THE PERFORMANCE OF CORRUGATED PLASTIC TUBING IN DIFFERENT TYPES OF SOILS

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ABSTRACT

The following four corrugated plastic drains were tested in three different types of soils. The soils used are, medium sand, fine sand, and very fine sand.

1) 100-mm nominal diameter pinhole pipe manufactured by Fratco
2) 100-mm nominal diameter pinhole pipe manufactured by Baughman Ltd.
3) 100-mm nominal diameter pipe with very small slots manufactured by Plastidrain Ltee.
4) 100-mm nominal diameter normal slotted pipe with a knitted polyester manufactured by Big "O" Drain Tile.

The four tubes were tested under ponded condition for a few days until they reached the steady state. Under a steady hydraulic gradient, the out flow rate showed a rapid drop, then reached a fairly constant level within 2 weeks and stayed costant for the remainder of the test.

Less sediment entered the 100-mm nominal diameter tubing with normal slots and polyester sock.

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1. SCOPE

This investigation involved the use of three different types of sandy soils (a medium sand, a fine sand, a very fine sand) and four different tubes (two pinholes, one small slots, and one normal slots with the polyester envelope material).

The soils used are known to have caused sedimentation problems for subsurface drainage systems. Since only results of one replicate is considered in this part of the project, the conclusions drawn must be considerd to be

Further experiments are needed, doing more replicates and using other soils, in order to achieve more universal conclusions.

2. OBJECTIVES

The objectives of this study were:

1. To measure the rate at which water drains from soil through tubing
   a) with normal slots and a fabric envelope
   b) with pinholes and no fabric envelope, and
2. To measure the amount of soil passing out of the drain tubes with the drainage water.
3. To measure the amount of soil settled in the tubing corrugation valleys after a few days of water drainage.

3. INTRODUCTION

The demand for food is increasing every day ,which results in the need to improve farm land in order for crop production to increase. Subsurface drainage is one important solution for most of the farms in eastern United States and Canada . About 25% of these farms are sandy loams or silt loams which require drainage pipes with fabric envelope material. The primary reasons for installing a subsurface drainage systems are the removal of excess water from the top metre of soil, and leaching out the accumulated salt.

In Quebec, there are about "250,000" hectares of land to be drained with synthetic envelope materials. The cost of this material is approximately "$60.0 million".

Due to this high cost, and problems,such as wrapping and installing the envelope material,"The Corrugated Plastic Tubing Association" has sponsered this particular project. Their goal is, by accumulating tests results, to be able to design the best possible perforated drainage tube as a substitute for envelope material. This tube is to give the best results in terms of :

a) adequate water entry flow rate,

b) preventing soil entering the tubing.

This study was undertaken to see the performance of different types of pipes in different types of soil.

4. REVIEW OF LITERATURE

4.1. History of Drainage Materials and Methods Research

According to J.L. Fouss (1974) the development of a rapid and low cost technique for subsurface drainage has presented a challenge to engineers and inventors for centuries. Many ideas have emerged, but only a few have ever found widespread application. With the advent of power trenching machines about 1875, the objective of mechanized drain installation seemed to have been reached. However, an extremely large amount of drainage work to be done in many countries forced further study to find even less labor consuming and lower cost methods. Most studies have involved some modification of the "mole drainage" method because its inherent high speed and its elimination of the usual slow ditching and back filling operations. Because the "mole drain" collapses after a short time in many soils, much of the research pertained to devising ways of stabilizing the mole-channel with a tube or liner.

A. Invention & Research Before 1940

French (1859) gave one of the earliest accounts of using a plow-type drainage machine-the "Fowler Drainage Plow" developed and tested in England. French described the plow's operation and the 'claims' for it as follows:

The pipes, of common drain tiles, are strung on a rope, and this rope, with the pipes, is drawn through the ground, following a plug like the foot of a subsoil plow, leaving the pipes perfectly laid, and the drain completed at a single operation. The work is commenced by opening a short piece of ditch by hand, and the strings of pipes, each about 50 feet long, are added as the work proceeds;-Drains, 40 rods long, are finished at one operation.

Fowler's plow was pulled by a horse-powered cable windlass, and the plow blade could be adjusted to control the grade on the drain line being pulled in. Weaver (1964) relates that "Mr. B. B. Briggs, of Sharon, Medina County, Ohio,in 1859, invented a machine which looks not very unlike a mole plow, to lay tile without digging a ditch." The operation described was similar to that given for Fowler's drain plow.

Both of these plow-type drainage machines were probably well ahead of their time for three reasons: (i) the lack of an adequate source of power, such as steam traction engines; (ii) the high cost of such heavy equipment; (iii) the attempt to use existing drainage material, ceramic tile, rather than some conduit material that would have been easier to handle.

There were many ideas tried regarding the combination mole-tile drainage method. Wallem (1931) reported on the

"Poppelsdorf Mole-Tile Drainage System" developed in Germany, which was one of the later attempts to improve the scheme for practical use. However, just prior to World War II German investigators did considerable work to develop continuous linings for mole drains. One such technique, using a tube formed from varnish-coated sheet metal, was patended by Sack (1933). Sack's sheet metal mole liners failed rather quickly from corrosion, but forming drain tubing from coiled sheet materials was a new idea that led to much additional research. Sack also developed a light beam projection instrument to establish the desired grade line, and a machine-mounted receiver for the light beam to aid the operator in controlling the depth of the drainage plow (G. O. Schwab, 1951. Subsurface drainage with small perforated flexible tubes in mole drains. Unpublished Ph.D. Diss.,Iowa State College Library, Ames). Schwab described a mole plow with special attachments developed about 1934 by Janert, another German engineer, for laying continuous porous concrete lining in a mole channel. Although a commercial version of this machine was produced in Germany before World War II, it evidently never met with great success. Later developmental research by Ede (1957) on a continuously formed concrete tube for drainage also was never put into practical use, mainly because of materials-handling problem and the heavy machinary required.

B. Plastic Drain Tubing

About 1941, polyethylene plastic, a British development, was made available for manufacture in the USA. According to Schwab, in his previously cited thesis , the U.S. Crops of Engineers investigated as early as 1946 the use of "perforated plastic tubing" installed with "cable-laying machines" for airport drainage. However, Schwab's research from 1947 to 1954 (Schwab, 1955) is considered the beginning of the development and use of plastic drain tubes in the USA, if not the world. He installed several field experiments where polyethylene plastic tubes of various diameters and wall thickness were pulled into a mole-drain channel with a mole plow. Schwab (1955) indicated that it was necessary to handle the smooth-wall plastic drain tubing in 6-m straight lengths, because the tubing would "kink" when coiled. From these studies, he provided guidelines as to the minimum tube-wall thickness for various drain diameters to insure drain conduit deflection of less than 20% of the original diameter. When inspected in 1966 (17 years after installation), these test drains were still in very good condition (Fouss, 1968). The results from these early field experiments provided much of the background data for today's minimum plastic drain strength requirements.

De Jager (1960) conducted experiments in the Netherlands with polyethylene tubes pulled into mole drains. The studies were abandoned because silt clogged the water entry "silts" in the tube walls during installation. De Jager (1960) also developed a method of installing 6-m lengths of rigid vinyl plastic drain pipe in a narrow trench dug with a high-speed trenching machine. This latter method received notable acceptance and use throughout the Netherlands during the 1960's (Van Someren, 1964). During the mid-1960's, 10 cm-diameter polyethylene plastic drainage tubing, installed as deep as 2.7 m with a special narrow-wheel trencher, was adopted for use in the Lower Rio Grande Valley of Texas (Myers et al.,1967; Rektorik & myers,1967).

C. Corrugated Plastic Drainage Tubing

By the mid-1960's, most of the research materials had begun to focus on corrugated-wall plastic tubing. Continuous extrusion and molding equipment had been perfected by German industry to fabrigate corrugated-wall plastic tubing and underground drainage with the new conduit caught on rapidly in Germany and soon spread to other parts of Europe. In the USA, the first users of the new tubing were the underground electrical and telephone conduit industries. Research in the USA on using the corrugated plastic tubing as an agricultural subdrain was begun in 1965 (Fouss, 1965,1968).

By 1967, corrugated plastic drain tubing was being fabricated commercially in the USA, and this new industry has grown rapidly since. Many clay and concrete tile manufacturers also have set up plastic drain extrusion plants.

Corrugated-wall plastic drain tubes are stronger, lighter weight, less expensive, and easier to handle because of better longitudinal flexibility than are smooth-walled plastic pipes.

4.2. Envelope Materials

According to Willardson (1974), the primary reasons for placing envelope material around subsurface drain conduits are: (i) to prevent the movement into the drains of soil particles which may settle and clog the drains (ii) to provide material in the immediate vicinity of the drain opening that is more permeable than the surrounding soil, (iii) to provide suitable bedding for the drains, and (iv) to stabilize the soil material on which the drain is being laid.

