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The Design of Ventilated Improved Pit Latrines

by D. Duncan Mara

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The Design of Ventilated Improved Pit Latrines

by D. Duncan Mara,
Technology Advisory Group (TAG)



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and World Bank Contribution to the International
Drinking Water Supply and Sanitation Decade

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PREFACE

This Technical Note by D. Duncan Mara develops a general approach to the design of ventilated improved pit (VIP) latrines, based on TAG's recent experience in Botswana, Brazil, Ghana, Kenya, Lesotho, Tanzania and Zimbabwe. Further details of country-specific designs (currently for Botswana, Tanzania and Zimbabwe) are given in other Technical Notes in this series.

This paper is one of a series of informal Technical Notes prepared by TAG on various aspects of water supply and sanitation programs in developing countries. The initial emphasis of TAG was on the promotion of policy shifts from high-cost to low-cost on-site sanitation technologies. This emphasis is now being progressively directed to a focus on institutional development for on-site low-cost sanitation program delivery.

This note was originally prepared as an internal discussion document. Its wide distribution does not imply endorsement by the sector agencies, government, or donor agencies concerned with programs, nor by the World Bank or the United Nations Development Programme.

TAG is interested in receiving comments and suggestions on the paper, and, in particular, information on costs of technology, delivery and support systems, and generally, information on experience in program implementation. All communication should be addressed to the Project Manager, UNDP Project INT/81/047, Water Supply and Urban Development Department, The World Bank, 1818 H. Street, NW, Washington, DC 20433.

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Project Manager

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INTRODUCTION

1. Excreta-related diseases are responsible for a large proportion of the morbidity and mortality in developing countries, especially amongst low-income communities in urban fringe and rural areas, where adequate water supplies and sanitation facilities are typically absent. Excreta control is thus of paramount importance if the incidence of these diseases is to be reduced. Recent research sponsored by the World Bank^{1/} has clearly shown that excreta-related diseases can be greatly reduced by:

- (a) the provisions of sanitary toilets, of whatever type, which people of all ages will use and keep clean;
- (b) the effective treatment of excreta or sewage prior to discharge or reuse;
- (c) the provision of an adequate water supply so that water consumption is in the region of 30 to 50 liters per capita per day, which is normally the minimum requirement for the control of those excreta-related infections which have a water-washed mode of transmission; and
- (d) an effective and sustained program of personal hygiene education by the responsible local authority.

2. Economic and financial constraints dictate that the water supply and sanitation technologies to be used for the control of excreta-related diseases in low-income communities must be affordable by these communities; these technologies must therefore have low capital and operating costs. In rural areas and urban areas up to a population density of around 300 persons per hectare, the least-cost technically feasible sanitation technology will often be the ventilated improved pit (VIP) latrine (Figure 1). It is the purpose of this Technical Note to discuss general design criteria for VIP latrines and to review recent developments in VIP latrine design.

VENTILATED IMPROVED PIT LATRINES

General Description

3. Traditional (unventilated) pit latrines are a very common sanitation facility in many developing countries. They have however two serious disadvantages: generally they have a bad smell, as well as substantial numbers of flies and other disease-carrying insects breeding in them. Additionally, they are all too often poorly constructed, with the result that pit collapses are common. These disadvantages are substantially reduced in VIP latrines, which have been found to be socially very well accepted in those countries where they have been installed.

^{1/} R.G. Feachem, D.J. Bradley, H. Garelick and D.D. Mara (1983). **Sanitation and Disease: Health Aspects of Excreta and Wastewater Management.** Chichester: John Wiley.

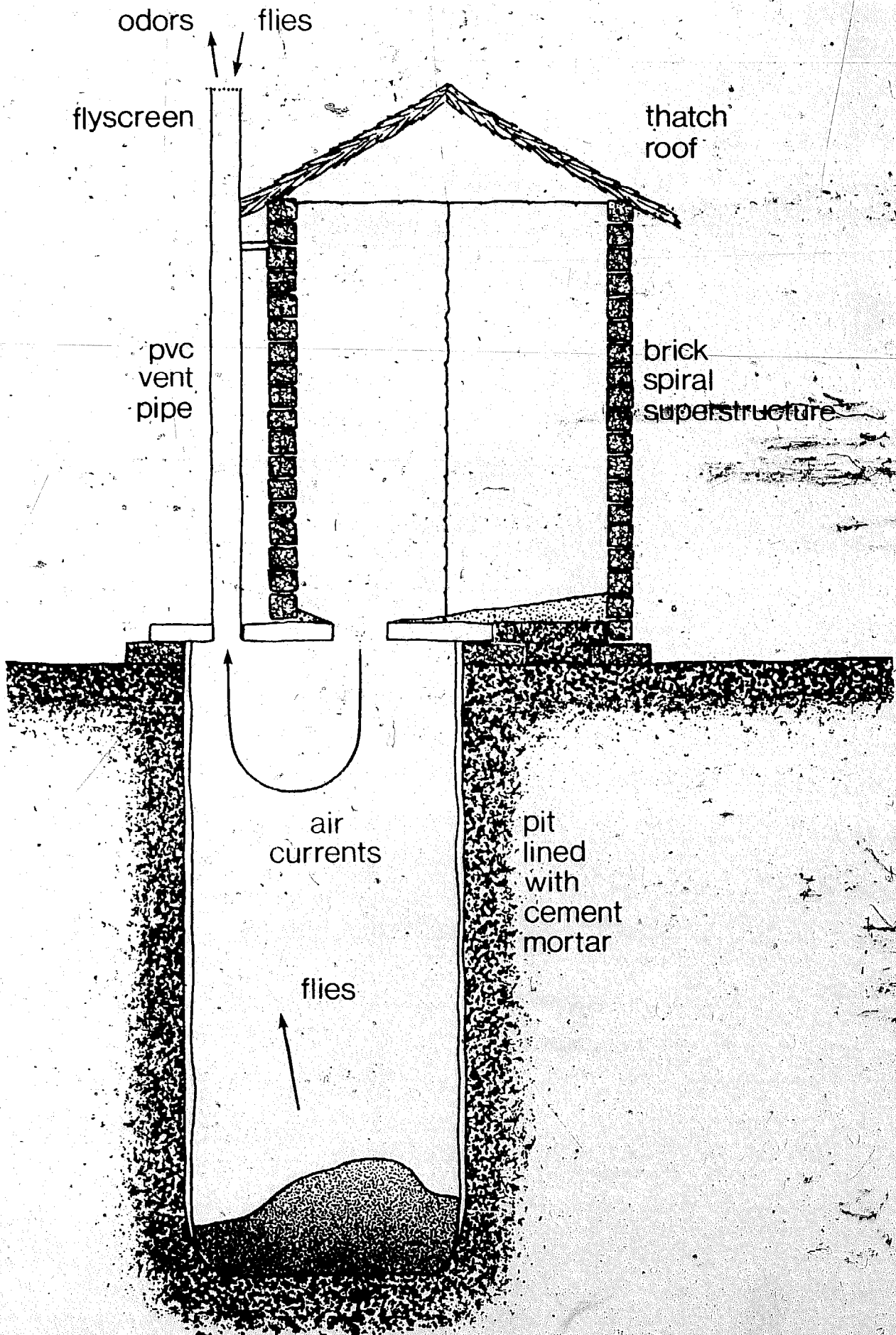


Figure 1. Schematic diagram of a ventilated improved pit latrine.

4. A VIP latrine differs from a traditional pit latrine in that it has a tall vertical vent pipe which has a flyscreen fitted at its top. The vent pipe is responsible for both odor and fly control, as explained in paragraphs 6 and 7, below.

5. There are two basic types of VIP latrine: the single-pit latrine and one with two pits, known as the alternating VIP latrine. The latter (described in paragraphs 45-52) is designed for the removal of the pit contents at regular intervals of two to three years; it is a permanent sanitation facility which is especially suitable for use in medium density urban areas.

Odor control

6. Fieldwork recently done in Botswana and Zimbabwe^{2/} has shown that the principal mechanism inducing ventilation in VIP latrines is the action of the wind blowing across the top of the vent pipe. The wind effectively sucks air out of the vent pipe and this air is replaced from the atmosphere via the latrine superstructure and squat-hole. Consequently there is a strong circulation of air from outside the latrine, through the superstructure and squat-hole, and up and out of the vent pipe. Thus, any odors emanating from the fecal material in the pit are exhausted via the vent pipe, and not via the squat-hole into the superstructure which, as a result, remains odor-free^{3/}. If the superstructure openings (doorways, etc.) face into the prevailing wind, the resulting increased air pressure within the superstructure increases the flow of air up the vent pipe and thus also helps to control odors in the latrine; the latrine should therefore be designed so that any openings face into the prevailing wind. Recommended vent pipe dimensions are discussed in paragraphs 27-38.

Insect control

7. **Flies.** The vent pipe controls flies in VIP latrines in two ways. Firstly, since flies are attracted to pit latrines by the fecal odors coming from them, almost all flies will try to enter the pit via the top of the vent pipe as that is the point from which the odors emerge; but they are prevented from entering by the flyscreen. Secondly, although a few flies may enter the pit via the superstructure and squat-hole and lay their eggs in the

2/ B.A. Ryan and D.D. Mara, **Pit Latrine Ventilation: Field Investigation Methodology**, TAG Technical Note No. 4; and **Ventilated Improved Pit Latrines: Vent Pipe Design Guidelines**, TAG Technical Note No. 6.

3/ An earlier explanation for the cause of ventilation was that the vent pipe absorbed heat from the sun and transferred some of this energy to the air inside the vent pipe, which consequently became less dense than the outside air immediately above it; it therefore rose out of the vent pipe and was replaced by air below, so establishing the air circulation pattern described above. The fieldwork done in Botswana and Zimbabwe showed that the shearing action of the wind and its direction relative to any openings (doorways, etc.) in the superstructure were much more important than the absorption of solar energy, except under very low wind conditions (see paragraphs 26 - 38).

pit, the newly-emergent adult flies eventually resulting from these eggs fly instinctively in the direction of the brightest light; provided that the superstructure is reasonably well-shaded, the brightest light seen by the flies is that at the top of the vent pipe: the flies thus fly up the vent pipe but their escape is prevented by the flyscreens. Fly control is very effective: in a 78-day monitoring period in Zimbabwe, only 146 flies were caught escaping from a VIP latrine, whereas 13,953 were caught from an unvented, but otherwise identical, pit latrine.

8. Thus the screened vent pipe has three important roles in the successful performance of VIP latrines:

- (a) it eliminates fecal odors in the superstructure;
- (b) it prevents most flies from entering the pit; and
- (c) it prevents those flies bred in the pit from escaping.

9. **Mosquitoes.** Culicine mosquitoes, which are the major nuisance (biting) mosquitoes in the urban tropics and in many countries also the vector of Bancroftian filariasis, breed in wet pit latrines--that is, pits which extend below the groundwater table. Newly-emergent mosquitoes are not so attracted to light as are flies, and therefore not all of them will try to escape via the vent pipe: many will leave via the squat-hole, even if the superstructure is well shaded. Several substances which kill mosquito larvae can be added to the pit; for example, kerosene, used engine oil or chemical larvicides. An alternative is to place a mosquito trap (Figure 2) over the squat-hole. This has been found to be very effective in field trials in Dar es Salaam (Tanzania); householders were keen to use them once they saw how many mosquitoes were being caught in the traps and they noticed as a result far fewer mosquitoes in their houses.

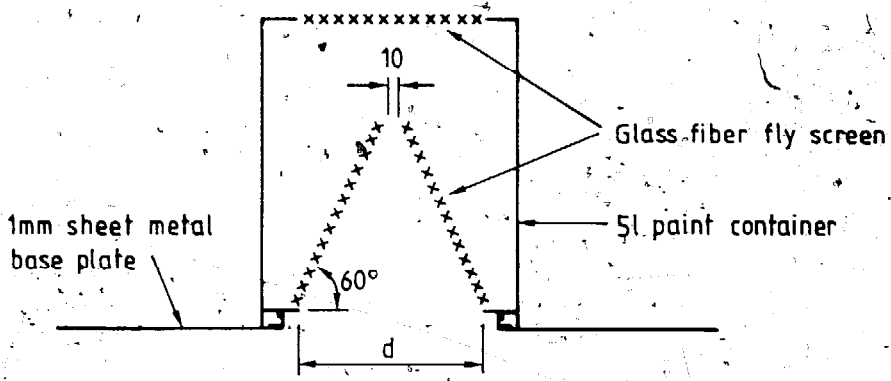
Component parts

10. Both single-pit and alternating twin-pit VIP latrines consist of the same basic component parts (Figure 1: see page 2):

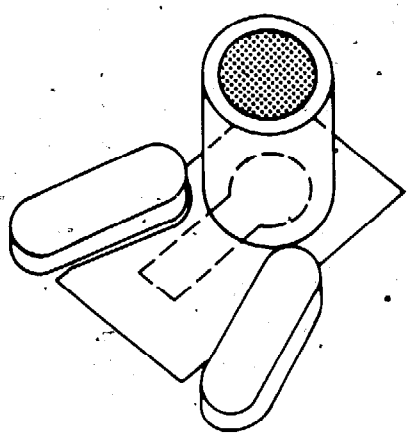
4/ P.R. Morgan (1976). **The pit latrine - revived.** Central African Journal of Medicine, 23, 1-4.

5/ C.F. Curtis and P.M. Hawkins (1982). **Entomological Studies of On-site Sanitation Systems in Botswana and Tanzania.** Transactions of the Royal Society of Tropical Medicine and Hygiene, 76 (1), 99-108.

