SOME ASPECTS OF THE USE OF PLASTIC PIPING IN LAND DRAINAGE

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Introduction

There appears to be little doubt that this country has accepted the advantages that can be enjoyed by employing irrigation schemes to assist in crop production. Not only are advantages expected, but automatically the assumption is made that irrigation implies continued high levels of production.

Irrigation engineers, expounding the benefits of packaged deal pipes, pumps and sprays fail to devote the same attention to the problems that can result when irrigation is practised in areas of low rainfall. For as much as irrigation can result in high levels of crop production, a gradual decline in production can result from waterlogging and the build-up of alkalinity and salinity in the soil.

It is estimated that from 15% to 20% of the total cane production area in South Africa is faced with these two problems. In particular, the arid areas in the Eastern parts of the country have shown evidence of just this type of problem, leading to the loss of crops or reduction in yields.

Installing suitable drainage is a means of overcoming these difficulties. Its function would be:

(a) to remove excess ground water in the root zone of the crop plants during the growing season.

(b) to maintain the water table below ground level throughout the year, particularly in reclamation areas.

(c) to reduce the levels of salinity by leaching out of salts carried by or absorbed by irrigation water.

(d) to allow free circulation of air in the rhizosphere

To safeguard our soils we have to recognise where drainage is needed, and what steps must be taken to provide adequate drainage. If we establish and irrigate a crop, but only consider drainage when saline or alkali conditions occur, it will cost a great deal more to install, if at all possible. Irrigation and drainage are complementary and should not be considered separately; they form part of a system, in which drainage might or might not be necessary.

Drainage and Plastics

Predictably, in view of the tremendous inroads that plastics have made as substitution materials on the conventionally accepted ones, drainage pipe made from polymeric materials was a natural development. In Holland for example, 20% of the total drainage was done by means of plastic pipe by 1963. Apart from the European countries, our most interesting comparison is that Australia uses plastic drainage systems for a wide number of applications.

Some of the advantages of plastic pipe over the more conventional materials now used for drainage might help to explain the substitution.

1 Lightness—a 20 ft (6.1 m) length of 75 mm pipe weighs 6.7 lb (3 kg).
2 Ease of handling.
3 Toughness.
4 Availability in any length; quick and easy to lay.
5 Ease of stacking; taking up little space.
6 Once laid, resists misalignment by earth movement.
7 Controlled slots prevent blockage by large soil particles.
8 Ease of flushing out or rodding.
9 Grids are easily attached to exposed ends of pipes to prevent entry of rodents during dry weather.

Types of Plastic Materials used for Drainage Pipe

Three pipe compounds, based on polyethylene, acrylonitrile/butadiene/styrene and polyvinylchloride have been used for this type of application. Of these, PVC has been the most successful and economical compound and the discussion is accordingly limited to this material.

Early History

The first existence of the monomer vinyl chloride was reported as early as 1838, but was only born as a polymeric compound around 1912 when the Germans patented the first polymerisation process. By 1933 two further companies, one being B. F. Goodrich, patented other allied processes.

By the start of the Second World War, the significance of plasticising PVC was fully realised. Due to the shortage of rubber, plasticised PVC was used as a substitute material, and has been permanently used ever since. The point to be made is that PVC as a material already has a 30 year history, and is not as unconventional as is commonly accepted.

Properties of PVC Compounds

In general, most thermoplastics are delivered in a form suitable for processing. This is not so for PVC which is in a form which usually requires compounding. This is necessary because of the relatively low thermal stability and high melt viscosity of the material. By correct choice of compounding additives it is found that processing is made easier. By changing the combination of additives the physical properties of an end product made from the compound can be varied and controlled.

Polyvinyl compounds normally contain the base polymer together with stabilizer, lubricant, filler and pigments, and are then classified as 'rigids'. By adding a plasticiser, the hard horny rigid compound converts into a flexible grade, and is accordingly termed a semi-rigid or flexible compound. Table 1 outlines the properties of these two types of PVC compounds.

For drainage purposes, pipes made from the rigid compounds are the most suitable. The term rigid is a little misleading, and is sometimes thought to convey brittleness. This is not true. Pipe extruded from rigid compound is tough and durable, and is sufficiently flexible for a 50 mm diameter pipe to be coiled. What's more, by altering the geometry of the pipe surface, for example by corrugating it, an even more flexible effect is achieved. Coiling is made easier.

Pipe and Slot Dimensions

The slot patterns on drainage pipe vary between countries, some of which are listed.