Luthin (1957) and Lyons, Werenfels, and Houston (1964) have suggested other reasons for using envelopes, but they are all related to the four above mentioned reasons.

As stated by Willardson, consideration of the primary reasons for using envelope materials will indicate why they are referred to as envelopes rather than filters. Filters by definition (Webster's, 1959) "a porous mass through which fluid is passed to seperate it from matter held in suspension." A filter used with a subsurface drain would be self-defeating, because particular matter would be deposited on or in the filter, thereby reducing its permeability.

Means of preventing soil materials from entering subsurface drains have been sought since the beginning of tile drainage. As cited by Willardson (1974), Sisson (1965) reported that in 1859, H. F. French recommended double-walled or sheathed drains with collars as one method of preventing drain sedimentation. French's second choice was clean, fine gravel. Brown (1915) reported use of gravel along the sides of wooden box drains in 1906. Hart (1917) (as stated by Willardson) recommended graded gravel ranging from sand to 3 cm in diameter as an excellent filter. He also recommended a porous fabric covering for the tile joints such as burlap or cheesecloth for quick sand conditions.

Materials For Envelopes

Envelope materials used for subsurface drains have included almost all permeable porous materials that are available economically in large quantities. They can be divided into three general categories, organic, inorganic, and man-made.

A. Organic Materials

As Willardson stated (1974), Organic materials that are byproducts of agriculture production have often been used as envelope materials. The two most common materials are straw and sawdust, but other organic materials tested include peat litter, corncobs, woodchips, reeds, heather, and grass sod (Juusela, 1958).

Baghott and Houston (1965) installed drains in the Tulelake Basin in northeastern California using 15 cm of wheat straw (Triticum spp.) as envelope material around the pipe. After 6 years the drains were still controlling the water table effectively. They recommended straw as an envelope material where gravel was unavailable.

In a laboratory experiment by Cavelaars (1966), all of the various organic envelopes materials compared improved drain performance. Peat litter was about equal hydraulically to a single thin fiberglass sheet.

Willardson stated (1974), that the life and suitability of organic materials as envelopes for subsurface drains are not known for a range of soil conditions. Organic matter may affect chemical and biological reactions in the soil that cause clogging problems. Where iron oxide or orchre clogging of drains is expected, organic matter should be used with caution. Even mixing organic matter with the trench backfill material may cause problems in some soils.

Successful use will depend on the material, careful installation, and the physical and chemical characteristics of the soil.

B. Inorganic Material

Willardson cited (1974), that the practice of blinding or covering subsurface drains with a layer of topsoil before backfilling the trench actually provides many drains with permeable envelope material. Surface soil in poorly drained areas tend to have a well-developed, stable, and permeable structure. In stratified soils, drains are blinded by shaving the coarsest textured materials in the soil profile down over the pipe. The practice of blinding undoubtedly furnished the nucleus of the idea of using improved granular envelope materials. Blinding is a standard recommended part of drain installation (Hore et al., 1960; Irwin, 1960; USDA Soil Conservation Service, 1971,p. 4-114),especially in humid regions.

The most common and most widely used envelope materials are naturally graded coarse sands and fine gravels. Such materials are widely available and are as permanent as the soil itself. The envelope material used is primarily pit run sand with a minimun of fines. Experiments by Lembke and Bucks (1970) and ASAE (1967) have shown that a graded fine gravel or sand envelope placed around a subsurface drain helps protect it from sediment and improves its performance.

C. Man-made Materials

The unavailibility of natural sand and gravel for use as envelope material in some areas has led to a search for manufacturing process materials that could be used as substitudes. The man-made material that has received the most attention is fiberglass, which is relatively inexpensive and can be manufactured in large quantities of exact specifications. The fiber should be made of lime-borosilicate glass. Some other types of glass dissolve in the soil.

Buras and Pillsbury (1963) conducted tests on the longitudinal permeability of fiber glass sheets. They concluded that a fiber glass sheet around a drain would improve water movement toward the openings.

Watts and Luthin (1963) published the results of tests of permeability of 2.5-cm thick fiberglass mats. Compressing the mats to simulate a backfilled drain reduced the hydraulic conductivity of the mat; however, the compressed mats were as permeable as natural sands. Shull (1967) found fiberglass mats to be superior to fiber glass sheets in filtering properties.

Hansen (1963) found that drains in a number of soils in Vermont would be better protected with a fiberglass sheet than with the local naturally graded gravels in current use.

McKyes and Broughton (1974) performed tests on a horizontal section of perforated plastic tubing with a filter enclosed in a cylindrical tank. They found that, compared with unfiltered tubes, those with polyester weave stocking envelopes and fiberglass sheeting showed very little soil entry and did not reduce water flow over a period of up to two months. Hemp and jute twine wrapped within the drain corrugations were also tested and also prevented sediment entry; however, they clogged up and reduced water inflow significantly within 10 days.

A number of studies were performed to determine the feasibility of using synthetic versus gravel envelopes. In laboratory tests, Hermsmeir (1976) found little or no increase in head loss using synthetic envelopes when compared to a gravel envelope in a loamy clay and a sandy loam; however, he did find an increase of 20-40 percent in a sandy soil.

Broughton and Gibson (1977) found that using envelopes can increase the water inflow rate into subsurface drains under the same head conditions.

Broughton et al. (1977) furthered the experiments of Mckyes and Broughton of 1974 to observe any possible drop in drainage rate over time. A drainage rate reduction was observed and attributed to possible envelope cake formation and/ or microbial growth at the soil-envelope interface.

Long term use of thin synthetic drain envelopes became a possibility when an increase in observed drainage rate was noted after a short period of no flow.

As cited by Willardson (1974), other man-made materials that have been tried out for which there is no available test information include cinders, slag, artificial aggregates, and bonded fibers of nylon and polypropylene. Bonded synthetic fiber fabrics can be made with controlled opening sizes. Opening sizes can be adjusted so that the fabric will function as an envelope rather than a filter.

As stated by Bonnell (1984), Reeve (1982) performed further tests on drain envelopes using a "size ratio" factor defined as the ratio between screen opening size to the D60 size of the soil. He postulated that a screen with openings too large would allow all soil to pass, leading to clogging of the drain tubes and one with the openings too small would not allow any soil to pass, leading to clogging envelope itself. He concluded that between the two extremes was an optimum size opening, which would allow some small soil particles to pass, but which would support the larger soil particles and creat a stabilizing effect on the surrounding soil. This, along with the internal friction and shear forces within the soil would provide and maintain a stable structure. He found that this "bridging" occured when the size ratio reached a value of three or less, for uniform sized spheres.

The U.S. Dept. of reclamation (1960) present granular filter criteria as follows:

a) D15 (filter) / D15 (base) = or greater than 5

b) D15 (filter) / D85 (base) = or less than 5

c) D85 (filter) / Max. size opening of drain = or greater than 2

When using a geotextile as a filter on cohesionless soils Girould proposes the following criteria:

i) to insure good permeability:

K (fabric) = or greater than 10 K(soil)

ii) to prevent clogging:

iia) for soil with coefficient of uniformity from 1 to 3

loose soil, F95 less than Cu * D50

Medium soil, F95 less than 1.5 Cu * D50

Dense soil, F95 less than 2.0 Cu * D50

iib) for soil with coefficient of uniformity greater than 3

loose soil, F95 less than (9/Cu) * D50

medium soil, F95 less than (13.5/Cu) * D50

dense soil, F95 less than (18/Cu) * D50

Where; Loose soil is such that,

$I = (e_{max} - e)/(e_{max} - e_{min})$ is less than 35%

Medium soil, I is between 35 & 65%

Dense soil, I is greater than 65%

e = void ratio

Cu = coefficient of uniformity (D60/D10)

F95 = apparant opening size of the fabric and is equal to the D95 of the soil.

D50 = particle diameter at which 50% of the total soil particles are smaller on a weight basis.

As Bonnell cited (1984), Broadhead (1981), working with various combonations of synthetic envelopes and soil types, presented some general ratios of the envelope opening size 'EOS' to the D60 size of a soil. With a ratio in the range of 3.6 to 5.1 (average of 4.4) no soil was retained and with a ratio in the range of 1.5 to 3.0 (average of 2.4) failure would not occur. He also found that as the degree of uniformity of the soil increased then the smaller was the range in EOS sizes between complete failure and no failure.

5. MATERIALS & METHODS

A. TUBING USED

The four types of tubing used were:

1. 100-mm nominal diameter pinhole pipe manufactured by Fratco
2. 100-mm nominal diameter pinhole pipe manufactured by Baughman Ltd.
3. 100-mm nominal diameter pipe with very small slots manufactured by Plastidrain Ltee.
4. 100-mm nominal diameter normal slotted pipe with a knitted polyester manufactured by Big "O" Drain Tile.