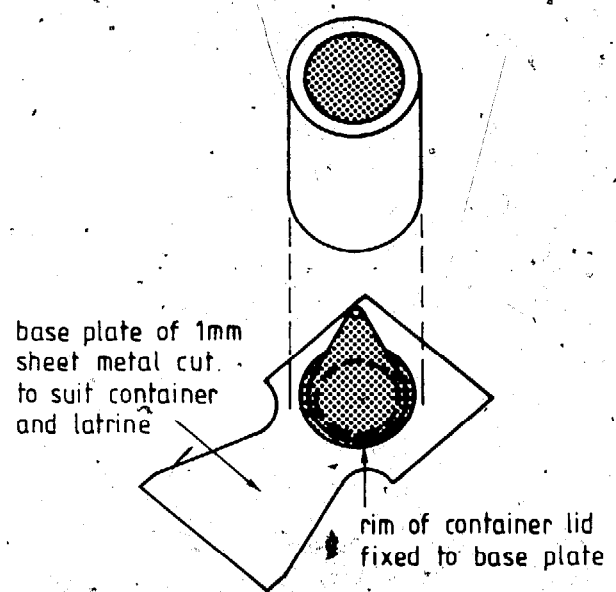
6/ C.F. Curtis (1981). **Insect Traps for Pit Latrines.** Mosquito News, 40 (4), 626-628.



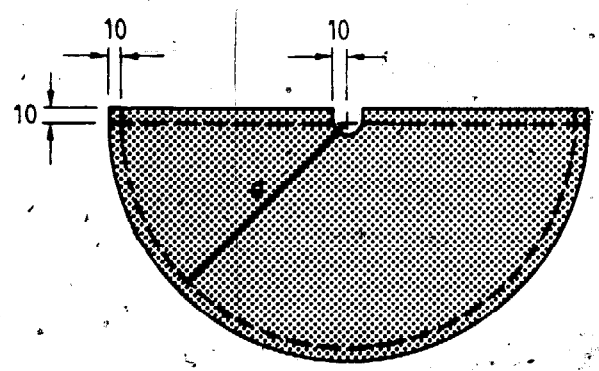
Section through mosquito trap



Mosquito trap in position over squat-hole



Mosquito trap with container removed for emptying



Pattern for cutting fly-screen material

Figure 2. Squat-hole mosquito trap (6/).

- (a) the pit;
- (b) the cover slab and its foundation;
- (c) the superstructure; and
- (d) the screened vent pipe.

There are minor design differences between the components for each type of VIP latrine, but the basic principles remain the same. The component parts and their design requirements are first described for single-pit VIP latrines; specific differences for alternating twin-pit latrines are described in paragraphs 45-52.

SINGLE-PIT VIP LATRINES

Pit functions and design

11. Excreta are deposited directly into the pit, which has two essential functions:

- (a) the liquid fraction of the excreta (mainly urine), together with the small amount of water that enters the pit from cleaning the cover slab, infiltrates into the surrounding soil; this may give rise to problems in soils which are not sufficiently permeable or which become unstable when saturated, and may also cause groundwater pollution (see paragraphs 15, 16 and 58); and
- (b) the fecal solids in the excreta are digested anaerobically by bacterial activity - this results in the production of (i) gases such as methane, carbon dioxide and hydrogen sulphide which are exhausted from the pit via the vent pipe; and (ii) soluble compounds which are either further oxidized in the pit or are carried into the surrounding soil by the infiltrating liquid fraction.

12. The anaerobic digestion of the fecal solids, which proceeds rapidly at tropical temperatures, does not however remove all of the solids. Some compounds are biodegraded only very slowly; as a result there is a gradual accumulation of solids in the pit, although the rate of solids accumulation is much smaller than the rate of excreta addition. In dry pits (those that do not extend below the groundwater table) the solids accumulation rate varies between 0.03 and 0.06 m³ per person per year, and in wet pits between 0.02 and 0.04 m³ per person per year. Accumulation rates are lower in wet pits because biodegradation is faster under wet conditions than under the only just moist conditions in dry pits.

13. **Volume.** The required pit volume depends on the solids accumulation rate, the number of users and the desired life of the pit. In practice the

7/ Very little information exists on solids accumulation rates in pit latrines. The effects of climate and diet are largely unknown, although it is known that the addition of sullage to dry pits (e.g., by using the latrine for "bucket showers") reduces the rate of solids accumulation. TAG is currently working on "pit biokinetics" and the results of this research will be published as a separate Technical Note in this series.

pit must not be allowed to fill up completely (right to the underside of the cover slab), so a small free space at the top of the pit must be allowed for in the design; usually 0.5 m is sufficient for this. The effective pit volume m^3 , which is the total volume less the free space volume, is calculated as the product:

$$\begin{matrix} \text{solids accumulation} & & \text{number} & & \text{design} \\ \text{rate,} & \times & \text{of} & \times & \text{life,} \\ m^3/\text{person/year} & & \text{persons} & & \text{years} \end{matrix}$$

The solids accumulation rate may for design purposes be taken as 0.04 and 0.06 m^3 per person per year in wet and dry pits respectively; a lower value may be used if known to be locally more appropriate. These design values should be increased by 50% if bulky anal cleansing materials (for example, corn cobs, cement bags) are used, as these degrade only very slowly. The design life should be as long as possible; 10 years should be considered desirable. The longer the design life, the longer the interval between relocating or emptying the latrine, and so the cost of the latrine (when calculated in annual terms) is generally lower.^{8/}

14. **Dimensions.** Usually the pit cross-sectional area is not more than $2 m^2$ in order to avoid cover slabs with large spans. In practice VIP latrines serving one household commonly have a diameter of 1-1.5 m or, in the case of square or rectangular pits, a width of 1-1.5 m; communal or institutional latrines can of course be much larger. The pit depth is then calculated from its required effective volume, and the total depth is this depth plus the desired free space which is normally 0.5 m.^{9/}

15. **Soil permeability.** The hydraulic loading on pit latrines is very low (less than 2 litres of excreta are added per person per day), so soils of lower permeability than would be considered for the disposal of septic tank effluent are still suitable for pit latrines. Soils with permeabilities as low as 2.5 mm per hour (such as clays and silty clays) are acceptable, provided expansive clays are not present.

16. **Soil stability and pit lining.** For the purposes of pit design soils can be considered as either stable or unstable. Stability is defined

^{8/} This assumes that the cost of extra depth in the pit is less than the present value of more frequent emptying or relocation. This may not always be true, especially in very deep pits in difficult soils.

^{9/} For example, for a circular pit with an effective depth of 2.5 m which serves six people with a solids accumulation rate of $0.06 m^3$ /person year, the pit life for various diameters can be calculated as follows:

Diameter (m)	Cross-sectional area (m^2)	Effective volume (m^3)	Effective life (years)
1.0	0.79	1.98	5.5
1.2	1.13	2.83	7.9
1.5	1.77	4.43	12.3

as resistance to collapse, and should be assessed as described in Annex I. Local experience of pit latrines is useful: if pit collapses due to soil failure^{10/} have occurred, the soil should be considered unstable and lined as described in paragraph 18.

17. As a precautionary measure stable soils should be protected against possible failure (caused by, for example, gradual release of pore water pressure) by plastering the soil face with a 1 cm thick layer of cement mortar (1 part cement, 5 parts sand). This is clearly only feasible when the groundwater table is below the pit base, and so suitable only for permanently dry or only seasonally wet pits. Linings for permanently wet pits are discussed in paragraph 19.

18. Pits in unstable soils must be fully lined, otherwise there is the risk--all too often realized--that the pit will collapse and the superstructure may fall into it. A wide variety of materials can be used to line the pit; for example, concrete blocks, bricks, cement-stabilized soil blocks, masonry, stone rubble, perforated oil drums, rot-resistant timber and wire-mesh-supported geofabrics [Figure 3 (a) through (f)]; local availability normally determines what material is used. Where blocks, bricks, masonry or stones are used, the lining joints should be fully mortared in the top half-metre of the pit; below this, the vertical joints should be left unmortared to allow the liquid fraction of the excreta to infiltrate into the soil. If the surrounding soil is very fine sand, for example, which would enter the pit through the open vertical joints, a thin (say, 100 mm) packing of fine gravel should be placed between the soil and the lining to prevent this.

19. It is difficult to excavate and line pits in areas with a permanently high groundwater table. If petrol or diesel driven portable pumps are available, the groundwater can be removed and short lengths of concrete pipe inserted as excavation proceeds; this "mini-caisson" approach is the most satisfactory, provided that the concrete pipes are made with sufficient holes for infiltration. Perforated oil drums coated with bitumastic paint are an alternative, but corrosion is a problem in the long term.^{11/}

Cover slab and foundation

20. The cover slab and its foundation serve to isolate the pit from the atmosphere (to prevent the escape of flies and odors) and to support the superstructure and vent pipe. The foundation is generally a simple

10/ Pit collapse may, however, be due to poor engineering design: for example, the omission of a grassed slope or bund to carry away stormwater which is then able to erode the soil at the top of the pit; or by building too heavy a superstructure on inadequate foundations. It may also be due to poor "social design" of the latrine, where for example no allowance is made for local customs such as taking "bucket showers" in the latrine.

11/ Oil drums have been used in Zambia as aqua-privy tanks and have lasted approximately 10 years.



Figure 3 (a). Pit lining in open-joint brickwork
(Zimbabwe)

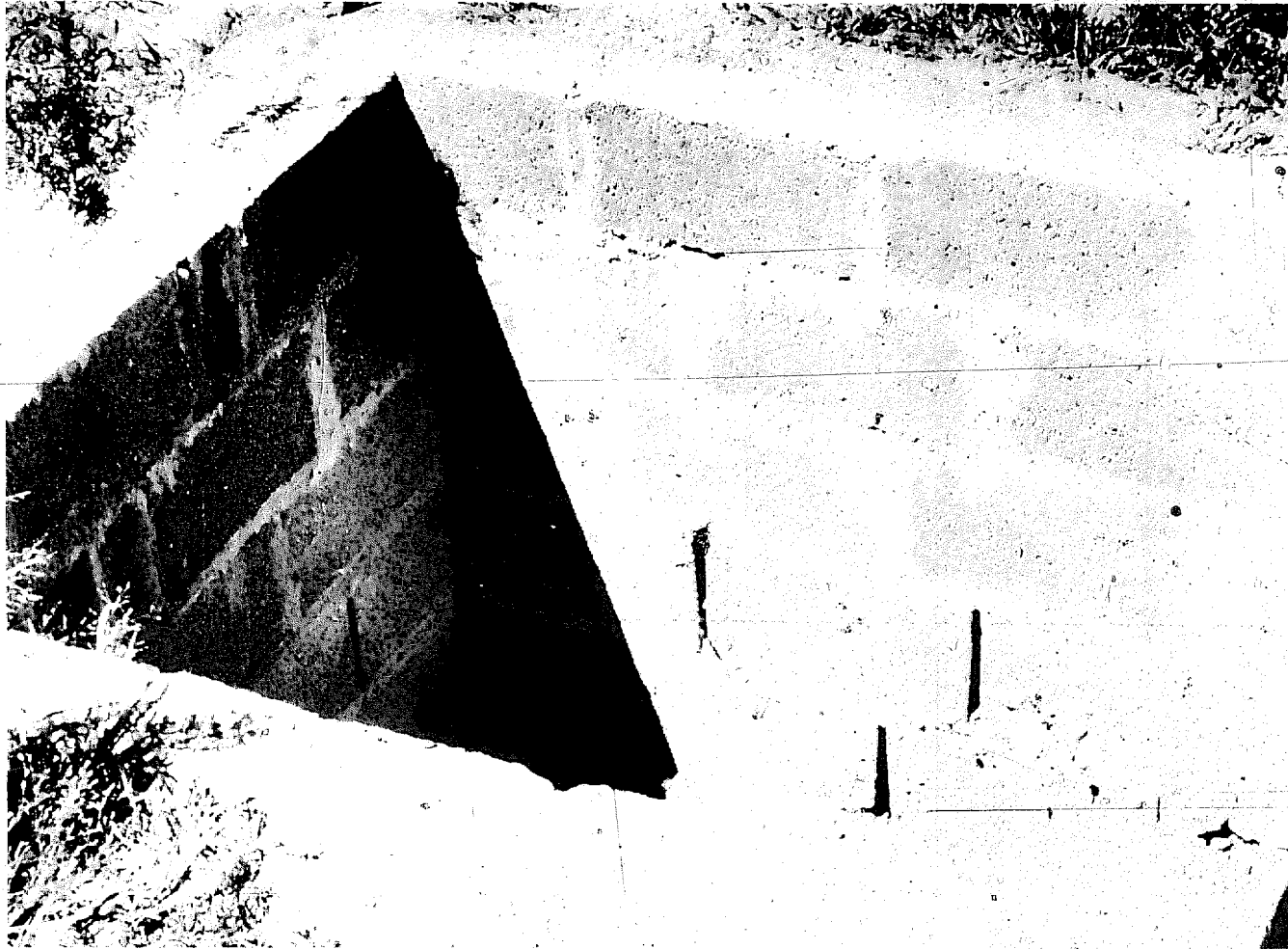


Figure 3 (b). Pit lining with concrete blocks
(Botswana).



Figure 3 (c). Pit lining with rough coral
(Kenya).



Figure 3 (d). Pit lined with perforated oil drum
(Kenya).