	Australia	Denmark	Netherland	Gt. Britain
Pipe sizes	2″ 3″ 4″	50mm/ 90mm	40mm/ 63mm	2″
Area of perforation		10 sq.cm/m	9 sq.cm/m	0.6%
Slits/m	60 in 4 rows		60 in 4 rows	
Slot size length	1¾″	7.8mm width	2.5 cm	1¼″ traverse
width	1/16″	2mm width	0.6 mm	

A generally accepted pattern in South Africa is

9 sq cm per metre area of perforation

60 slots per metre

2.5 cm slot length

0.6 mm slot width

It is anticipated that a 0.6 mm wide saw slit will prevent silting up of the drainage pipe in most soils. An exception could be found in sandy soils in which case two preventative measures can be taken. The first is to backfill the areas in contact with the drainage pipe with a coarser grain material, or alternatively to cover the saw slits with a strip of fibre glass. Experimental work in Holland has shown that fibreglass pre-wrapped drainage pipe has given results as good as those found from tile drainage in sandy subsoils.

In clay soils the silting up of the drains does not appear to coincide as much with the fineness of the soil particles as with the cohesion and the structure of the soil. The use of filtering material is in general not necessary here.

Laying a plastic drainage system

The two most important advantages of laying drainage with plastic pipes are:-

1 Transport-- A 75 mm pipe weighs approximately 6.6 lbs (3 kg) per 20 ft (6.1 m) length. Packed in bundles of 10 they make loading and unloading a relatively easy task. This all means a saving of time and labour, particularly in the field. Breakages very rarely occur.

2 Labour employed--Compared to other drainage materials, laying plastic pipes requires a smaller number of workers. Labour organisation is simpler, in that the same workers are employed on the project all the time.

In South Africa trenching will often be done manually. Savings can be expected to accrue from the use of plastic pipes in manual installations because of the speed of laying the pipe. Several lengths of pipe can be joined and snaked into the trench as fast as the trench is dug. This means that narrower trenches can be used.

But plastic pipes particularly lend themselves to mechanical means of installation. Drain laying machines can easily be modified to handle plastic pipes.

For best results, plastic drainage pipe must be laid firmly on the base of the trench and not on loose soil which has fallen back after the trencher has passed. To ensure this, a "box" consisting of two parallel plates running along either side of the trench wall is attached at the back of the machine. The pipes are then laid within and between these plates before soil can fall onto the bottom of the trench. A chute of about 15 ft (4.75 m) radius is recommended down which the pipe can be fed to rest on the freshly cut V base of the trench. The pipe is fed continuously either from a coiled length of pipe or from straight lengths joined by a spigot and socket method. This means that the one end of each straight length is belled. It is not necessary to improve the joint strength with cementing compound.

Under bad laying conditions where fall-in of the trench occurs soon after the trenching machine has passed, it is desirable to cover the pipe as soon as possible with a permeable layer. The necessity for manual removal of fallen earth from the top of the pipe will be avoided by following the trenching machine with a gravelling unit.

Although plastic pipe has more than adequate strength for its intended purpose. it will not withstand a man jumping into the trench on top of it. If it is necessary to remove any earth from on top of the pipe, this should be done from the side of the trench, using a suitable tool.

Conclusion

Drainage is a very important but somewhat neglected feature of crop production. Most drainage problems are associated with irrigation. Continued application of irrigation water will add salts to soil, and rainfall or further application of water will be necessary to leach out the salts and to remove these through drains.

Drainage costs are reasonable in relation to other aspects of capital expenditure for crop production. Plastic pipe drainage should in the near future offer the most attractive savings on drainage schemes in South Africa, as has been found in other parts of the world.

Drainage on anything other than a very small scale, requires expert advice and design. Advice should be called for on matters pertaining to drainage whether it be design, installation, operation or maintenance.

APPENDIX

TABLE I

Properties of PVC compounds

	Flexible	Rigid
Specific gravity	1.2–1.6	1.4—1.6
Tensile strength lbs/sq/in	1 500–3 000	6 500
kg/cm²	106–210	460
Elongation at break %	100–500	25–100
Compression strength lb/sq in	1 250	10 000
kg/cm²	88	700
Shore hardness	A50–95	D75–85
Shearing strength kg/cm²		400
Coeft. 1 in expansion (0c× 10–5)	1	6
Flammability	Self extinguishing	
Water absorption (24hr %)	.25	.05–.2

Chemically resistant to all common acids and alkalis.
Will not rot or deteriorate in moist conditions.