B. SOIL & WATER TEST TANK SET UP

Three tanks 1.2m * 2.43m * 0.76m (4 ft * 8 ft * 2.5) deep built, as indicated by figure 1 and photograph 1. Permeable dividers are provided between each of the four sections in each tank so that the water supply to the 4 tubes placed in each soil tank can be identical. In this way, no tube will have an adverse effect on any other tube, and problems in sealing up leaks where tubes pass through tank walls are minimized.

Water is supplied from the college chlorinated water supply. The water is distributed through a perforated pipe

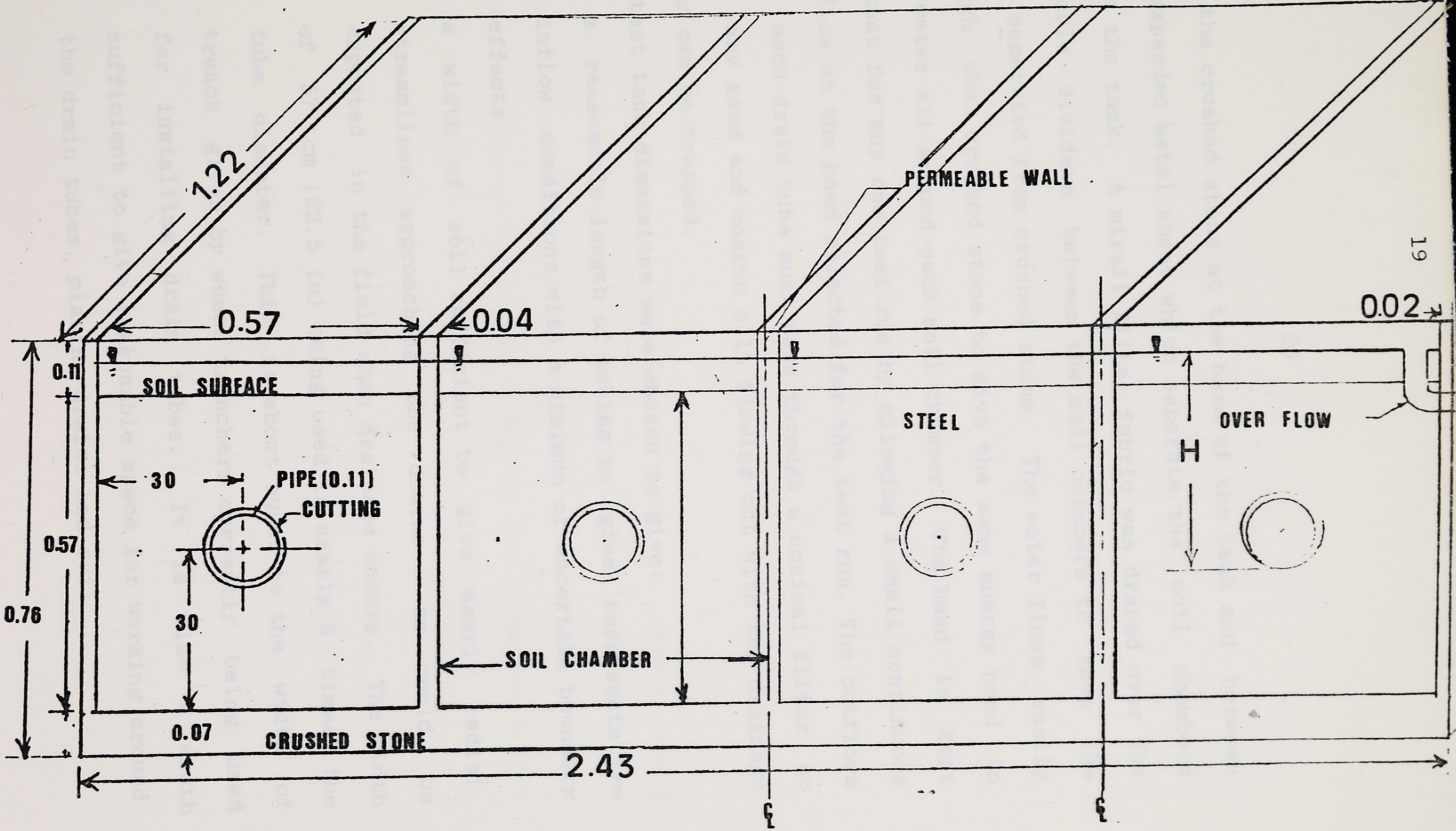


Figure I. Dimensions of tank used for tests of drain tubes. (meters)

The same soil is used in all 4 sections of the tank
on any one test run with 4 drain tubes.

into the crushed stone at the base of the tank and between the expanded metal sheet which seperate the soil chambers within the tank. A mirafi filter fabric was draped over the permeable dividers between the soil chambers to keep the soil seperated from crushed stone. The water flows easily through the crushed stone to give the same energy head in the water all around each soil chamber. The head is kept constant for any one test run by allowing a small continuous overflow at the head selected for the test run. The outflows from each drain tube must pass through a conical filter so that any sand and coarse silt flowing out with the drainage water can be trapped.

The test tank dimensions were chosen to give:

1. a reasonable length of tubing to give representative inflow conditions with a minimum of uncertain boundary effects
2. a width of soil sufficient to give nearly radial streamlines approaching the drains, as could be expected in the field when drainage occurs. The width of 57 cm (22.5 in) being used is nearly 5 times the tube diameter. This is about equal to the width of trench given by wheel trenchers currently being used for installing drain tubes. It is also a width sufficient to give reasonable space for working around the drain tubes, placing drains and soil.

C. SOILS USED

Three soils have been used . The particle size distribution for these soils is given in figure 2.

The soils may be identified briefly as:

1. a medium sand
2. a fine sand
3. a very fine sand

The soils have been taken from a depth near drain depth (0.5 to 1.3 m) from soil areas where fabric envelopes are normally recommended for use on drain tubes.

Definitive effective particle diameters for these soils are listed in Table 1.

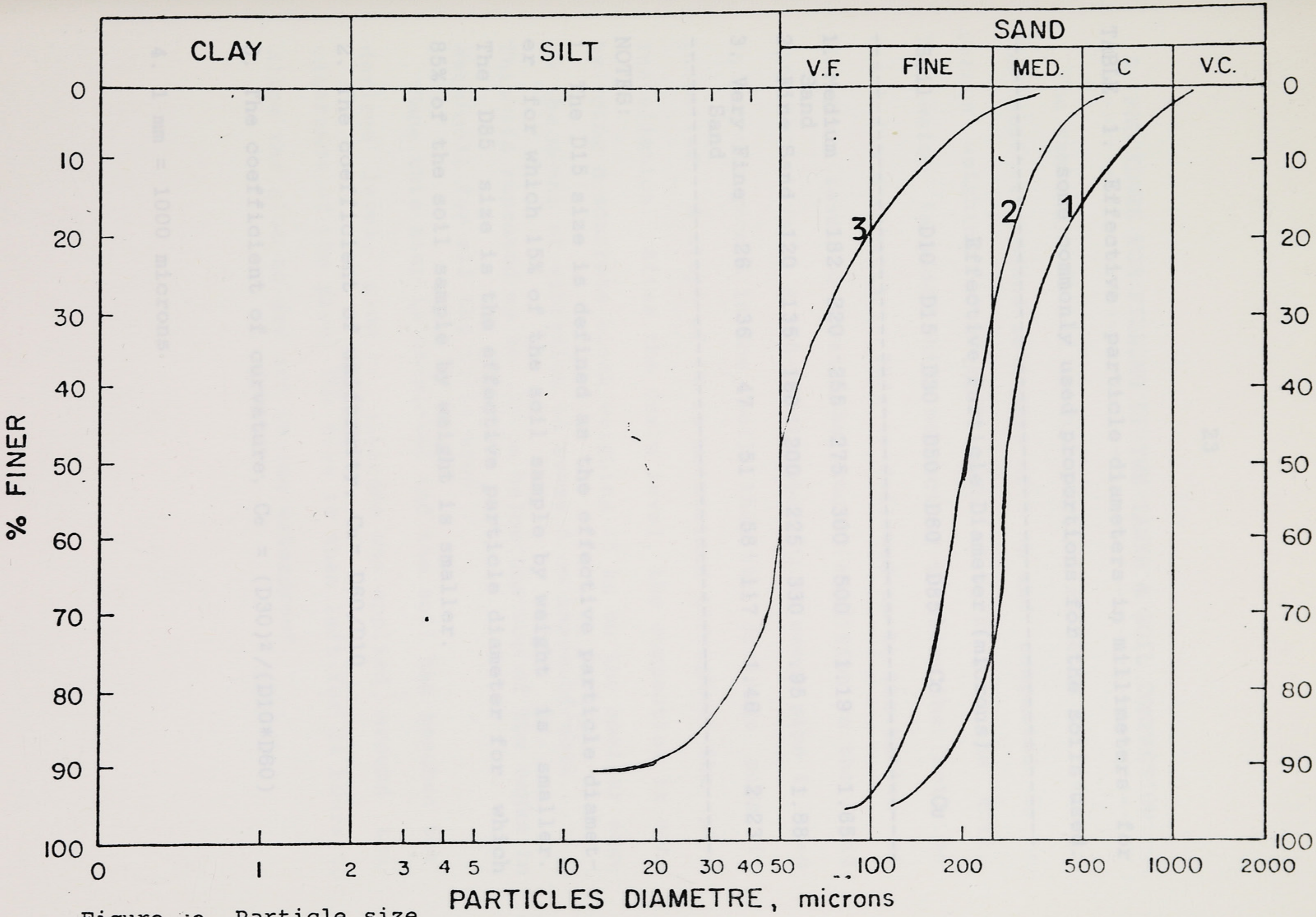


Figure 2 : Particle size distribution of soils used in the tests.