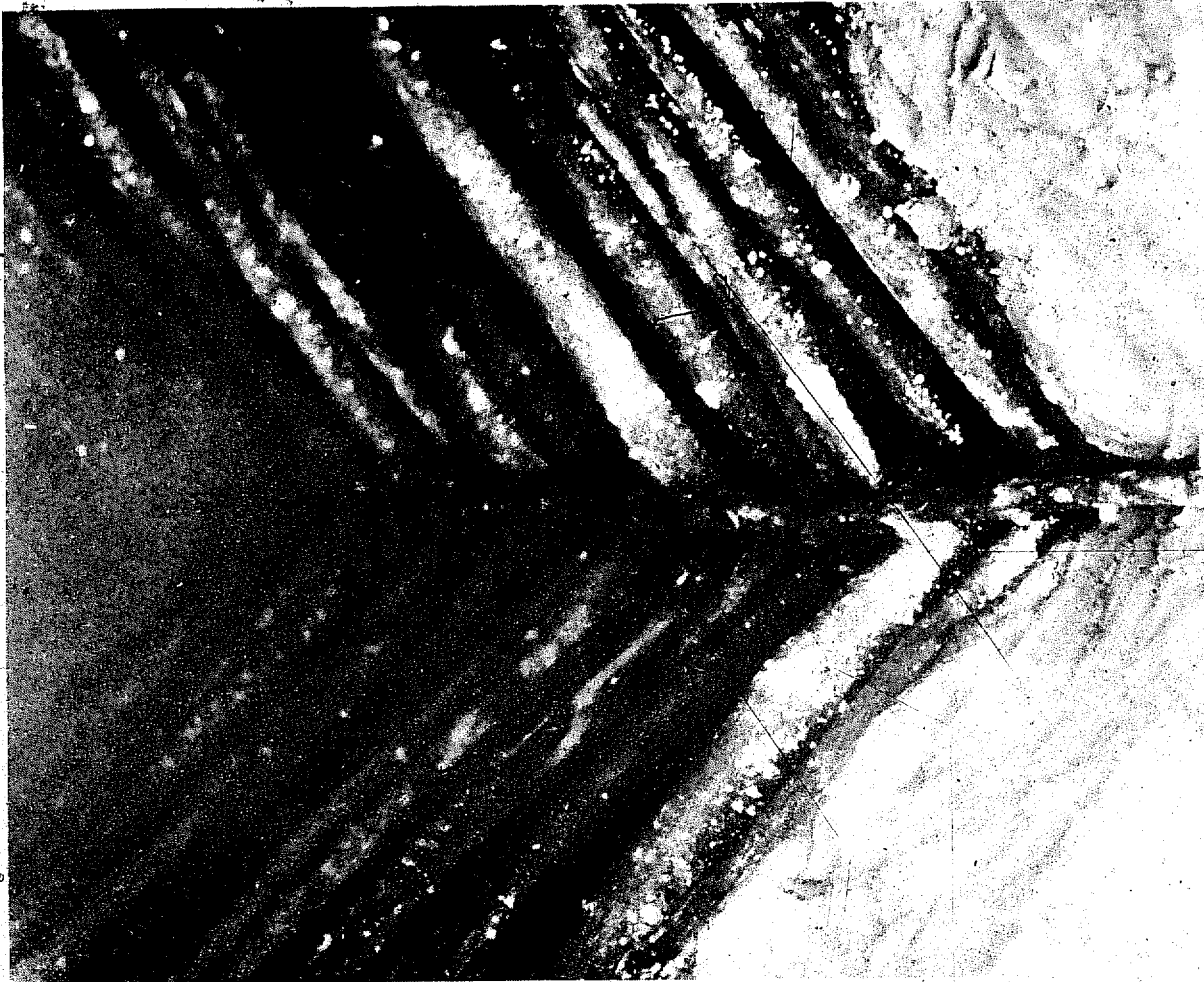


Figure 3 (e). Pit lined with mangrove poles
(Kenya).

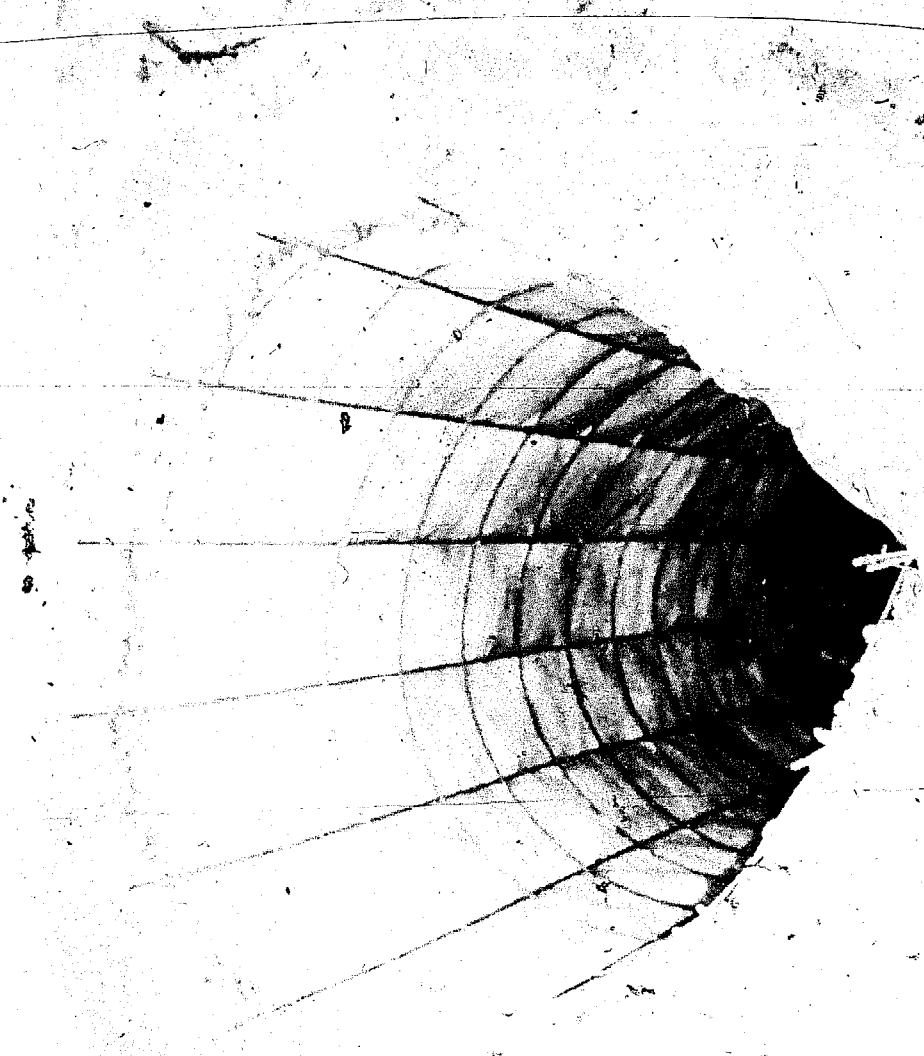


Figure 3 (f). Pit lined with wire-supported geofabric
(Botswana).

ring beam of reinforced concrete or, more commonly and less expensively, bricks set in cement mortar; a single course of bricks laid on the ground surface with their inner edge flush with the pit wall is sufficient (concrete ring beams are of similar dimensions). Setting the base of the foundation on the ground surface enables a gentle grass slope or cement-stabilized soil to be made to carry away stormwater which might otherwise erode the upper part of the pit wall, so endangering the structural stability of the latrine.

21. The cover slab must be strong enough to support the weight of the superstructure, vent pipe and user. It should also feel safe and should not deflect detectably when the latrine is being used. The cover slab, which should be flush with the outer edge of the foundation, can be made from reinforced concrete (Figure 4) or from rot-resistant timber (Figure 5) which is covered with soil and then mortared. The cover slab has two holes in it: the squat-hole and one for the vent pipe. The size of the squat-hole is important: it should not be large enough for a child to fall through; key-shaped or pear-shaped openings (Figure 6) with a maximum width of 200 mm are generally used. If the locally preferred defecation posture is sitting, rather than squatting, a simple pedestal seat can be provided (Figure 7).

22. Where the preferred posture is squatting, it is important that the surface of the cover slab should slope towards the squat-hole in order to provide drainage for urine and the water used to clean the cover slab. The recommended slope is 5%. Although the slab could be cast with this surface slope, it is usually simpler to plaster the slab to give the required slope, and also to provide a smooth finish, after the superstructure has been built. It is also worth considering whether foot-rests are to be provided; although not strictly necessary, they may be a social requirement and they have the advantage that, provided they are in the correct position themselves (Figure 6), they help to locate the user directly over the squat-hole and so minimize fouling of the cover slab with excreta. A glass-fiber reinforced plastic cover, with integral squat-hole and foot rests, which is set in cement on the coverslab within the superstructure is shown in Figure 8.

23. It is important that the squat-hole is not kept covered when the latrine is not in use. Squat-hole (or pedestal seat) covers interfere with the essential circulation of air which is responsible for fly and odor control (paragraphs 6 and 7). Traditional (unventilated) pit latrines often rely on squat-hole covers to control fly breeding, but they are not only unnecessary in the case of VIP latrines but also positively detrimental to their proper operation. This is an important point to stress in user education programs.^{12/}

^{12/} If covers or seat lids are required for sociocultural or aesthetic reasons, then they must be raised clear of the slab or seat so that an air space of at least 25 mm is left when the cover or lid is in the "closed" position. Further details are given in the references referred to in footnote 2.



Figure 4. Reinforced concrete cover slab (Tanzania).

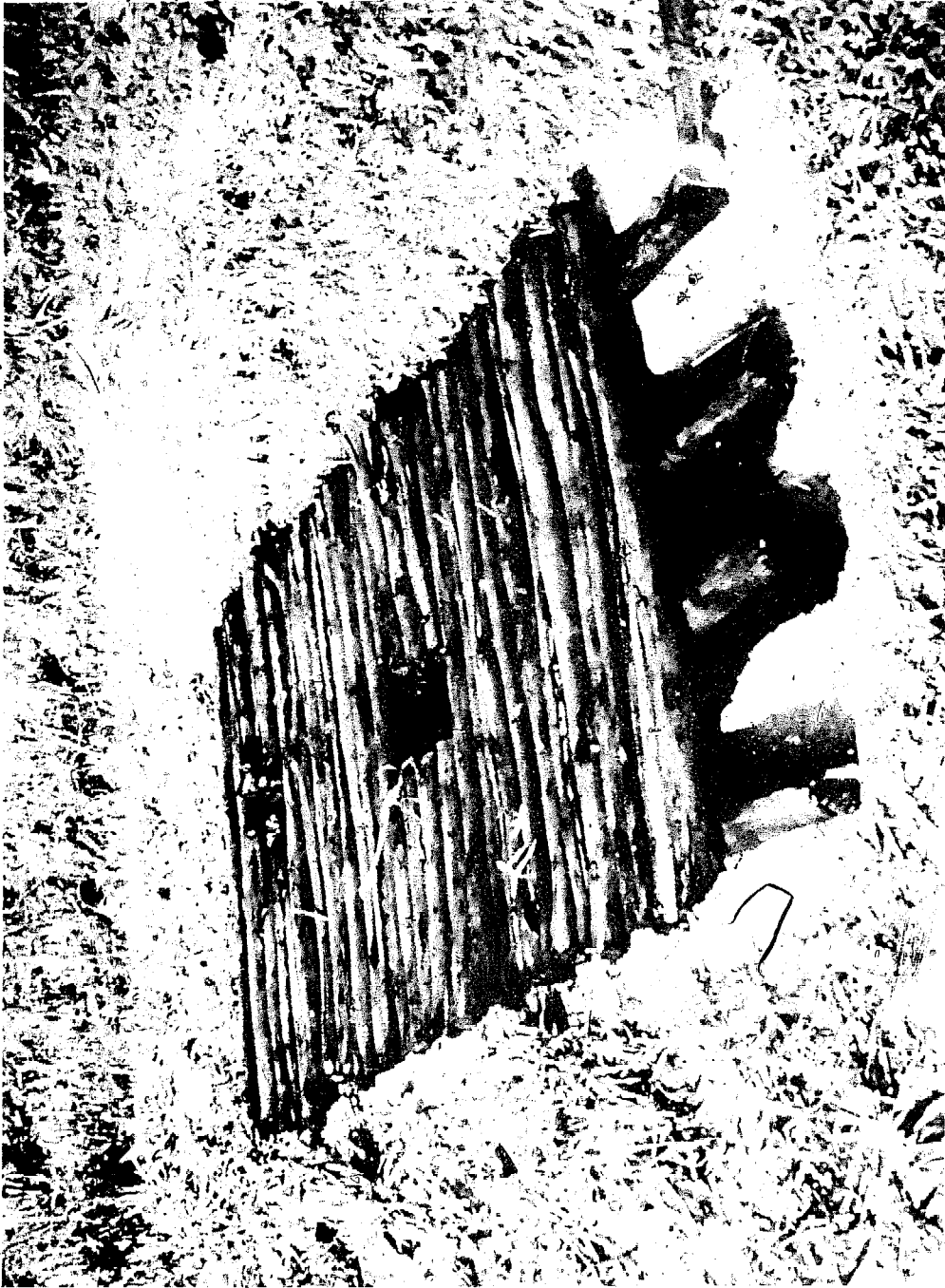


Figure 5. Timber cover slab (Zimbabwe).