Buried PVC Pipelines

Discussion

When pipes are buried underground, loads such as back filled soil, liquid weight inside the pipe and moving vehicles, besides internal pressure, act on them. Though internal pressure acts favourably on the pipe to the deflection of vertical direction, deformation stress by external pressure makes it extremely difficult to find the optimum wall thickness of the pipe to insure safety. The complexities involved are tremendous. As a guide to this problem the following information is offered:

Calculation

The earth load on the pipe rests almost entirely on the top 90° sector of the pipe, and it is the trench width at the top 90° sector of this pipe which determines the total load on the pipe and not the diameter of the pipe itself. Indirectly, the diameter of pipe affects the calculation in that it determines the width of trench excavated to accept the pipe.

The following formula applies in determining the load on the tube, calculated in lbs per foot run of tube.

Load = CWB^2

where C is a load coefficient which is dependent on the ratio of depth to width of trench, and the back-filling method which can be determined from the attached graphs. W is the weight of back-fill material in lbs/cu ft, which is normally,

Loam	110
Sand	115
Gravel	125
Sandy or gravelly clay	120
Saturated clay	130

B is the trench width slightly below the top of the pipe, measured in feet.

From the graphs it will be noted that the load coefficient does not increase substantially for ratios between 5 and 10, and remains practically constant above 15. This means that after reaching certain proportions, the back fill tends to support itself against the sides of the trench with further increase in depth.

With a flexible tube, it can be assumed that upon deflection of the pipe section, i.e. from circular to oval, the tube and the side-fills will each carry the same amount of load per unit of width. The calculated vertical load can be determined from the above formula, and is adjusted by multiplying the calculated figure by the ratio of the tube O.D. to the trench width.

In determining the strength of the tube, the Spangler formula for cross-sectional deflection of the flexible pipe under load is as follows:-

$$d\,(\text{ins}) = \frac{f.\,k.\,l.\,r^3}{Et^3 + 0.732\,.\,e.\,R^4}$$

where K = bedding constant, which depends on the shape of the bed underneath the pipe, i.e. whether flat or shaped.

These figures are as follows:-

Bedding contact on pipe circumference	Constant K
0°	0.110
30°	0.108
45°	0.105
60°	0.102
90°	0.096
120°	0.090
180°	0.083

L = calculated load on pipe in lbs per ft run
R = mean radius of pipe in inches
E = Modules of elasticity = 500 000 psi for rigid PVC
t = tube wall thickness (inches)
e = Modules of passine pressure of side fill, and this varies with the type of back-fill and degree of compaction.

It averages between 10 and 15 for wide trenches and untamped back-fill and between 30 and 40 in tamped back-fill in common width vertical side trenches.

f = Deflection lag factor which is initially 1, but on final settling of the back-fill could be taken as between 1.25 and 1.50.

Worked Example

A 160 mm Class 6 pipe i.e. 4.7 mm wall suitable for working pressures of 85 psi is buried in a trench which will be 24″ wide at the pipe top, to a depth of 6 feet (to top of pipe) in a compacted sandy loam back-fill, with only a slight shaping of the pipe bed to give circumferential contact of 30°.

(*a*) *Load on pipe*

L = CWB^2
Ratio of depth to width = 72/24 = 3
From the graphs C = 1.9
W = 110 lbs per cu ft
L = ± 838 lbs.

As flexible tube is involved, the load will be shared by the side fills and the tube, and the vertical load can be adjusted by the ratio of tube O.D. to the trench width.

The load thus becomes 219 lbs, i.e. 838 × 6.3/24

(*b*) *Deflection*

Substitute into the formula
L = 219
R = 80 mm = 3.15 inches.
t = 5.05 mm = 0.198 inches.
Assume e = 35
Assume f = 1.50 (max. value)
K = 0.108

This gives a deflection of about 0.173 inches, or 2.7%.

For flexible pipes, a deflection of approximately 20% can occur before collapse. In the above example, the installation will work satisfactorily.

Discussion

Professor Sumner: Mr. Pithey has, I noticed, made no mention of America when referring to slot patterns on drainage pipes in other countries.

I saw corrugated piping being laid in California and the amplitude of the corrugations appeared much greater than in the sample shown by Mr. Pithey and the walls seemed thinner.