1. Ste-Barbe (medium sand)
2. Ste -Sophie (fine sand)
3. Bainsville (very fine sand)

TABLE 1. Effective particle diameters in millimeters for some commonly used proportions for the soils used.

	Effective Particle Diameter (microns)							
Soil	D10	D15	D30	D50	D60	D85	Cc	Cu
1. Medium Sand	182	220	255	275	300	500	1.19	1.65
2. Fine Sand	120	135	160	200	225	330	.95	1.88
3. Very Fine Sand	26	36	47	51	58	117	1.46	2.23

NOTES:

1. The D15 size is defined as the effective particle diameter for which 15% of the soil sample by weight is smaller. The D85 size is the effective particle diameter for which 85% of the soil sample by weight is smaller.

2. The coefficient of uniformity, Cu = D60/D10

3. The coefficient of curvature, Cc = $(D30)^2/(D10*D60)$

4. 1 mm = 1000 microns

D. PROCEDURE FOR FILLING UP THE TANKS & SOIL COMPACTION

The tanks are filled up with crushed stone up to 7.62 cm. The soil is added in layers of 5 cm and compacted by a person weighing 50-90 kg by means of walking on the soil. The water is added while compacting to allow the soil to reach field capacity. This is followed up to the bottom of the drain level to create the natural condition in the field. At this level, a 100-mm diameter (O.D) sewer pipe is used to cut the groove in the soil, then the drainage pipe is installed. A slope of 1% is maintained throughout the pipe installation. After the drain level, the compaction is done by using a concrete block weighing 15 kg on the smaller edge by the means of vibration on every 5 cm layer of soil. This is repeated up to 12 cm below the top of the tanks in each cell for all the soils used.

Once this step is completed and the soil has reached the desired level, glue or silicone was applied around the clearance of the pipe. The pipe is then left for 24 hours to allow the glue to dry and become waterproof.

6. RESULTS & DISSCUSION

A. Drain Opening Areas :

The total area of drain openings per unit length of tubing as required by various standards are given in Table 2. The total area of drain openings per unit length measured for the tubes under tests are given in Table 3.

B. Drain Opening Dimension

The dimensions and number of holes measured for this project are indicated by the data in Table 4.

TABLE 2.Area of Drain Openings Required by Various Standards

Standards	cm^2/m of Length	in^2/ft of Length
ASTM	21.30	1.00
SCS CODE 606	21.30	1.00
Canadian Government Specification Board	16.00	0.76
Bureau de Normalization du Quebec	31.75	1.50

TABLE 3. Area of Drain Openings Measured for the Tubes

Designation	Holes/m	cm^2/m
Pinhole Pipe (Black)	5376	19.55
Pinhole Pipe (Yellow) ...	6231	29.69
Pipe With Small Slots ...	2528	56.91
Normal Slots with Knitted Polyester envelope	244	51.54

TABLE 4. Measured Dimensions of Drain Openings in Tubes

Table 4a. Diameter of Holes in The Pinhole Pipes (mm)

Designation	Ridges				Valleys			
	# of Holes	1.	2.	3.	# of Holes	1.	2.	3.
Black	48	0.69	0.0	0.99	48	0.67	0.0	0.91
Yellow ...	48	0.66	0.0	1.02	45	0.88	0.0	0.99

1 ; Average Diameter of Holes per Ridge/Valley

2 ; Minimum Diameter of Holes per Ridge/valley

3 ; Maximum Diameter of Holes per Ridge/Valley

Table 4b. Dimensions (mm) of Slots in Tubing with Slots

Designation		Average	Minimum	Maximum
Small Slot [a]	Width	0.65	0.51	0.71
	Length	3.56	3.18	3.79
Normal Slot [b]	Width	1.50	1.30	1.63
	Length	14.08	5.66	18.19

[a] : Average Width/Length out of 320 Slots (10 Rings)

[b] : Average Width/Length out of 80 Slots (20 Rings)

C. Rate of Water Flow

The tanks started running within an interval of one week from each other. The water was supplied for a period 20-30 days for each tank without interuption depending on the type of the soil. The water flow rate through the soil was measured by placing a graduated cylinder under the outlets of the drain tubes and the time required to obtain a 500 ml volume was observed. The minimum time required was about 30 seconds. This was done at least 3 times a day and 3-5 readings per tubing were taken at each time. The average discharge was obtained per day.

D. Calculation For Discharge & Drainage Rate

The discharge was directly calculated by dividing the amount in the cylinder (ml) by observed time (sec). Then converting it to lit/min.

$$\text{Discharge} = \frac{\text{Amount in cylinder (ml)}}{\text{Observed time(sec)}} * \frac{1(\text{l})}{1000} * \frac{60(\text{sec})}{1(\text{min})}$$

$$\text{Drainage Rate (mm/day)} = \frac{(\text{Discharge}/1000)\ (\text{cubic m/min})}{\text{Length of pipe} * \text{spacing} * 60 * 24}$$

Where;

Length of pipe was averaged at about 1.12 m. Spacing was assumed to be 20 m. That is recommended by many people to be in a suitable range for a very fine sandy loam soil used for growing corn or beans in eastern Canada and United States.

A discharge of 1 lit/min from 1.12 m of drain tubing gives 1440 lit/day or 1.44 cubic metre per day. That gives a drainage rate of 0.064 m/day, or 64 mm/day, (2.52 inches).

If the spacing between drain lateral was wider, say 40 m as might be expected for medium sand soil, a discharge of 0.40 lit/min would be required to give a field drainage rate of 12.7 mm/day.

The discharge and drainage rates of water from the four drain tubes for the three soils tested are given in figures 3,4, and 5. In all the graphs the discharge (left axis) is given in liters per minute from 1.12 meters of drain. The drainage rate at 20 metre spacing is given in millimeters per day. The head is different from soil to soil.

In figure 3, the head is kept constant at 26 cm above drain invert. This is not the ponded case due to the high rate of infiltration in the medium sand.

The out flow rate starts high and decreases sharply in the first few days. However, it becomes steady after a few days of running. On the eighth day water supply was shut down over the night and when the next day the operation was back to normal the water flow rate was higher than the previous day. As a result, a sharp increase and decrease of water flow occured. The cause could be soil movement and settlement due to variation of the water table. However, after the problem was corrected the out flow rate once again became steady within a few days of operation. The water flow rate was very high in all four tubes and all of them performed very well.

The required drainage rate as previously mentioned was about 10mm/day in this type of sandy soil. Drainage rates much higher than this were achieved with all four pipes.

In figure 4, as shown, the head was kept constant at 36 cm above drain invert which caused the ponded case. The ponded case represents the natural condition in eastern Canada and United States or humid region, in the spring when the snow is melting or when precipitation is fairly high and there are depressional areas in the fields over the drain pipes. The water flow rate seemed to be very steady in this soil for all four pipes. All pipes were working adequately and there was no problem in any of in terms of the flow rate.

The required drainage rate in this type of fine sandy soil is essentially the same as for medium sand. Again the drainage rate is much higher than expected in all four tubes.

In figure 5, the same head of 36 cm was maintained. As shown in the graph, there is a significant difference in the flow rate between this very fine sandy loam soil and the fine and medium sand. The flow rate is about 10 times less than the other two types of soil. Despite having a low flow rate, it was fairly steady from the beginning.

The required drainage rate in this very fine sandy loam is also 10 mm/day . As a result, the only pipe that can satisfy the required condition is the one with the sock envelope.

Overall the pipe with polyester sock performed the best in terms of flow rate in all soil conditions.