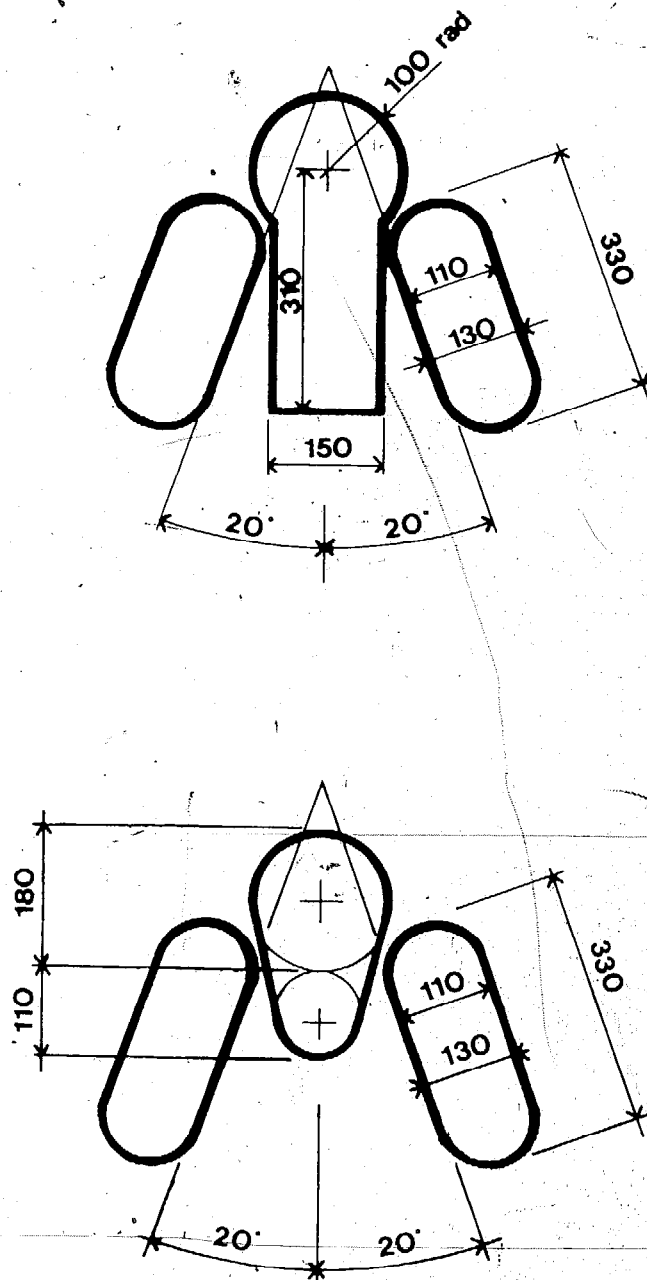


Figure 6. Squat-hole geometries.

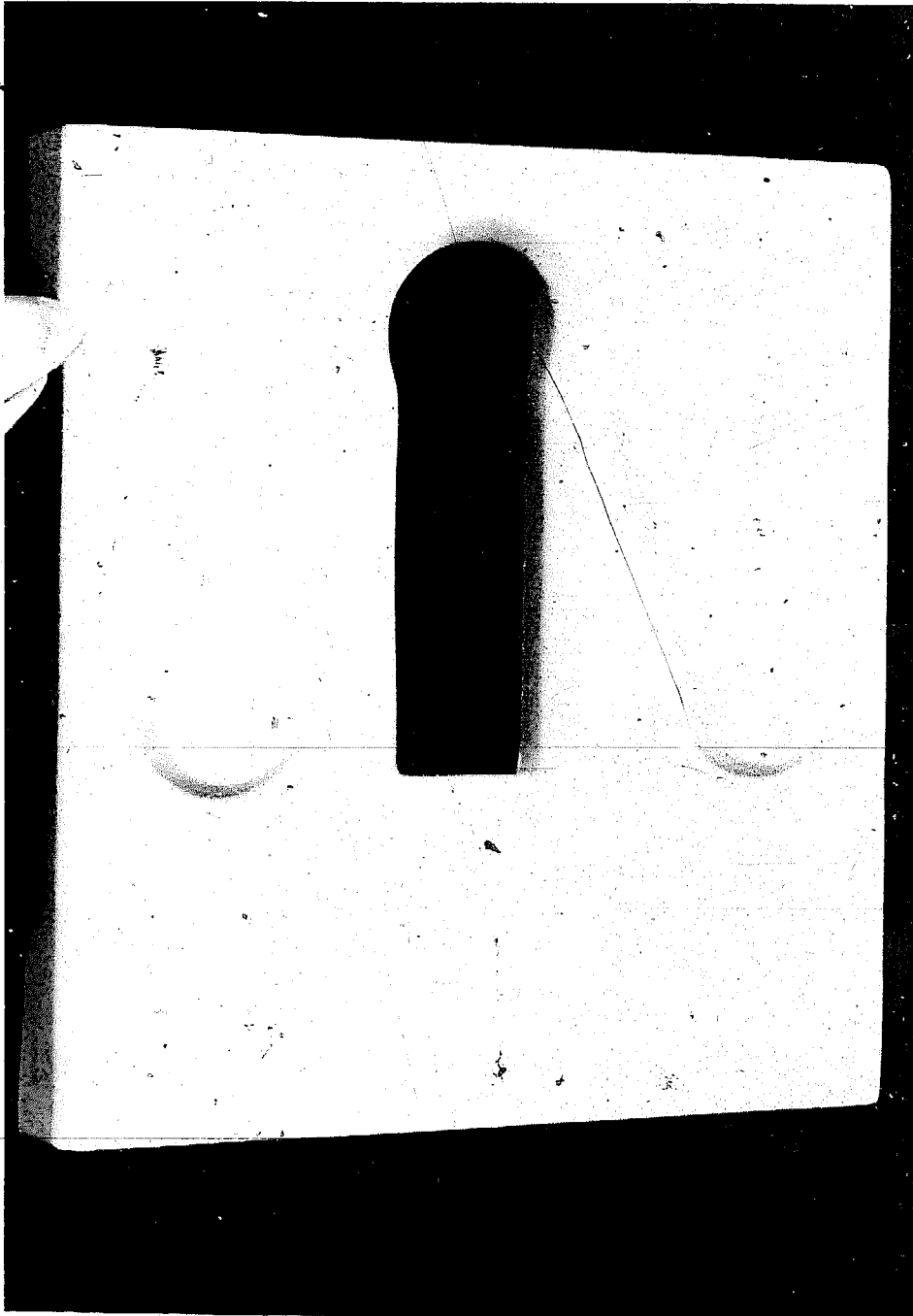


Figure 7. Glass-fiber-reinforced plastic cover for cover slab for VIP latrines (Kenya).

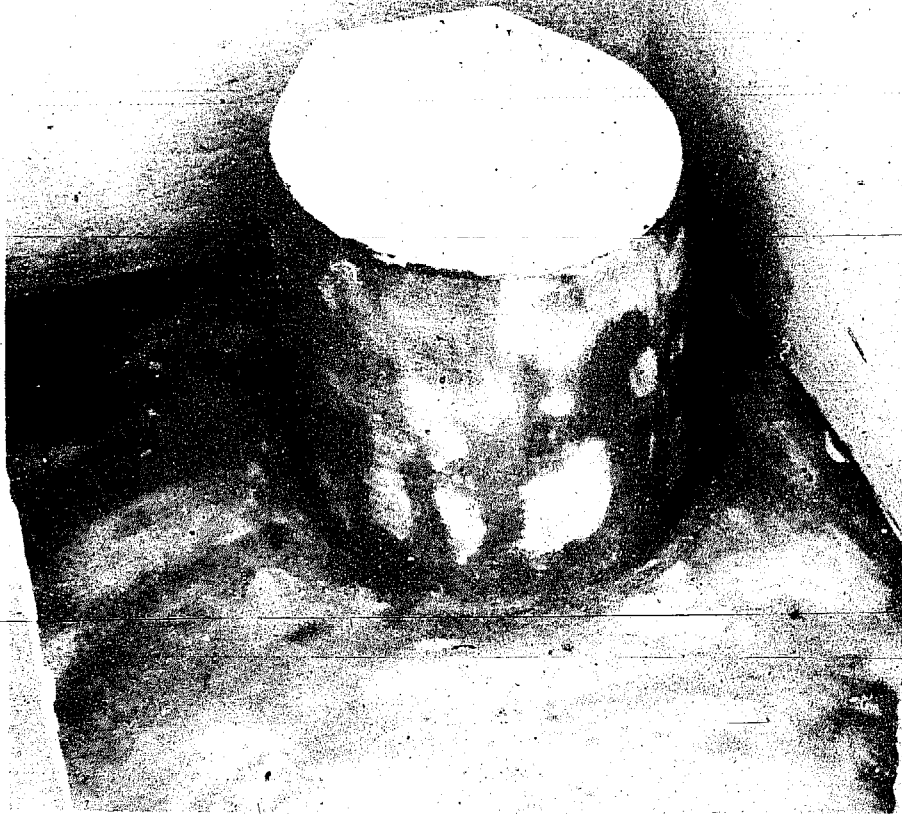


Figure 8. Glass-fiber-reinforced plastic, pedestal seat for VIP latrine (Brazil).

Superstructure design

24. The function of the superstructure of any type of latrine is to provide the user with privacy, comfort and protection from the elements. There are two additional functions in the case of VIP latrines: (a) to provide sufficient shade over the squat-hole so that newly emergent flies are not attracted to leave the pit via the squat-hole; and (b) to channel air through the squat-hole and up the vent pipe, in order to control both flies and fecal odors.

25. Provided the superstructure is able to perform these functions, its design details are relatively unimportant from a strictly technical point of view. The superstructure can be built in a wide variety of forms and from a wide variety of materials [Figures 9 (a) through 9 (d)]. In urban areas materials such as brick, blockwork or ferrocement are often used; the roof can be tiled or made from a thin concrete slab, corrugated steel or asbestos cement sheet. In rural areas, it is generally more appropriate to use local materials such as mud and wattle, thatch or sun-dried earth blocks; the roof is often made from thatch. The design adopted in any one locality depends largely on social preference and the availability of materials; in general, the superstructure form should be architecturally similar to the local houses, and this principle normally determines what materials are used. In this way not only are local sensibilities taken into account and so not offended, but (especially in rural areas) traditional housebuilding skills can be used and the householder knows how to repair the superstructure, for example, after damage during the rainy season.

26. **Latrine entrance.** Traditionally the latrine is entered through a doorway, with the door providing the user with privacy. It is very important that the door remains closed while the latrine is not in use; if it is left open, any newly-emergent flies in the pit will be presented with an alternative source of bright light and they may not therefore try to escape via the vent pipe, but leave the latrine via the squat-hole and superstructure. Fly control, which is one of the principal advantages of VIP latrines, therefore becomes ineffective. Self-closing doors can be used (a counterweight attached to the top of the door via a rope and pulley is sufficient for this purpose, as shown in the early example from the USA in Figure 10). Alternatively, the latrine should be locked on the outside; this is often done by the users in order to prevent casual use of the latrine by unauthorized people such as passers-by or neighbors without latrines. If doors are used then there should be a sufficient air gap (equivalent to at least three times the cross-sectional area of the vent pipe) at the top^{13/} of the door to maintain ventilation. In Zimbabwe^{14/} it was found that doors were undesirable not only because they were frequently left open with

^{13/} The air space could be provided (at least partially) at the bottom of the door, but this may be socially unacceptable if the latrine user's feet can be seen from the outside.

^{14/} P.R. Morgan and D.D. Mara (1982). **Ventilated Improved Pit Latrines: Recent Developments in Zimbabwe.** TAG Working Paper No. 2. The World Bank.

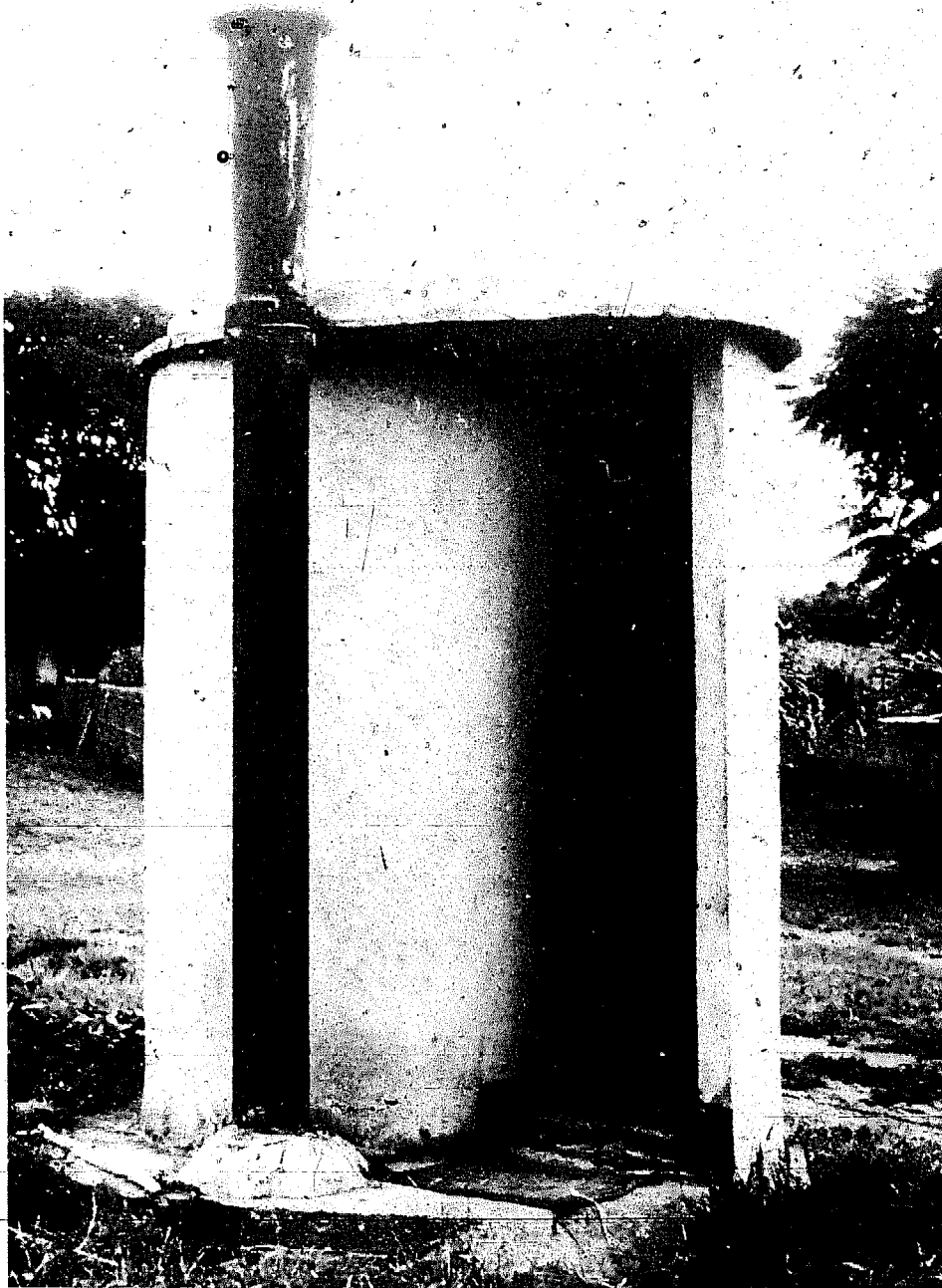


Figure 9 (a). Ferrocement spiral VIP latrine superstructure (Zimbabwe).