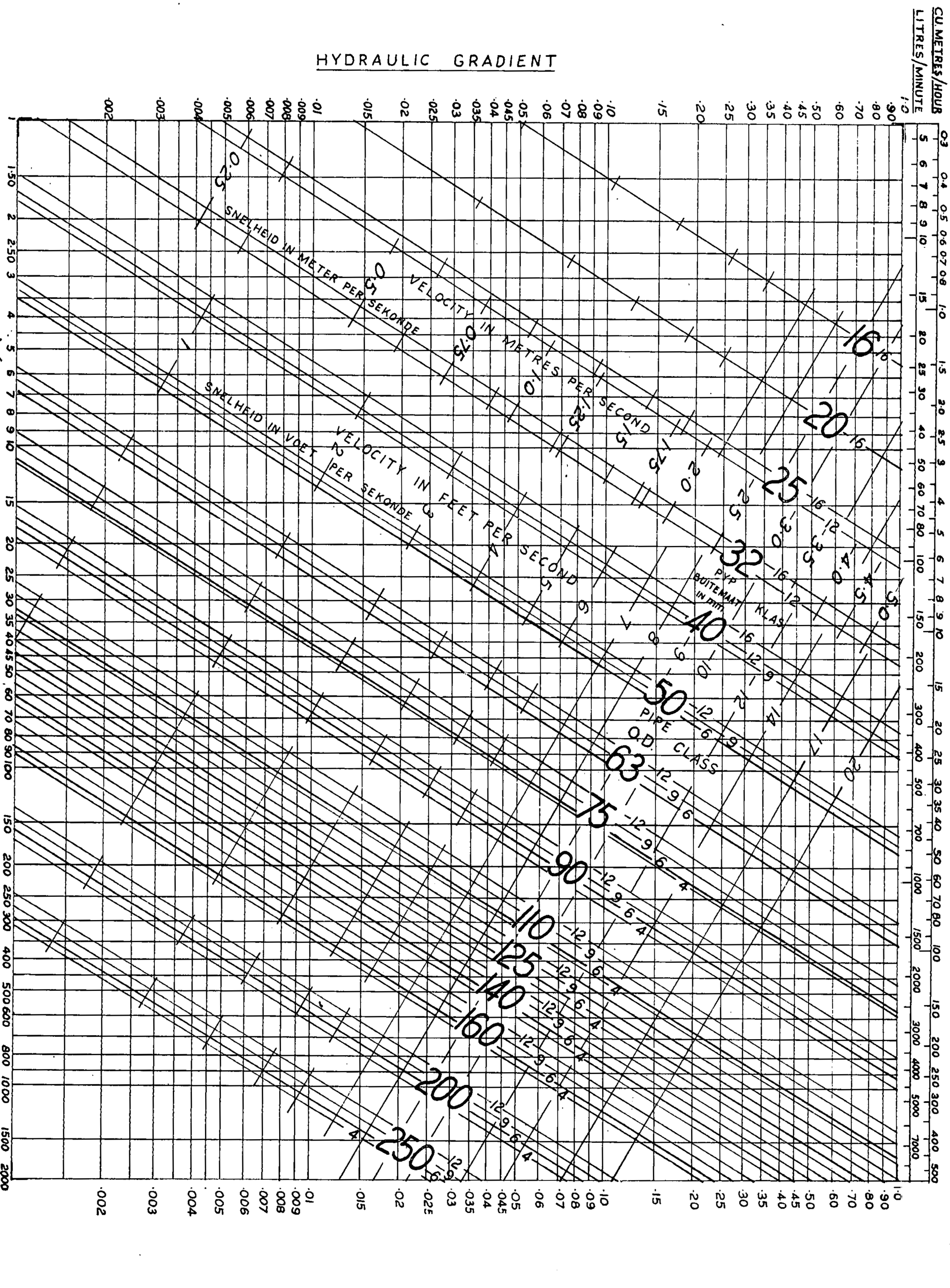
Is it cheaper to have a thin walled corrugated pipe than a non-corrugated pipe?