Figure 3. Discharge & Drainage rate Vs. Time
Tank No.1 Medium Sand.
H=26 Cm Above Drain Invert

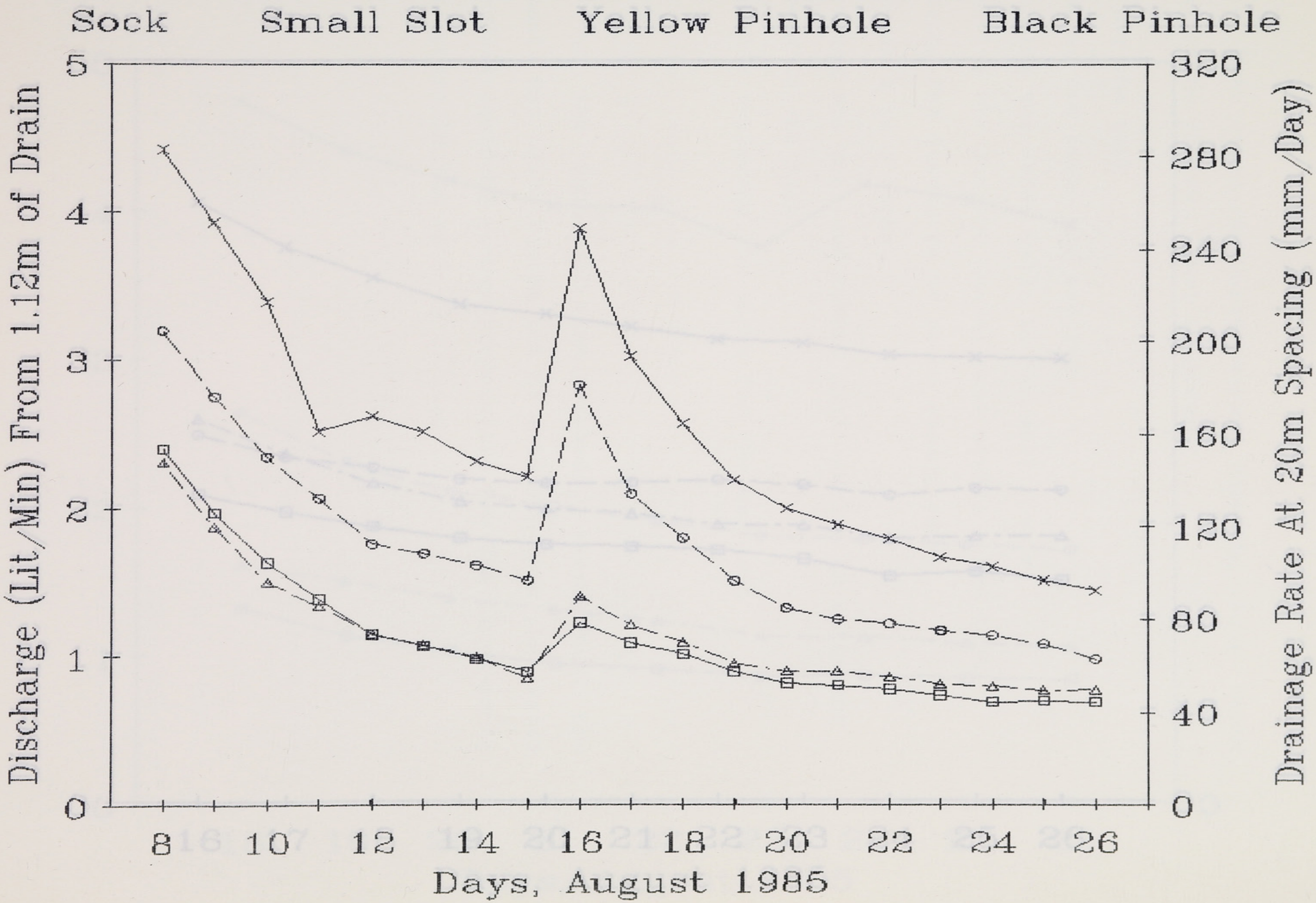


Figure 4. Discharge & Darinage Rate Vs. Time
Tank No.2 Fine Sand.
Ponded Case;H=38 Cm Above Drain Invert

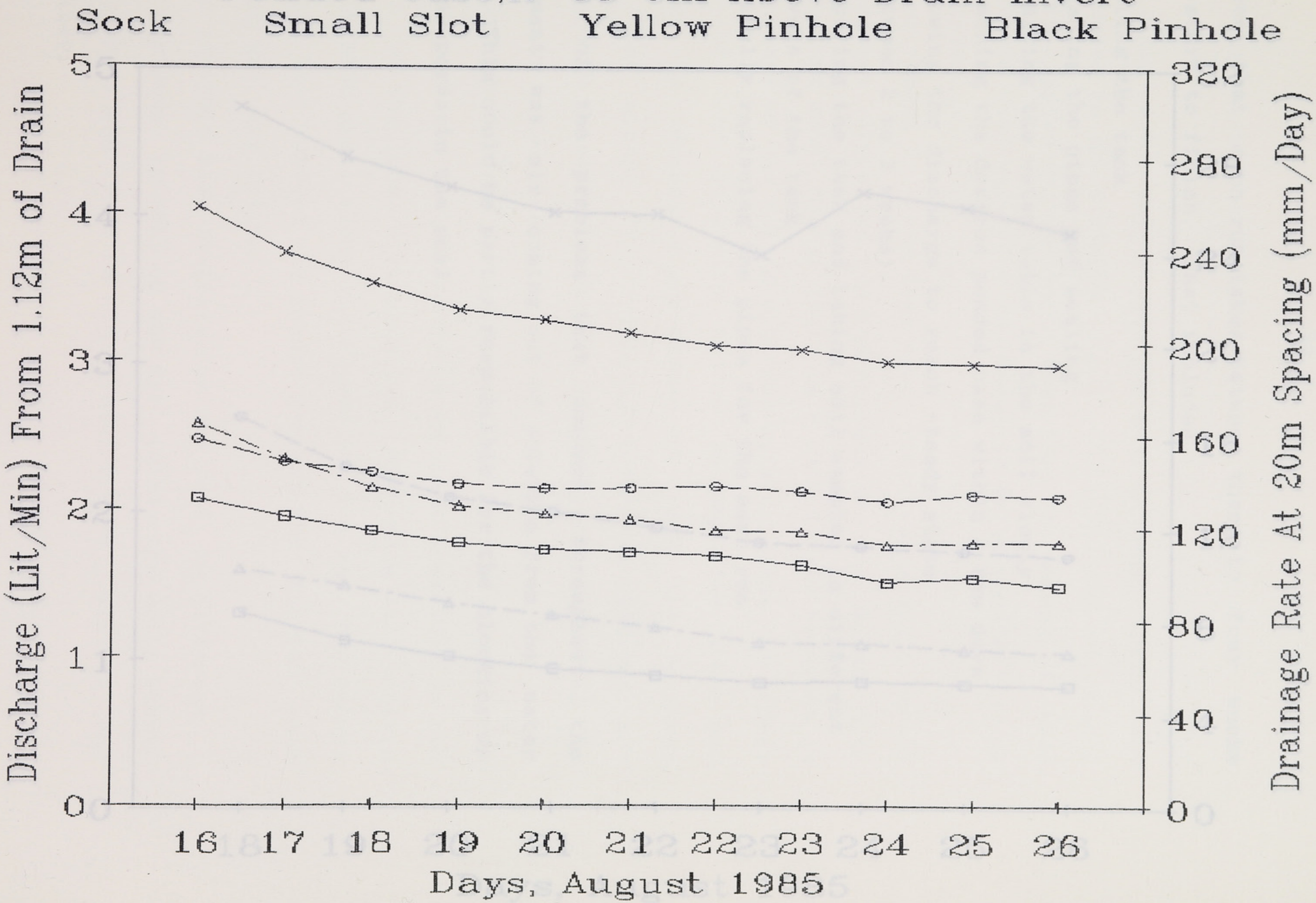
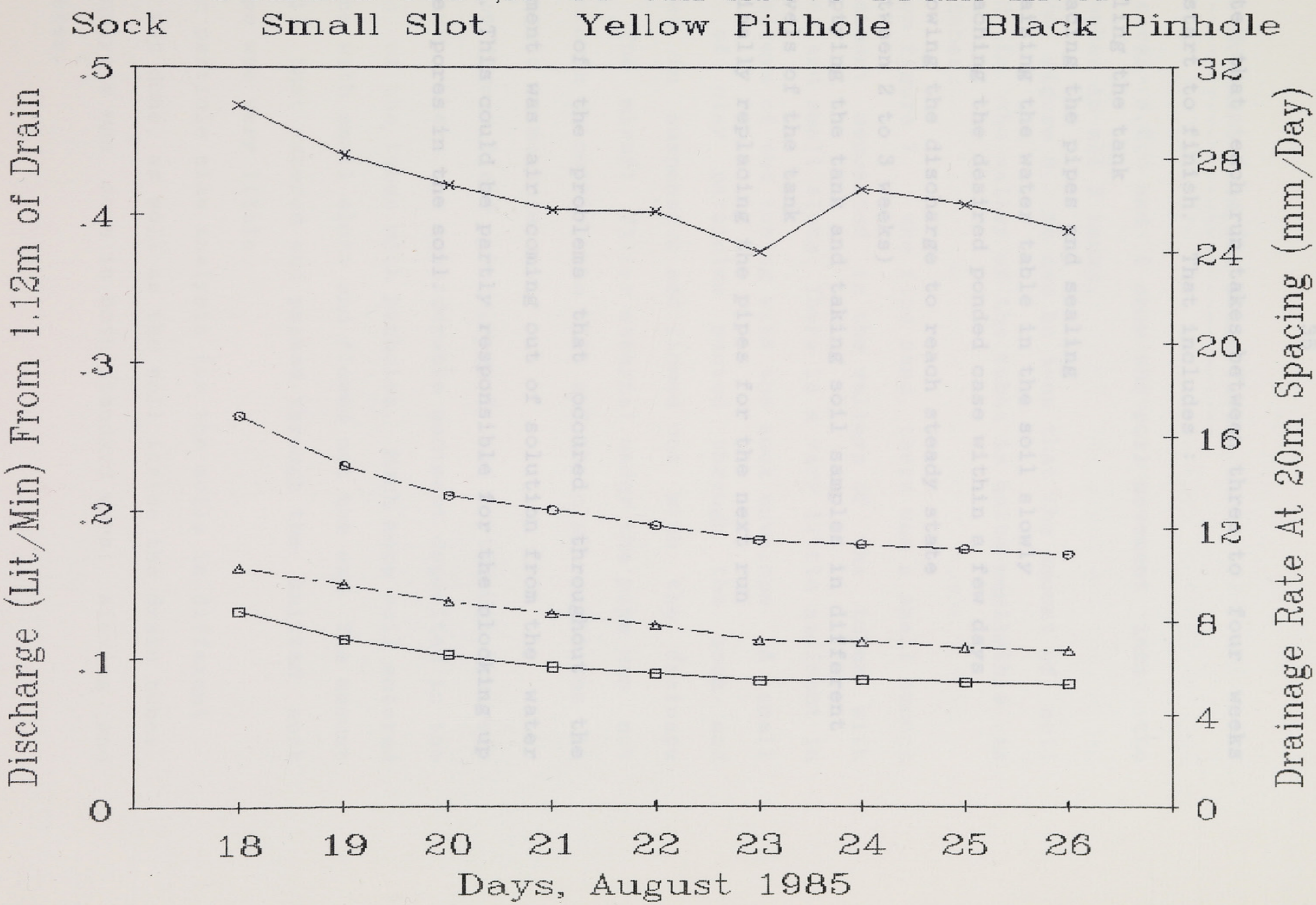