Figure 9 (b). Brick spiral VIP latrine superstructure with thatched roof (Zimbabwe).



Figure 9 (c). Mud and wattle VIP latrine superstructure with thatched roof (Zimbabwe).

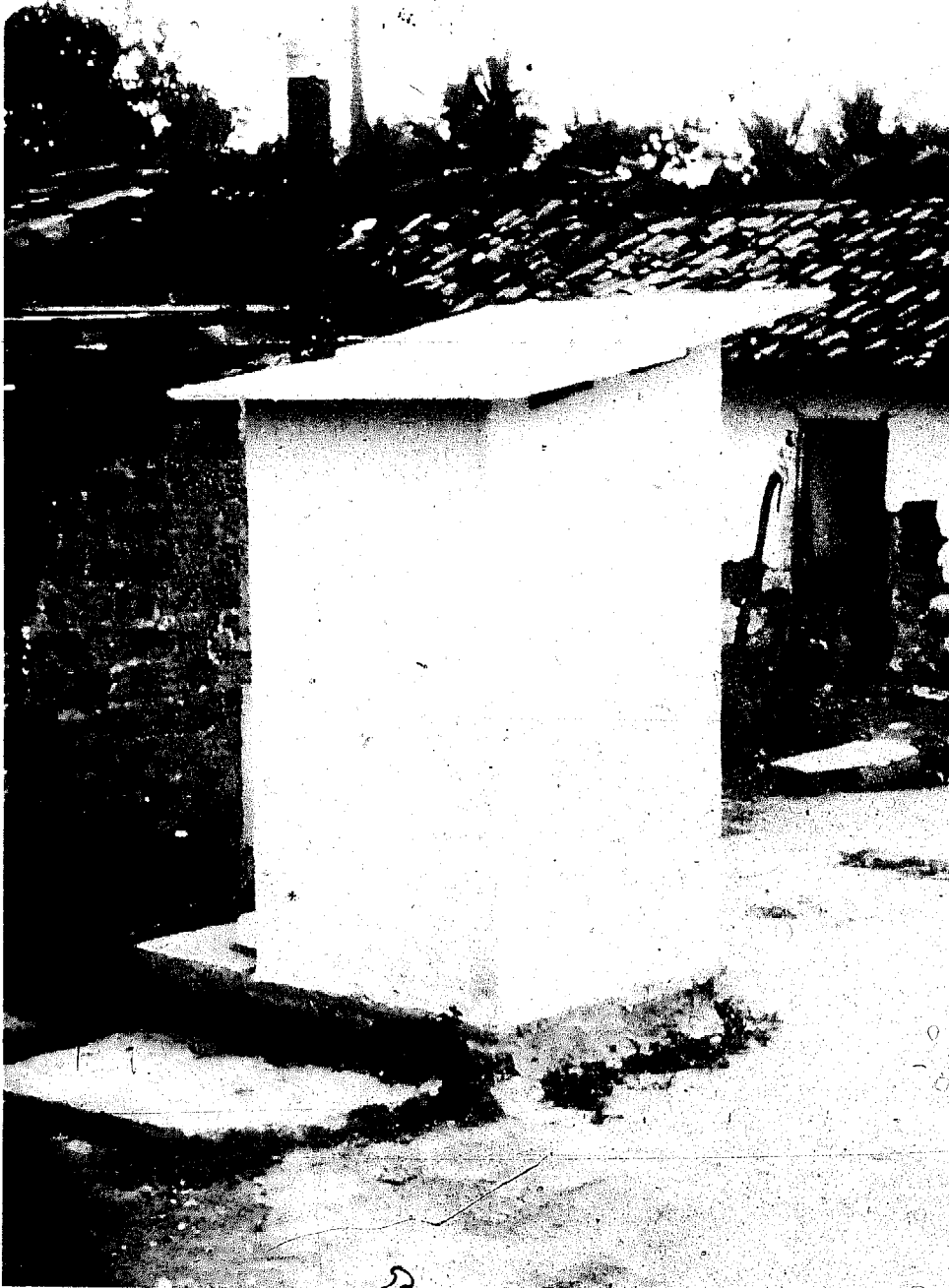


Figure 9 (d). Precast ferrocement VIP latrine superstructure (Brazil).

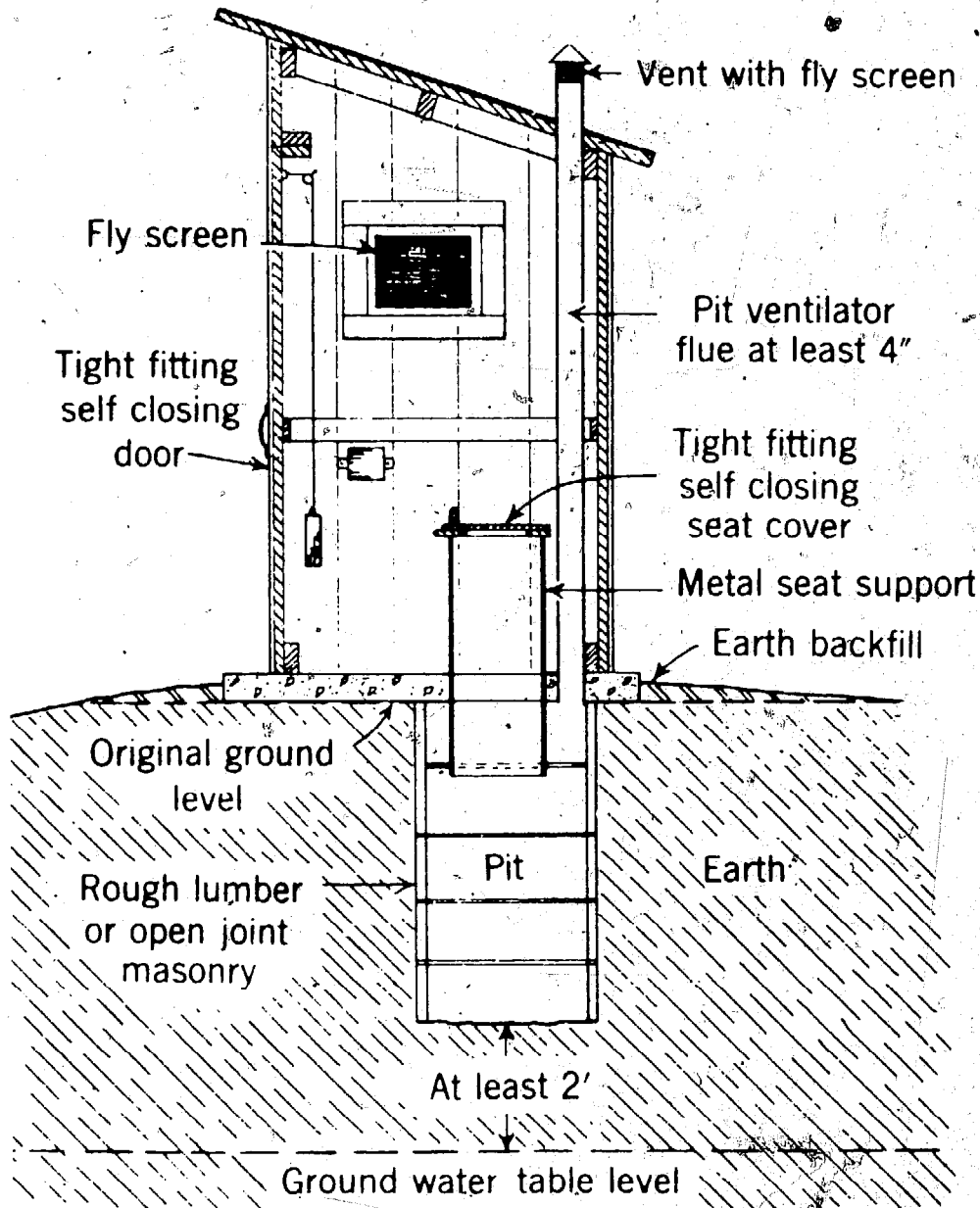


Figure 10. Early pit latrine design from the United States showing self-closing door. [Reproduced by courtesy of John Wiley Inc, from F.B. Wright, "Rural Water Supply and Sanitation", 1939.]

resultant poor fly-control, but also because wood is expensive, hinges rust and occasionally the doors were removed and chopped up for firewood. The superstructure was then redesigned with a spiral form to avoid the need for doors [Figure 9 (see page 22); see also Annex II].

Vent pipe design

27. Vent pipes of a wide variety of different materials have been used successfully: for example, asbestos cement (AC), polyvinyl chloride (PVC), unplasticized PVC (uPVC), bricks, blockwork, cement-rendered reeds, cement-rendered hessian supported on steel mesh, and even anthill soil; large diameter bamboo with the cell dividers removed could also be used. Methods for the construction of cement-rendered reed and hessian pipes and other essentially rural vent pipes are described in paragraphs 30-32. Whatever material is used, its durability (including corrosion resistance), availability, cost and ease of construction are important factors. Thus, vent pipes made, for example, from thin galvanized steel sheets are not recommended as they are prone to corrosion, especially in humid areas. PVC pipes become brittle when exposed to high sunlight intensities, and thus it is better to use PVC pipe made with a special stabilizer to prevent damage by ultra-violet radiation; however, this grade of PVC may not be generally available.^{15/} Cost is particularly important in rural VIP latrines; for example, the use of a PVC pipe, rather than a cement-rendered reed pipe, more than doubles the cost of a mud and wattle latrine in rural Zimbabwe.^{16/}

28. **Length.** The vent pipe should be sufficiently long so that the roof does not interfere with the action of the wind across the top of the vent pipe. With flat roofs, the top of the vent pipe should be at least 500 mm higher than the roof, and in the case of sloping roofs the vent pipe should also be 500 mm above the highest point of the roof. When the roof is made from thatch and shaped conically, the vent pipe should be at least as high as the apex of the roof.

29. **Diameter.** The internal diameter of the vent pipe depends on the required venting velocity necessary to achieve the recommended ventilation

15/ In Zimbabwe it has been found that PVC pipe manufactured to Central African Standard K21, "Unplasticized polyvinyl chloride pressure pipe", (Standards Association of Central Africa, Harare, 1971) performs more satisfactorily than that manufactured to the less stringent requirements of British Standard BS 3505 or ISO Standard 3127. See also R.W. Doughty, **UPVC pipes and fittings for hot climates**, in: Institution of Public Health Engineers 1982 Handbook, London.

16/ P.R. Morgan and D.D. Mara (1982). **Ventilated Improved Pit Latrines: Recent Developments in Zimbabwe.** TAG Working Paper No. 2. The World Bank.

rate of 20 m³/hr^{17/}, and this in turn depends on such factors as the internal surface roughness of the pipe and its length (which determine the friction losses), the head loss through the flyscreen and squat-hole mosquito trap (if any), and the wind direction. Thus cement-rendered reed vent pipes, for example, need to have a much larger diameter than AC or PVC pipes since their internal roughness is considerably greater; brick vent pipes, which have a square cross-section, also need to be larger not only because the roughness is greater but also because a square cross-section is inherently less efficient than a circular one in inducing updraft.^{18/} Current recommendations for the minimum internal size of vent pipes are as follows:

AC or PVC	150 mm diameter
Brick	230 mm square
Cement-rendered reed or hessian (and other rural types)	230 mm diameter

In exposed locations where wind speeds are greater than 3 m/s, the minimum diameter of AC and PVC pipes may be reduced to 100 mm, and to 200 mm in the case of "rural" vent pipes.

Fabrication of rural vent pipes

30. **Cement-rendered reed vent pipes.** Local reeds, approximately 1 cm diameter, are tied together with wire or string to form a mat measuring 2.5 m by 1 m. The mat is then rolled around four or five rings of green saplings to form a tube of some 30 cm external diameter. The flyscreen is then fixed to one end. Cement mortar (1 part cement, 3 parts sand) is applied to the tube along its entire length but only around half its circumference; when this has hardened, the vent pipe is fixed in position with the mortared half next to the latrine superstructure and the other (outer) side then plastered with cement mortar. Thin poles or bamboo sticks may be used instead of reeds. Larger bamboo sticks, split longitudinally into 1 - 2 cm wide strips may also be used.

31. **Cement-rendered hessian and wire-mesh vent pipes.** Spot-welded mild steel mesh (4 mm bars at 100 mm centers), 2.5 m long and 0.8 m wide, is rolled into a tube to give an internal diameter of approximately 25 cm. Hessian or jute fabric is then tightly stitched around the outside of the tube, and the flyscreen fixed to one end by stitching with string or thin galvanized wire. Cement mortar (1 part cement, 2 parts sand) is then applied by brush to the hessian surface in thin layers, to a final thickness of at least 1 cm. The vent pipe is then fixed in place.

^{17/} B.A. Ryan and D.D. Mara, **Pit Latrine Ventilation: Field Investigation Methodology**, TAG Technical Note No. 4; and **Ventilated Improved Pit Latrines: Vent Pipe Design Guidelines**, TAG Technical Note No. 6.

^{18/} D.R. Wills, E.W.G. Dance and G.T. Blench (1959). **The Design and Performance of Natural Flue Terminations**. Gas Council Research Communication No. GC61. London: Institute of Gas Engineers.

32. **Anthill soil vent pipes.** Well-kneaded anthill soil is rolled into "sausages", approximately 10 cm in diameter and 90 cm long, which are made into circles of approximately 28 cm internal diameter. The vent pipe is constructed in situ from these circles; vertical reinforcement with short lengths of reed or thin bamboo (or other suitable material) can be driven in between adjacent circles as construction proceeds. When the vent pipe has been built to a height of 2.5 m, its external surface is smoothed off by adding more soil; the flyscreen is attached to the upper end and then a thin coat of cement mortar (1 part cement, 6 parts sand) applied.

