.24
5	17.78	76.20	15.24

The pattern of settlement during both stages of loading was similar in all the sections, settlement occurred rapidly at the beginning and then settled down to occur at a slower rate. The vertical drains appear to have influenced the rate of settlement in the initial phase but appear to have had a little effect during the secondary phase. The average rate of settlement during the period from 380 to 550 days after the initial loading ranged from 15.24 to 22.86 cm/year.

The performances of the sections after the second loading was placed conformed to the theory that reducing the length of the drainage path leads to an acceleration of the rate of the settlement, and that the rate of settlement is related to the length of drainage path. The settlements which occurred at the center of each section from the time that placing of the second loading was commenced are shown in Figure (3).

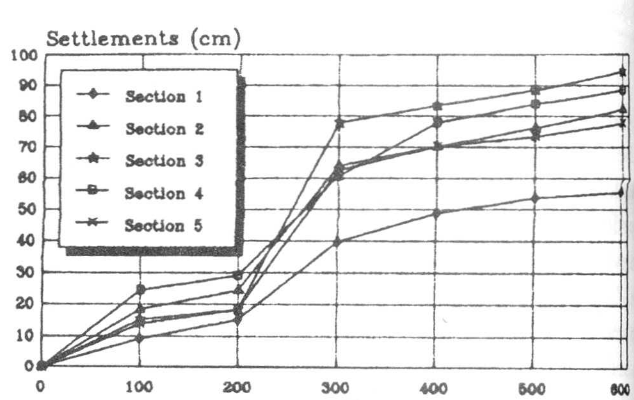


Figure 3. Settlement-time data for center of each section from completion of first loading.

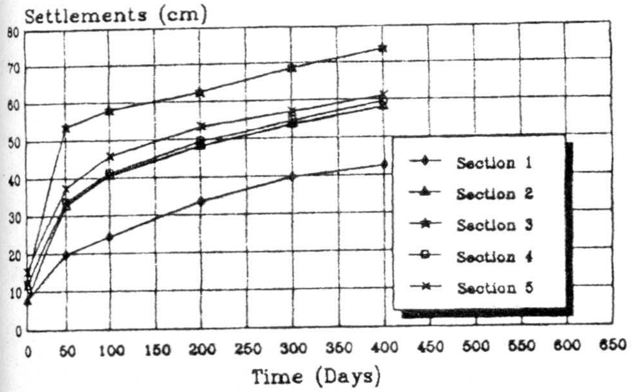


Figure 4. Settlement-time data for center of each section from commencement of application of second loading.

The settlement-time curves for the three sections with pipes 1.20 m centers are very similar, and indicate that the settlement was not influenced by the size of pipe. The curves for these three sections lie between the curve for section 3, with pipes at 0.60 m centers, and the curve for the control section 1.

The settlements which occurred during the first 200 days were relatively small. A possible reason for this is that the lower part of the gravel may have been below the level of the water table for some of the time, so that the effective load on the sections was reduced due to the apparent loss in weight brought about by immersion of the gravel in water. The order of settlement in the sections with pipes was different during this period to that which occurred after the second loading was applied. It is possible that settlement of the sections under the initial loading of 30-cm of gravel may have been influenced by preconsolidation of the peat mattress and the underlying peat under the weight of persons installing the pipes and similar trafficking before the sections were loaded.

The in-situ shear strength of the peat under each section increased under the loadings imposed on the sections. The increases were larger for the sections with pipes installed than for the control section. The largest increase in shear strength was measured in section 3 where the range of mean shear strength of 0.081 - 0.098 kg/cm^2 in October, 1988 had increased to 0.12 - 0.15 kg/cm^2 in May, 1989

CONCLUSIONS

1. The settlements which occurred show that the use of the slotted plastic pipes as vertical drains led to an acceleration of the consolidation of the peat under the imposed loading.
2. The largest settlement occurred in the section with the pipes installed at the closest spacing, and the performances of the sections after the second loading was applied conforms to the theory that reducing the length of the drainage paths leads to an acceleration of the rate of the settlement.
3. There was no significant difference in the performance of pipes with diameters of 1.25, 2.50, and 5.0 cm.
4. The performances of the sections did not provide sufficient information to enable conclusion to be drawn concerning the practicability of using the slotted pipes for constructing a road over the peat soil. It is probable that the settlements in the sections would have been larger and would have occurred more rapidly if larger loadings were applied and if further increments of loading were added as soon as the major part of the settlement brought about by each application of load was achieved. Further experiments to determine whether this technique would provide a practical method of constructing a road on this site are planned.

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