Figure 5. Discharge & Darinage Rate Vs. Time
Tank No.3,Very Fine Sand
Ponded Case;H=38 Cm Above Drain Invert



Note that each run takes between three to four weeks from start to finish. That includes :

i) filling the tank

ii) placing the pipes and sealing

iii) raising the water table in the soil slowly

iv) reaching the desired ponded case within a few days

v) allowing the discharge to reach steady state (between 2 to 3 weeks)

vi) emptying the tank and taking soil samples in different levels of the tank

vii) finally replacing the pipes for the next run

one of the problems that occured throughout the experiment was air coming out of solution from the water supply. This could be partly responsible for the blocking up of some pores in the soil.

F. Soil Movement Into The Drain Tubes

Figures 6,7, and 8 show the soil movement into the drain tubes in all 3 tanks.

From figure 6, it can be seen that the amount of soil settled in the valley of the tubes is quite negligible in all 4 tubes.

From figure 7, the fine sand, there was a small amount of sediment deposited in the valleys of the tubes with pinholes and small slots. There is a very little sediment in the valleys of the tubing with the sock envelope. A small amount of clay particles passed through the sock and remained in suspension and flowed out with the drainage water. The mirafi filter material under the pipe was not fine enough to collect the silt and the clay particles in the funnels to measure.

From figure 8 and photograph 3 and 4, through the very fine sand, there was considerable sediment deposited in the valleys of the tubes with pinholes. Much more soil entered the tube with small slots and flowed out the end. The amount of soil that entered and passed through the knitted sock envelope was very little.

The particle size analysis for the soils in different depths was done, as well as the soil inside the drain tubes. The analysis was done in both standard ways; sieving and hydrometer.

As shown in figure 2, the soils are basically sandy and the soil distribution was quite uniform throughout the tanks. The hydrometer analysis showed no significant difference between the soils inside the pipes and the soils on top of the corrugated tube.

The soils can be classified as sand (medium sand), loamy sand (fine sand), and loam (very fine sand), respectively.