33. **External surface preparation.** In areas where the mean wind speed is less than 0.5 m/s, the external surface of the vent pipe should be painted black in order to increase the absorption of solar radiation and, thus the magnitude of the thermally-induced venting velocity. In areas where the mean wind speed is above 0.5 m/s the color of the vent pipe is not important.

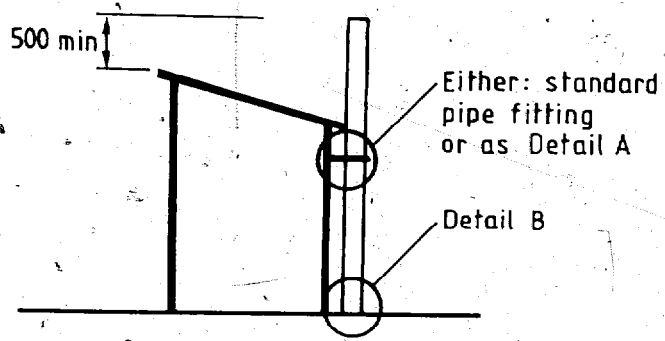
34. **Location.** The latrines should be located at least 2 m away from overhanging branches and anything else that might impede the action of the wind across the top of the vent pipe. The vent pipe itself should be located on the windward side of the superstructure, as also should any openings (doorways, windows, gaps between the roof and walls). If, however, it is impossible to have both vent pipe and any openings on the windward side, at least one of them must be (and this should preferably be the openings). It is extremely important to avoid openings on opposite sides, as this would significantly reduce the pressure differences causing updraft in the vent pipes. In latrines designed with doors the minimum size of ventilation opening(s) should be at least three times the cross-sectional area of the vent pipe (to allow for head losses in the superstructure).

35. In general, the vent pipe should be located on the outside of the superstructure, since it is more difficult and expensive to ensure a rainproof and wind-tight seal between the roof and a vent pipe going through it. Moreover, in very sheltered areas, thermally-induced ventilation may be more important than that due to the wind, and thus the vent pipe must be placed outside the superstructure on its sunny side and painted black. However, in urban areas especially, external vent pipes could be subject to damage by vandals, although, as yet, there have been no reports of this happening.

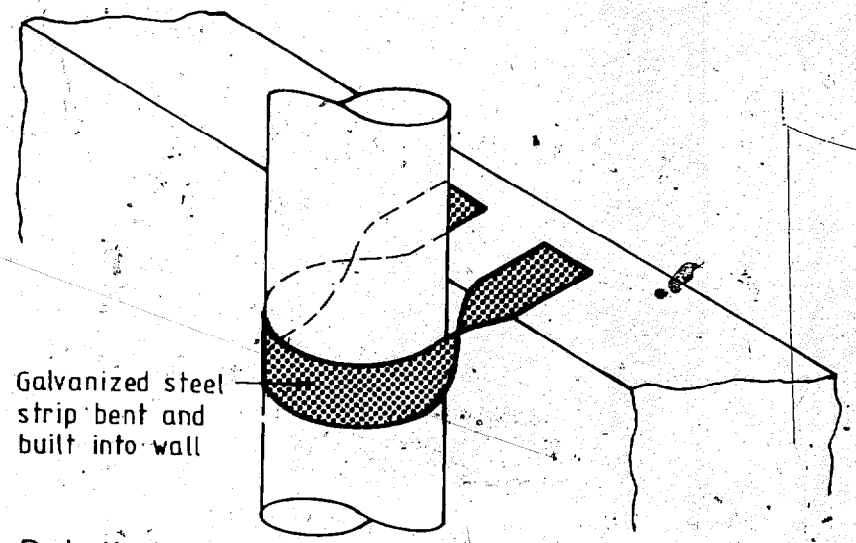
36. The vent pipe must be rigidly fixed to the superstructure and the cover slab; design recommendations are given in Figure 11.

37. **Flyscreen specification.** The purpose of the flyscreen is to prevent the passage of flies and mosquitoes; therefore the mesh aperture must not be larger than 1.2 mm x 1.5 mm (smaller apertures are not recommended as they will result in decreased ventilation rates, due to increased frictional losses). The flyscreen must be made of corrosion-resistant material that is able to withstand intense rainfall, high temperatures and strong sunlight. PVC-coated glass-fiber screens have been extensively used in Zimbabwe as they are inexpensive (around US\$ 0.50 per latrine), but after five years or so they become very brittle and susceptible to damage by birds and lizards. It is preferable to use stainless steel screens^{19/} which last indefinitely;

19/ For example, 16 mesh, 28 s.w.g. screening.

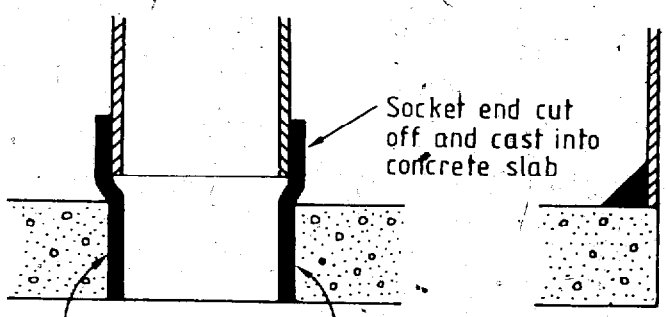


General arrangement



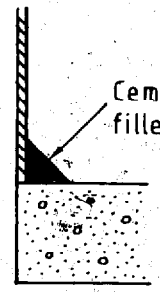
Galvanized steel strip bent and built into wall

Detail A
Method of fixing vent pipe to superstructure



PVC pipe roughened with solvent cement and sand

Socket end cut off and cast into concrete slab



Cement mortar filler

Detail B
Alternative methods of fixing vent pipe to slab

Figure 11. Recommendations for fixing vent pipe to cover slab and superstructure.

even though they are more expensive (US\$ 25 per m² ex works), the cost is small (less than 5%) in comparison with the total cost of the latrine.

38. It is important to ensure that the flyscreen is tightly fixed to the top of the vent pipe in order to prevent access by insects. Design details are shown in Figure 12(a) and (b). When the flyscreen is in place there should be no obstruction to the wind flow across the top of the vent pipe.

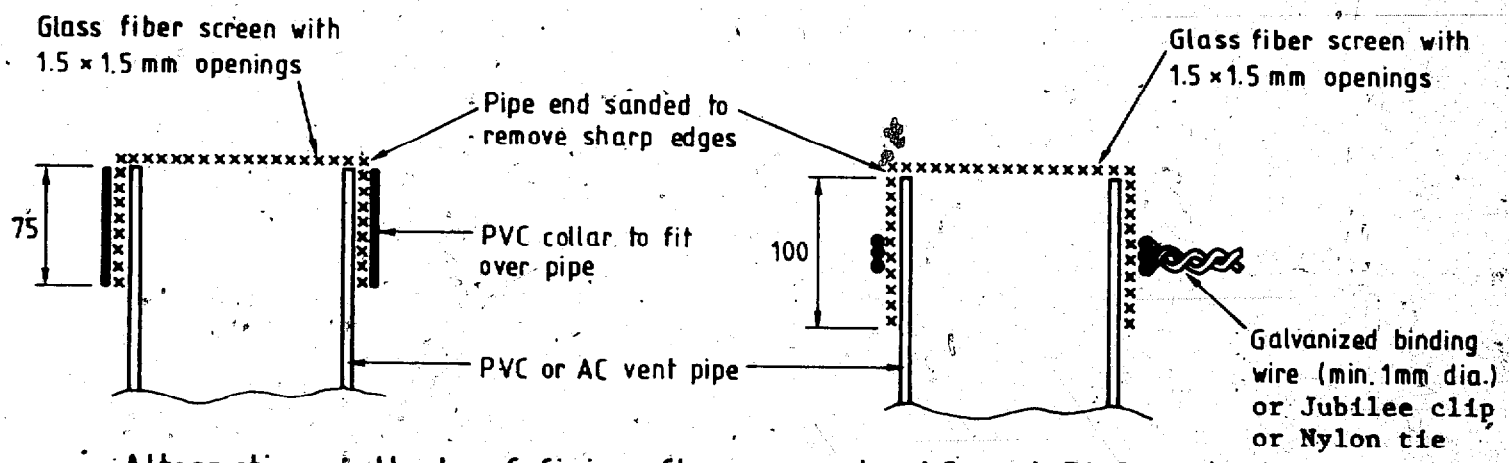
Relocation and emptying of pits

39. When single-pit VIP latrines become full, there are two options available to their owners: the construction of a new latrine on an adjacent site, or emptying the existing (full) latrine. In rural areas, construction of a new latrine, reusing as much as possible from the old latrine (for example, the cover slab and vent pipe), is generally the preferred solution, as space for the new latrine is usually available. Manual emptying poses health risks due to the excreted pathogens that may be present in the fresh fecal material at the top of the pit, and in any case this is often not a socially acceptable task; and mechanical emptying is not normally feasible in rural areas. In urban areas manual emptying has the same disadvantages, but mechanical emptying might be feasible, especially if the pit were wet, as the procedure is essentially similar to desludging septic tanks (although the solids at the bottom of deep pits may be highly compacted and therefore difficult to remove by the standard vacuum equipment used to desludge septic tanks). Dry pits are considerably more difficult to desludge mechanically than wet pits (see paragraph 52). A better solution in urban areas is to use single-pit VIP latrines with soakaways (paragraph 42) or alternating twin-pit VIP latrines (paragraph 45).

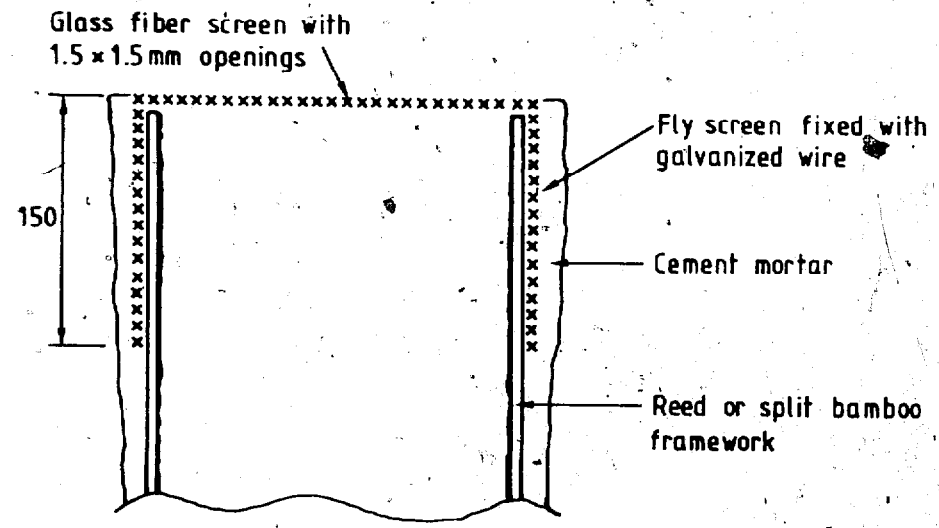
Double and multicompartment designs 20/

40. A recent development in southern Zimbabwe, where there is a strong sociocultural preference for separate latrines for male and female members of the household, is the use of double compartment VIP latrines of the type shown in Figure 13. In stable soils each compartment may have its own pit, but in unstable soils a common pit with a fully mortared brick dividing wall is used. In rural areas especially, this type of latrine is generally too expensive for one household but, in order to reduce costs to an acceptable level, neighboring households have been willing to share a single latrine of this type, with the men from both households using one of the compartments and the women the other.

41. Multicompartment VIP latrines have been developed for schools and other institutions. These are essentially the same as the double compartment unit but of course with more compartments. The number of compartments depends on the number of users, with a design guideline of 10 persons per unit (20 persons per unit in non-residential institutions, such as schools). The number of users per unit can be increased to 30 if soakaways are provided as discussed on the next page.



Alternative methods of fixing fly screen to AC and PVC vent pipes



Method of fixing fly screen to a 'rural' vent pipe

Figure 12 (a). Recommendations for fixing flyscreen to vent pipe.