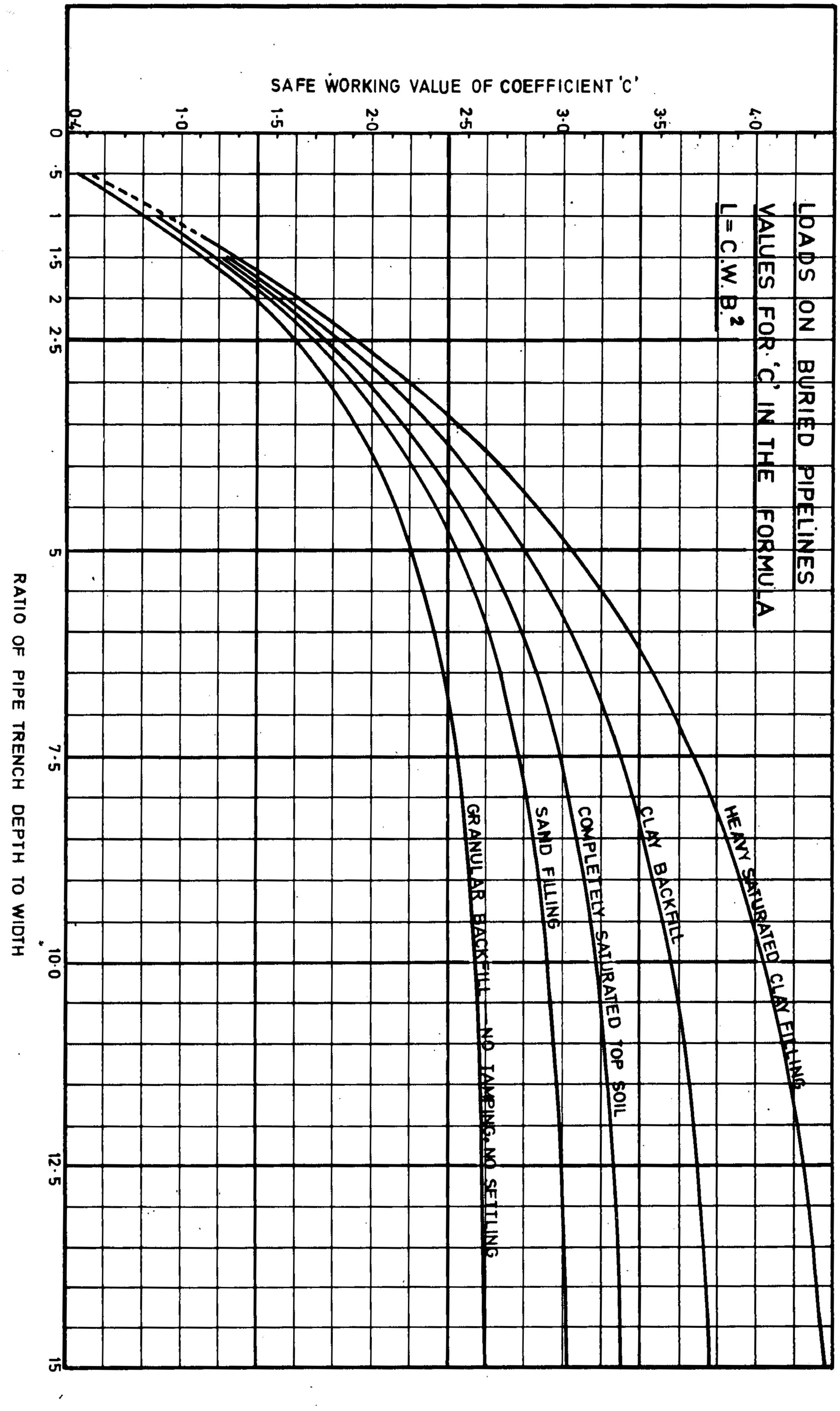
Mr. Pithey: Approximately 70% of the cost of manufacture of plastic pipe is for material.

The thinner the wall the cheaper the pipe, but of course there is a loss in mechanical strength.

The cost of a 50 mm pipe is about 5c a foot, or about R17 per acre.

Dr. Gosnell: In Rhodesia, concrete tiles are about 7 or 8 cents a foot and if we could get plastic tiles at 9 cents a foot or cheaper we would use them. Unless soil is stone free the trench laying machines are not very effective.


HYDRAULIC GRADIENT
VELOCITY IN METRES PER SECOND
SNELHEID IN METER PER SEKONDE
VELOCITY IN FEET PER SECOND
SNELHEID IN VOET PER SEKONDE
PIPE O.D. CLASS
PYP BUITEMAAT IN mm KLAS
FLOW IN IMPERIAL GALLONS PER MINUTE
CU. METRES/HOUR
LITRES/MINUTE


LOADS ON BURIED PIPELINES
VALUES FOR 'C' IN THE FORMULA
L = C.W.B²
SAFE WORKING VALUE OF COEFFICIENT 'C'
0·4
1·0
1·5
2·0
2·5
3·0
3·5
4·0
0
·5
1
1·5
2
2·5
5
7·5
10·0
12·5
15
RATIO OF PIPE TRENCH DEPTH TO WIDTH
HEAVY SATURATED CLAY FILLING
CLAY BACKFILL
COMPLETELY SATURATED TOP SOIL
SAND FILLING
GRANULAR BACKFILL — NO TAMPING, NO SETTLING