Figure 6. Sedimentation in 4 Pipes
In Medium Sand

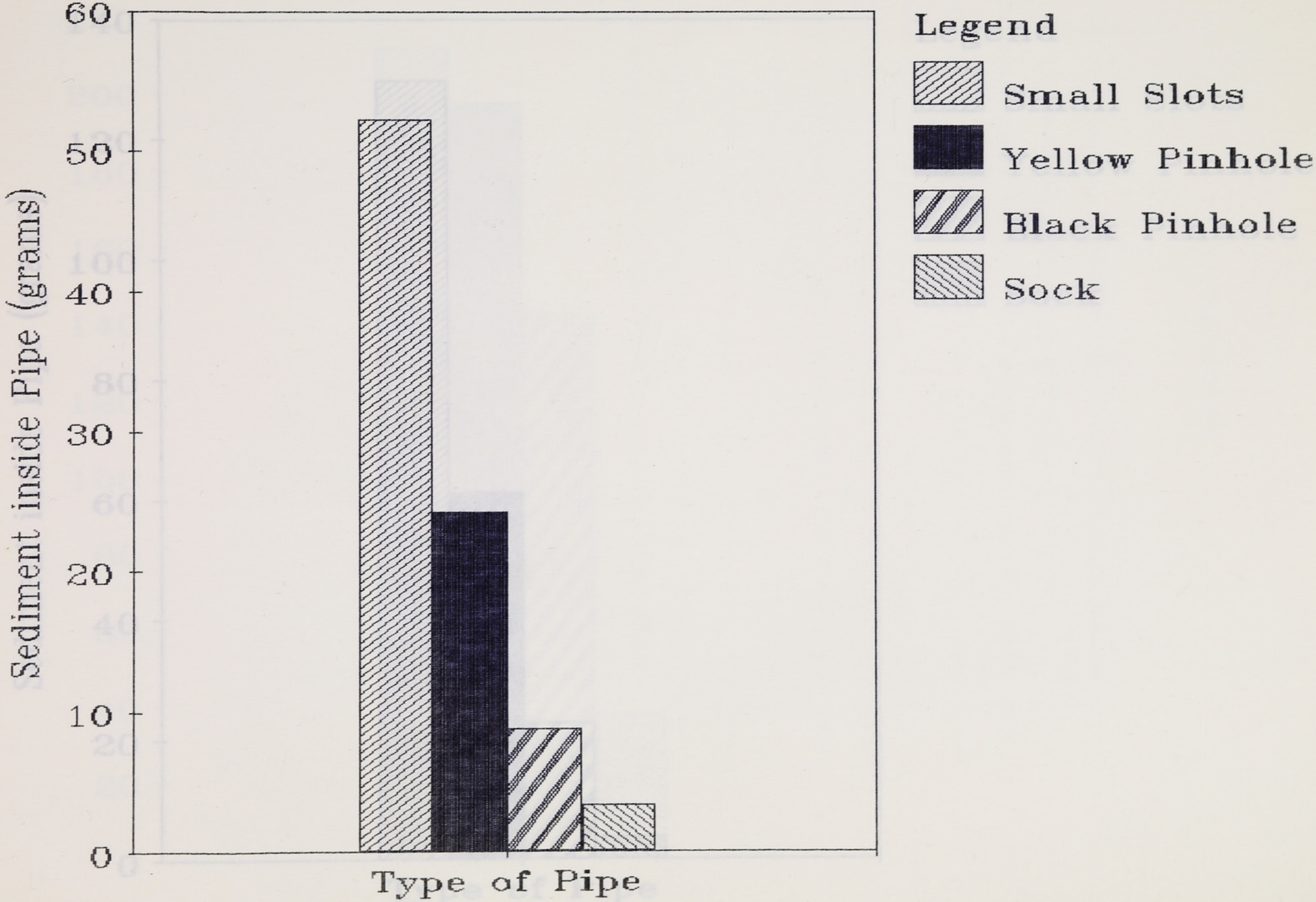


Figure 7. Sedimentation for 4 Pipes
In Fine Sandy Soil

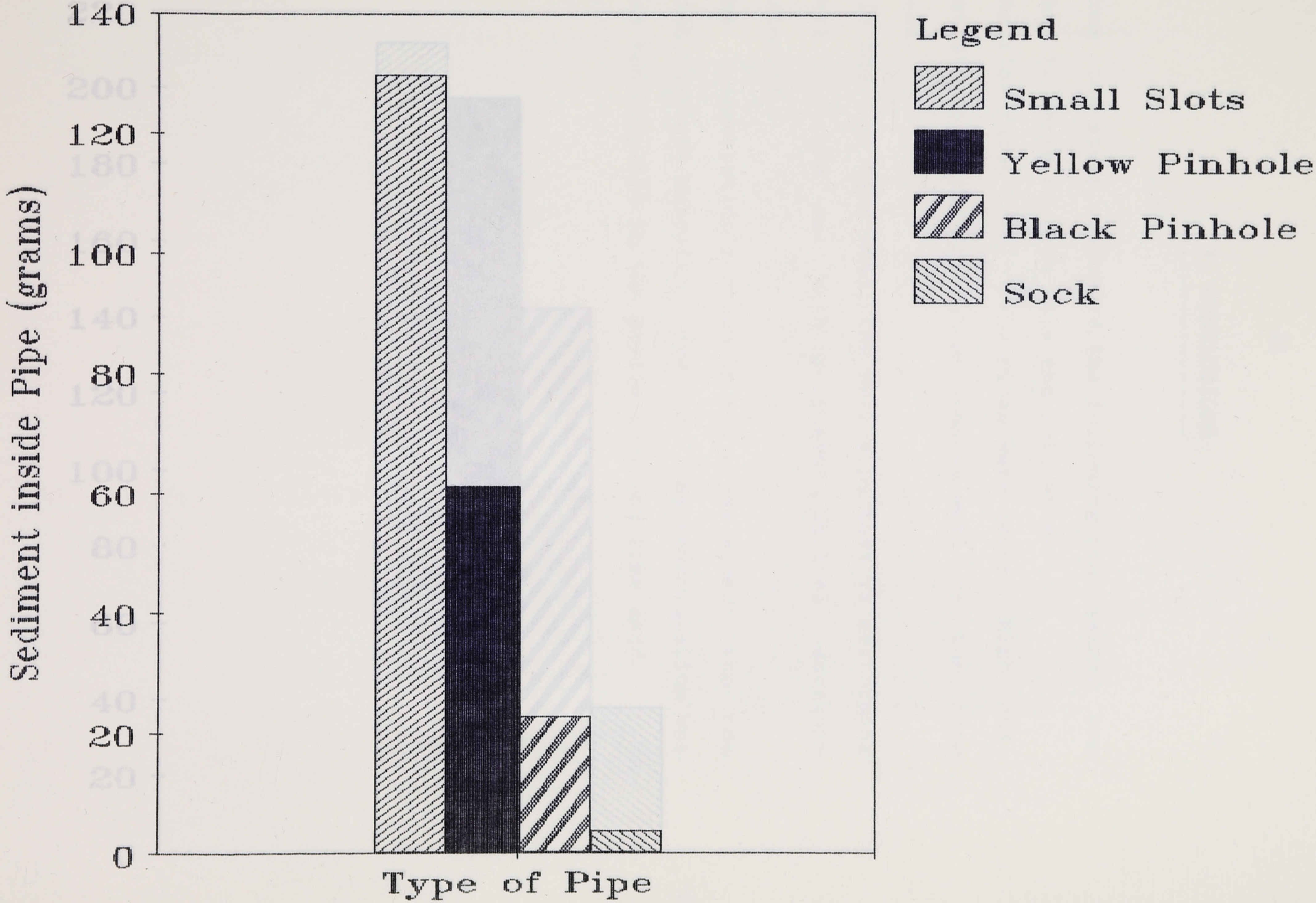
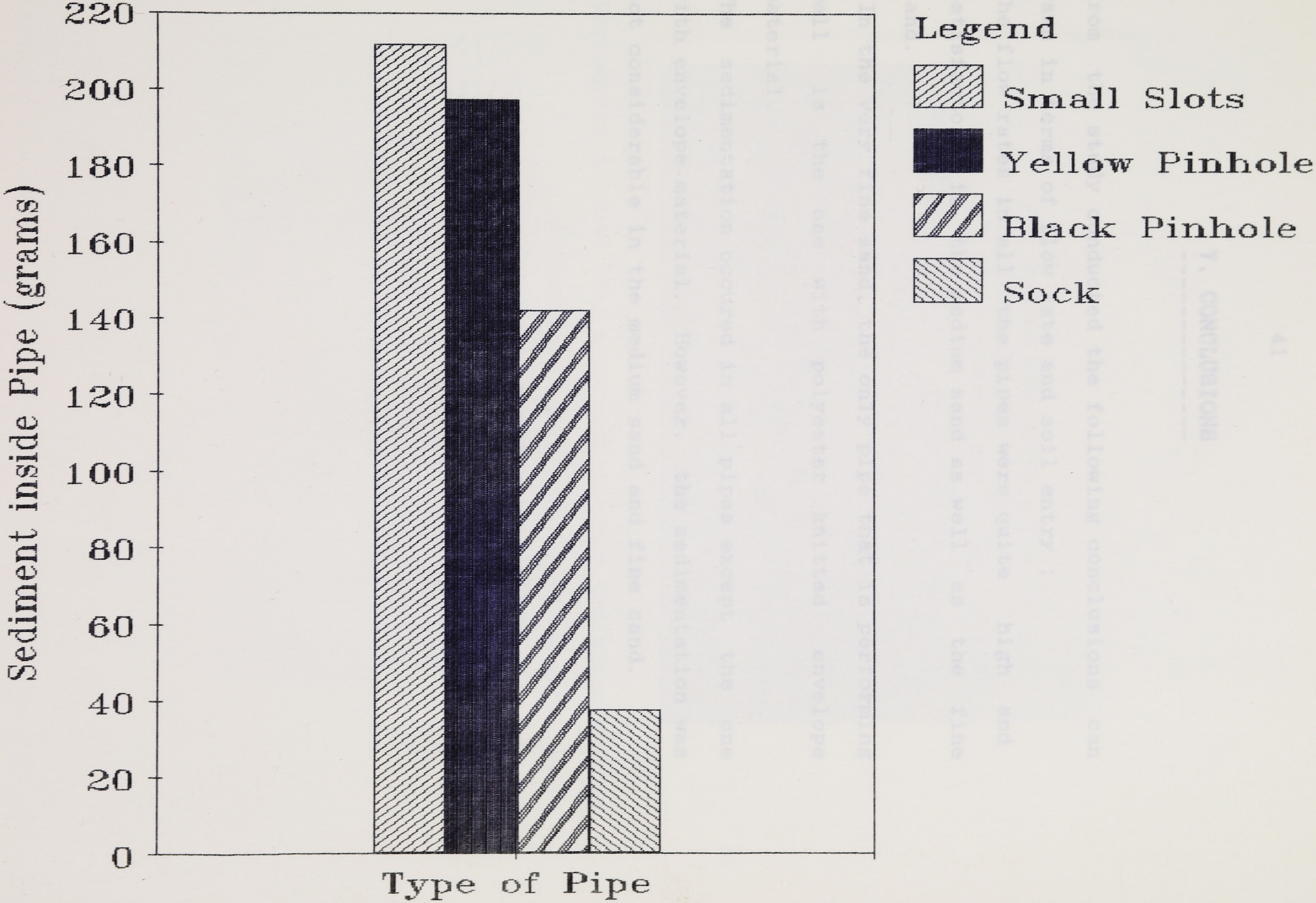