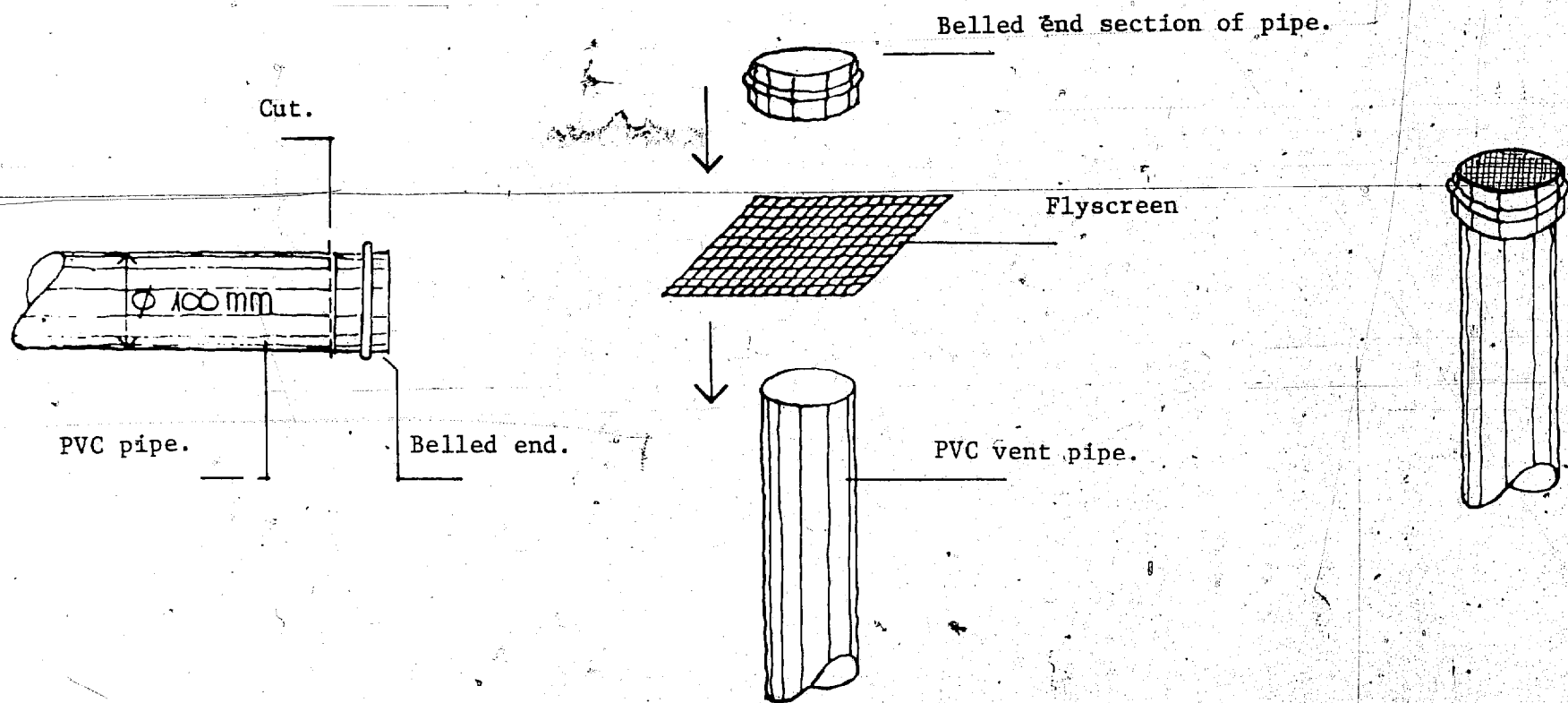


Figure 12 (b). Details for fixing flyscreen to Ventpipe (Brazil).
 (The belled end of 100 mm PVC pipe is cut off and used as a collar to hold the flyscreen in place.)



Figure 13. Double-compartment VIP latrine (Zimbabwe).

Designs with soakaways ^{21/}

42. Another recent development in Zimbabwe has been VIP latrines with adjacent soakaways (Figure 14). These have been designed to increase the pit life in peri-urban areas where the number of people using a single latrine can be as high as 20, or even, exceptionally, 30. The latrine pit, including its base, is completely sealed with cement mortar in stable soils or with fully mortared brickwork in unstable soils. At a point 2.25 m above the pit base a 75 mm diameter PVC pipe with a sanitary tee is installed which leads to an adjacent soakaway which is at least 1 m away from the pit. The soakaway has a diameter of 1.5 m and a depth of 2 m; it is lined with unmortared bricks to a depth of 1.4 m. At this depth a reinforced concrete cover slab is placed on the bricks and the remaining space above it backfilled.

43. This type of pit latrine (which essentially resembles an aquaprivy with a vent pipe in place of the drop-pipe) has been used only in Zimbabwe for the last seven years; thus, it has not been possible so far to estimate its total useful life. Early indications are that it is performing very well in periurban areas. With regular desludging of the pit (say, every five years), it may be expected to last for at least 30 years.

44. An even more recent development has been to discharge the effluent from a line of VIP latrines into a short small bore sewer (75 mm diameter, laid at a gradient of 1 in 200) which leads to a communal soakaway. This is a very useful option in areas where there is insufficient space on each plot for an individual soakaway. Moreover, it is possible to upgrade this type of latrine to a low-volume cistern-flush toilet for added user convenience.

Alternating twin-pit latrines

45. Alternating twin-pit VIP latrines (Figure 15) have two separate pits, each with their own vent pipe, but only one superstructure. The cover slab within the superstructure has two squat-holes, one over each pit. Only one squat-hole and pit are used at a time. When this pit is full, generally after one to three years, its squat-hole is covered up and the second pit put into service; after a further period of one to two years, when this pit is full, the contents of the first pit are removed to enable it to be used again. This alternating cycle is repeated indefinitely. This type of VIP latrine is thus a permanent sanitation facility suitable for use in urban areas where there is insufficient space on each housing plot for two or more single-pit VIP latrines. Alternating twin-pit latrines have even been "retrofitted" to replace existing in-house bucket latrines and so provide an indoor sanitation facility (Annex II). Many of the design details for alternating twin-pit VIP latrines are the same as for the single-pit type; specific differences are described on page 37.

^{21/} P.R. Morgan and D.D. Mara, **VIP Latrines: Zimbabwean Brick Designs**, TAG Discussion Paper, TAG/DP/01, World Bank. (Publications in the TAG Discussion Paper series are not routinely distributed to the recipients of TAG Working Papers and Technical Notes, but are available from the Project Manager on request.)

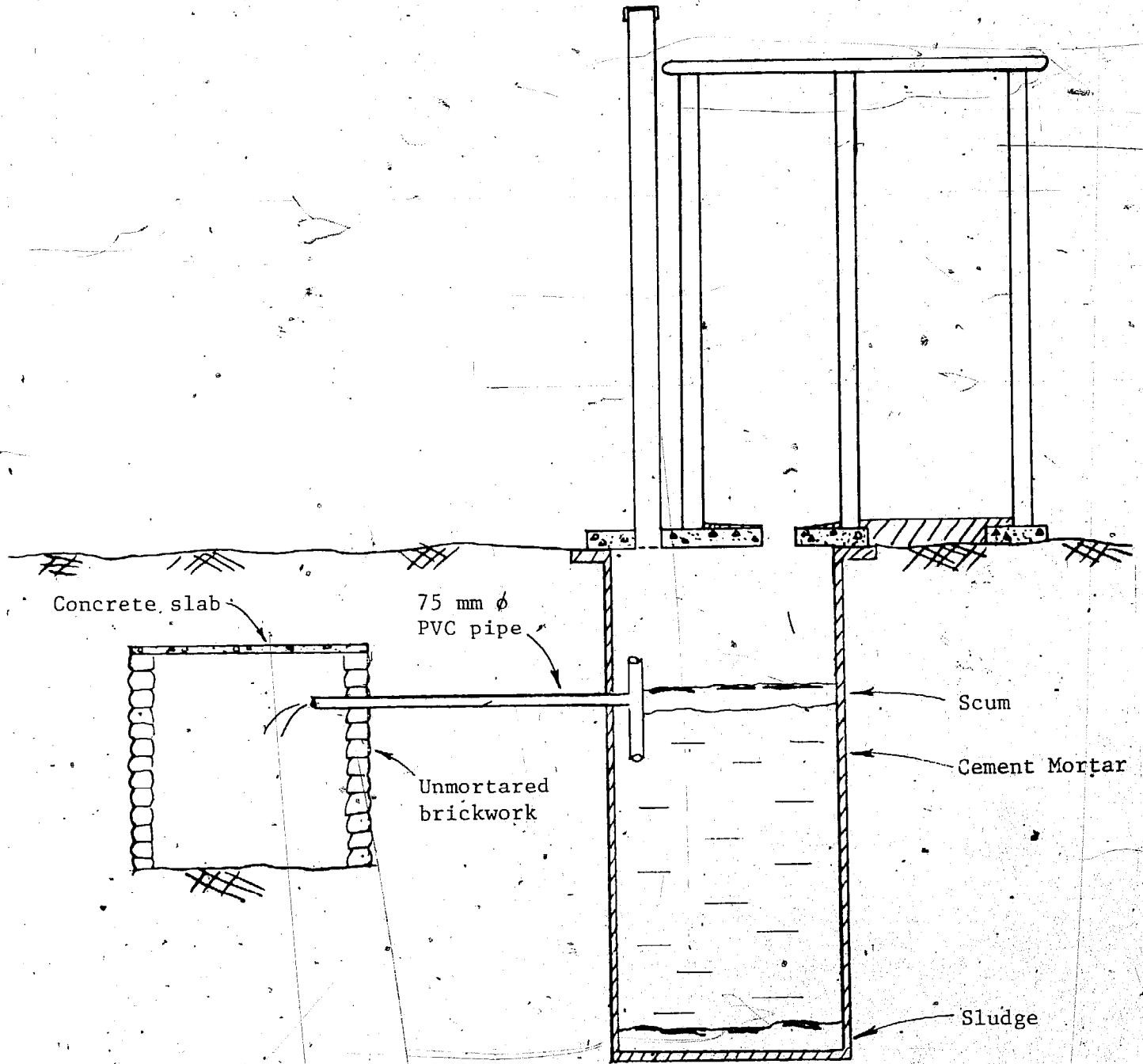


Figure 14. Schematic diagram of a VIP latrine with soakaway.



Figure 15. Alternating twin-pit VIP latrine (Tanzania).

Pit function and design

46. The function of the pit is to store the excreta until they can be safely removed. With the sole exception of a few ova of the human roundworm, *Ascaris lumbricoides*, all excreted pathogens die within 12 months at temperatures above 20°C.^{22/} In most developing country climates, one year is therefore the minimum storage requirement for each pit. Usually, to provide some degree of flexibility in the design of latrine emptying schedules (especially to allow for breakdown of any mechanical equipment and for seasonal problems of access), a minimum period of two years is specified. Calculation of the necessary pit volume (paragraph 13) shows that in most cases the pits are quite small: for example, for a family of 10 each pit should have an effective volume of only 1.2 m³, assuming a solids accumulation rate of 0.06 m³ per person per year only and a two-year storage time. Consequently the pits can be much shallower (often less than 1 m total depth) than in the case of single-pit VIP latrines, and this may be a significant advantage if groundwater pollution must be avoided (paragraph 58), or if soil conditions are difficult (for example, if there is shallow, unpickable rock).

47. The pit shape is normally rectangular and the pits may extend either to each side of the superstructure or to its rear (Figure 16). The pits are lined as necessary (paragraph 16), with any suitable locally available material (such as brick, concrete or cement-stabilized soil blocks) being used to build up the partition wall between the two pits. This partition wall must have a good foundation and be fully mortared to prevent any cross-flows of air between the pits which would interfere with the ventilation and might cause odors to enter the superstructure. For the same reason, the cover slab must be firmly bedded with mortar on the partition wall, as well as on the brick or blockwork collar.

Cover slab design

48. The cover slab is usually made in reinforced concrete in three or more sections (Figure 17): a central section with two squat-holes and holes for the two vent pipes, and at least two removable covers (one for each pit) to allow access for emptying. The edge details of the cover slab sections shown in Figure 17 are important as there must not be any gaps between the central and outer sections to allow the escape of either flies or odors. A lime mortar, or a weak cement mortar if lime is not available, should be used to bed the removable slab sections to the central section and to the collar. As with single-pit VIP latrines, the cover slab should be sloped towards each squat-hole (paragraph 22).

Superstructure and vent pipe design

49. The superstructure and vent pipe design details are essentially similar to those for single-pit VIP latrines (paragraphs 24-38). Alternating twin-pit VIP latrines have been installed inside existing houses, with the

22/ R.G. Feachem, D.J. Bradley, H. Garelick and D.D. Mara (1983). **Sanitation and Disease: Health Aspects of Excreta and Wastewater Management**, Chichester: John Wiley.

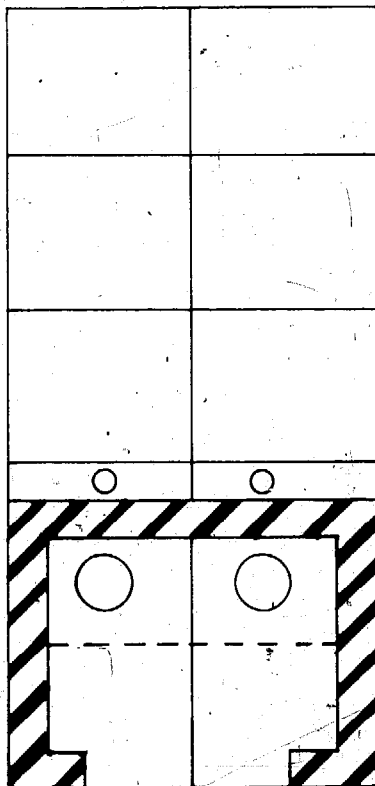
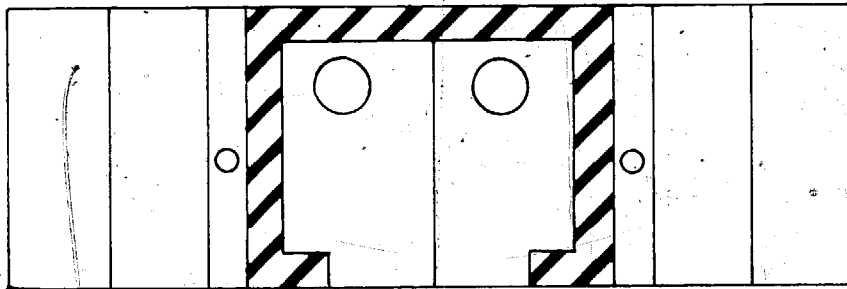


Figure 16: Alternative pit geometries for alternating twin-pit VIP latrines.