Figure 8. Sedimentation For 4 Pipes
In Very Fine Sandy Soil

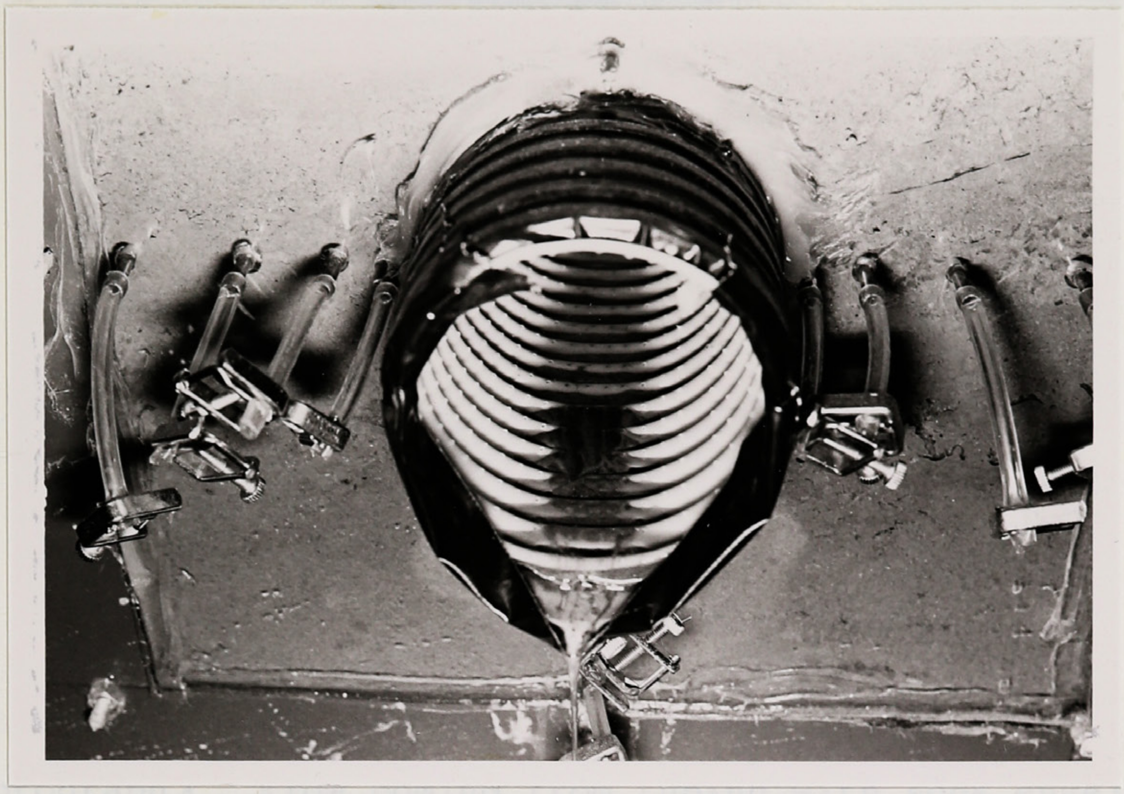


7. CONCLUSIONS

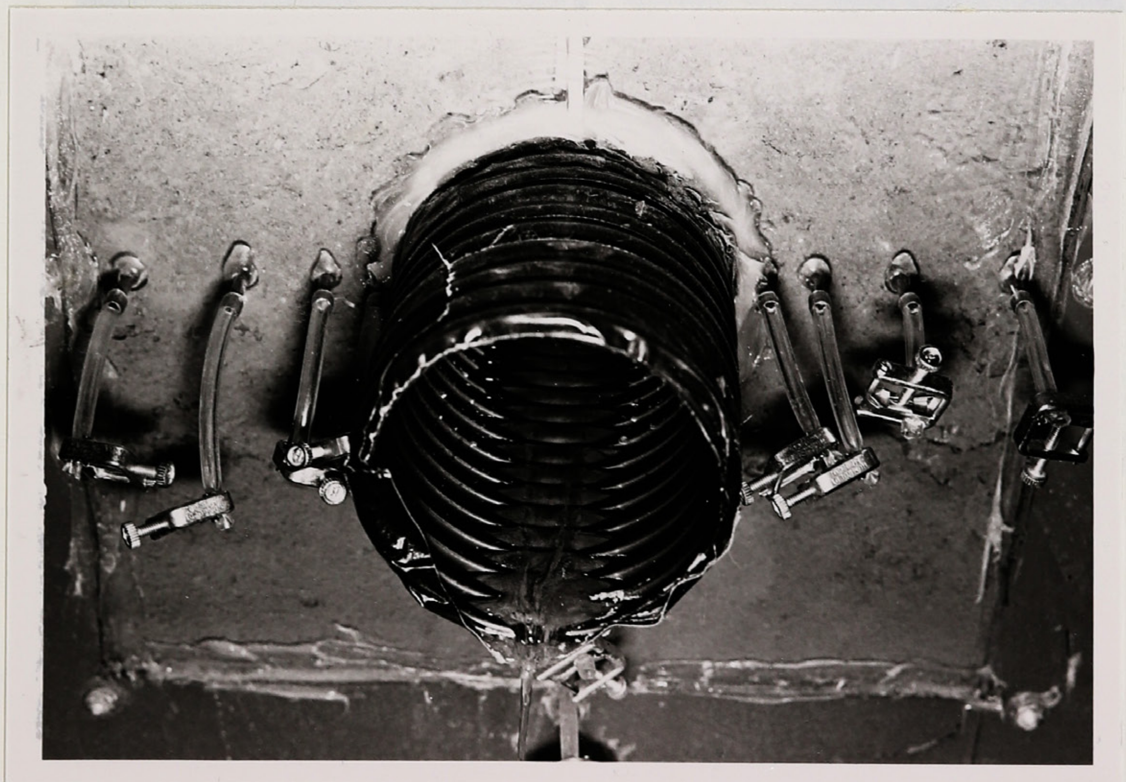
From the study conducted the following conclusions can be drawn in terms of flow rate and soil entry ;

1. The flow rates in all the pipes were quite high and satisfactory in the medium sand as well as the fine sand.
2. In the very fine sand, the only pipe that is performing well is the one with polyester knitted envelope material.
3. The sedimentation occured in all pipes except the one with envelope material. However, the sedimentation was not considerable in the medium sand and fine sand.

Photograph 1. Test tank no.3 with 4 drain tubes functioning in fine sand. Note, the overflow water level controls at each end of the tank.



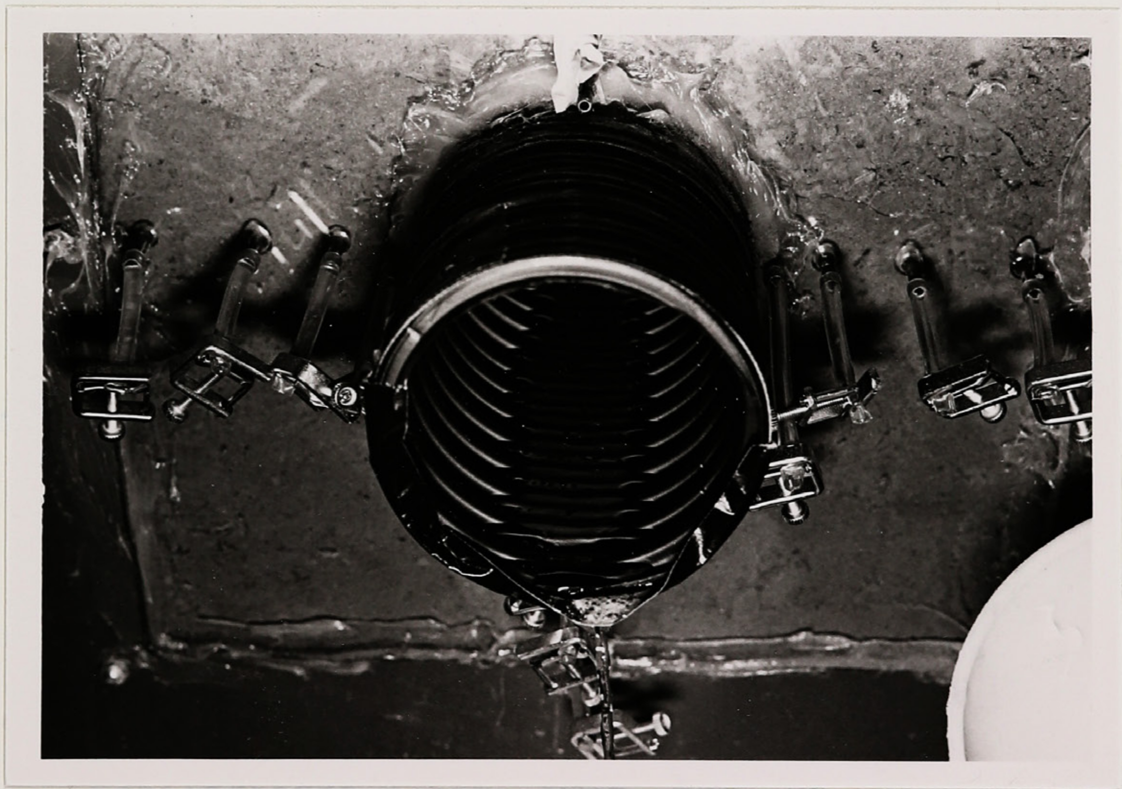
Photograph 2. Flow coming from tubing with pinholes and very fine sand.



Photograph3 . Flow coming from tubing with small slots and very fine sand.

Note; Low drainage rate and sediment deposited in the tubings.

Photograph 4 . Flow coming from tubing with sock envelope and medium sand.



Photograph 5 . Flow coming from tubing with sock envelope and very fine sand.

Note: Clean water & clean tubing, but significant difference in drainage rate between the tubes.

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