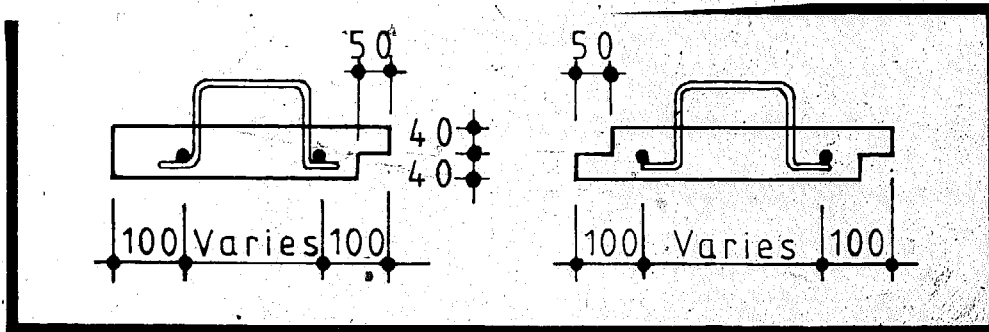
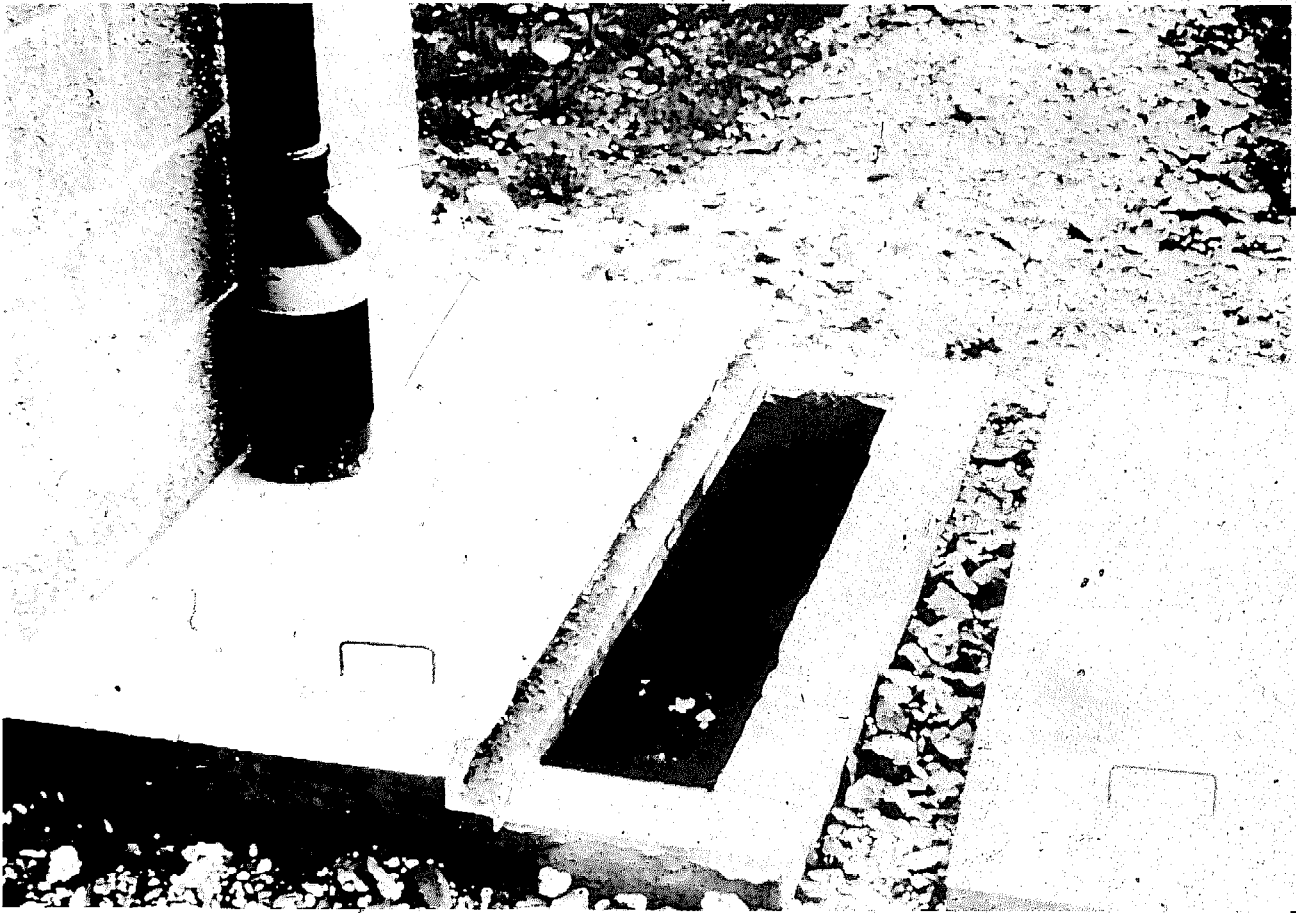


Figure 17. Coverslab details for alternating twin-pit VIP latrines.

pits accessible from outside (Annex II); in some cultures such an arrangement may be socially preferable to external superstructures.

Multicompartment units

50. Multicompartment alternating twin-pit VIP latrines have been developed in Ghana for use in rural institutions such as schools and as a village communal sanitation facility (Figure 18). All pits, except the two end ones, serve two squat-holes in adjacent compartments; for good odor control it has been found necessary for these pits to be ventilated by a 150 mm diameter vent pipe. The two end pits, being only half the size of the others and serving only one squat-hole, are ventilated by 100 mm diameter pipes. In all other respects multicompartment units are designed in the same way as single units.

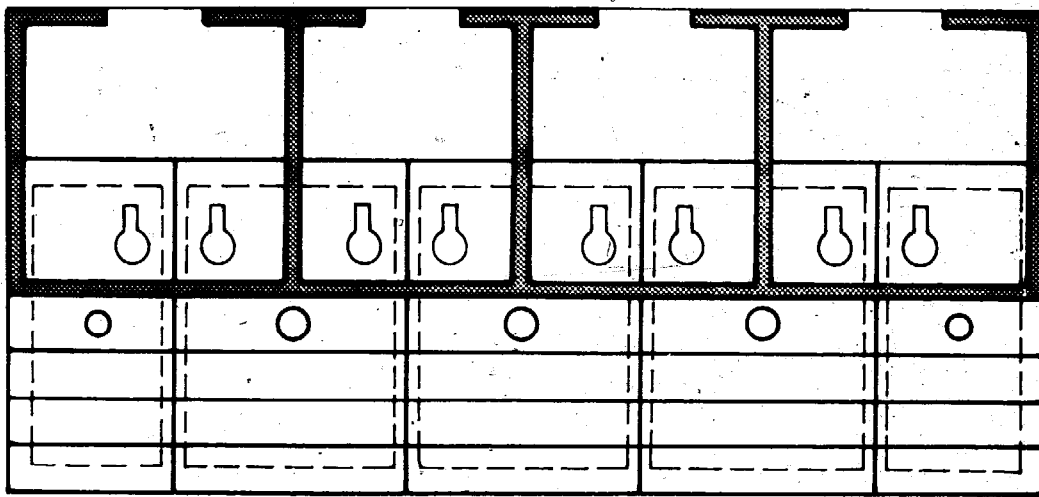
Emptying of pits

51. Manual removal of the humus-like material in the pits, which is at least two years old, presents no health risk as all the excreted pathogens are non-viable, except for a few *Ascaris* ova. Discussions with the intended beneficiaries (or their leaders) prior to the installation of alternating twin-pit VIP latrines may indicate that they consider the handling of the pit contents to be a socially-abhorrent task. Once however the two-year transformation of fresh excreta to harmless humus has been witnessed by the users, their attitudes may change. If this does not happen, then pit emptying is best left to the municipality (or other appropriate local government agency) for either manual or mechanical emptying by its employees. The contents so removed can be disposed of in sanitary landfills or, preferably, reused on agricultural land.

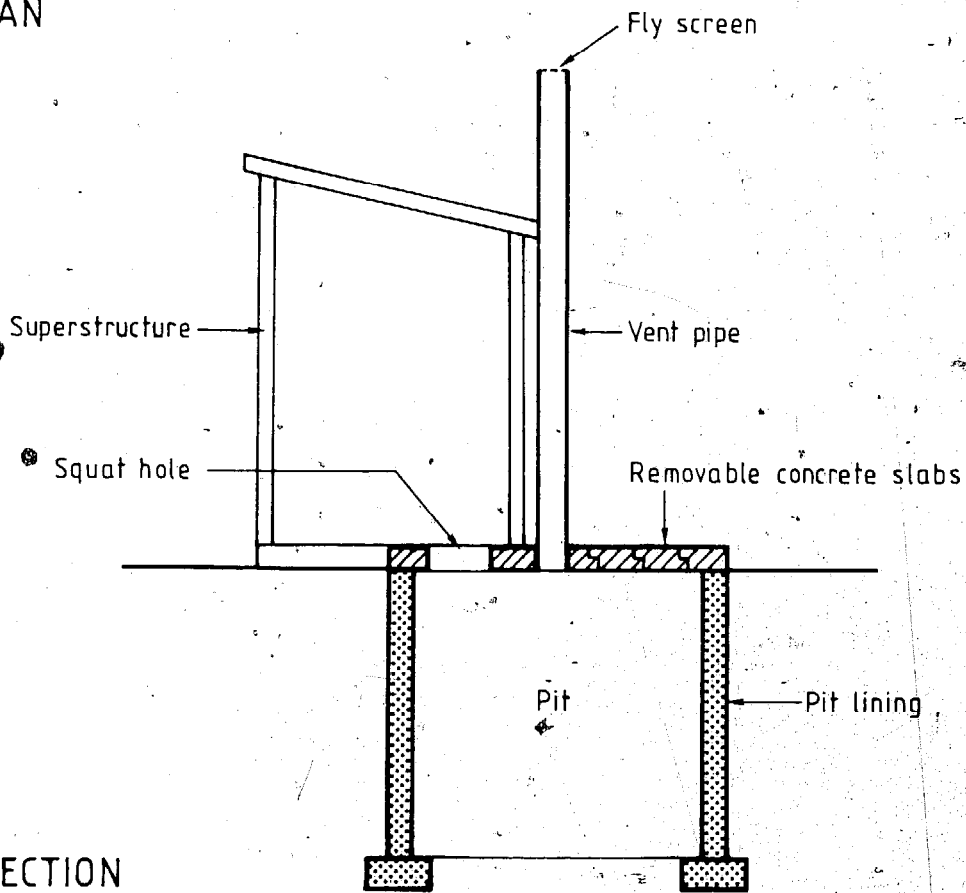
52. Mechanical emptying of wet pits is easily done with standard septic tank emptying equipment, but removal of dry materials presents more difficulty. Since most alternating twin-pit VIP latrines have shallow pits (paragraph 46), dry pits will be common. Research sponsored by TAG and the International Reference Centre for Wastes Disposal^{23/} indicates that air-drag systems are the only currently available option for emptying dry pits; recent field trials in Botswana have shown that suitable equipment is now available for this purpose.^{24/}

23/ P.M. Hawkins (1982). **Emptying on-site excreta disposal systems in developing countries: an evaluation of the problems.** IRCWD News No. 17. Duebendorf, Switzerland: International Reference Centre for Wastes Disposal.

24/ A report on these trials, held in Gaborone during October 1983-February 1984, will shortly be issued by TAG and the International Reference Centre for Wastes Disposal, Duebendorf, Switzerland. See also BRE Information Paper No. 84: **BREVAC: a Mechanised Method of Emptying Sanitation Chambers**, (Building Research Establishment, Watford, England, 1984), which gives a brief description of one of the vacuum tankers tested in these trials.



PLAN



SECTION

Figure 18. Multicompartment alternating twin-pit VIP latrine (Ghana).

APPLICABILITY AND CONSTRAINTS

Housing density

53. Single-pit VIP latrines are suitable for use in rural areas and low-density urban areas up to about 300 people per ha. It is difficult to be more precise in general terms, as local factors, such as average household size, housing design, plot layout and area, have such a large influence. At higher densities alternating twin-pit VIP latrines may be feasible, but other options--such as small bore sewers--may be a more appropriate solution.

Water supply service level

54. In areas where water use is low (say, less than 30 lcd) and where water has to be hand-carried from public standpipes or communal wells, VIP latrines (of whatever type) are a technically feasible sanitation option as they require no water for their operation, other than minimal amounts for cleansing.

Ground conditions

55. **Soil permeability.** Soils with permeabilities below 2.5 mm per hour (for example, expansive clays) are unsuitable for pit latrines as the liquid fraction of the excreta is unable to infiltrate into the soil (paragraph 15).

56. **Rock and unpickable soils.** The occurrence of rock or unpickable soil within 2 m of the ground surface generally militates against the use of single-pit VIP latrines. Shallow alternating twin-pit latrines, with the cover slab raised above ground level if necessary, are preferable in these circumstances.

57. **Groundwater table.** Wet pits have the advantage over dry pits that they last longer, as their rate of solids accumulation is lower, but they can pose problems of mosquito breeding and groundwater pollution. Experience in Zimbabwe has shown that if the groundwater table is within 300 mm of the ground surface, the ventilation performance of VIP latrines is satisfactory provided that the cover slab is raised 300 mm above ground level.

Groundwater pollution

58. The extensive literature on groundwater pollution from on-site sanitation systems has recently been critically reviewed.^{25/} This review highlights the need for a thorough understanding of the local soil and

^{25/} W.J. Lewis, S.S.D. Foster and B.S. Drasar (1982). **The risk of groundwater pollution by on-site sanitation in developing countries: a literature review.** Report No. 01/82. Duebendorf, Switzerland: International Reference Centre for Wastes Disposal. (An executive summary of this report appears in IRCWD News No. 16, January 1982.)

hydrogeological conditions before any prediction of the risk (if any) of groundwater pollution from on-site sanitation systems can be made. Bacteria and viruses are the only excreted organisms of importance in groundwater pollution and the depth of soil above the groundwater table ("the unsaturated zone") is the most important line of defence against them. Under most conditions a depth of 2 m of unconsolidated material (silt, sand) is sufficient to avoid groundwater pollution (yet, of course, by their very excavation single-pit VIP latrines remove 2 - 3 m of the unsaturated zone, and alternating twin-pit latrines 1 - 2 m). If, in any given locality, the soil and hydrogeological conditions are such that groundwater pollution from VIP latrines will occur, three questions should be posed and answered:

- (a) Does it matter if the groundwater is polluted? If the groundwater is not being used as a source of supply (for example, via shallow wells), then its pollution is unimportant; it is better to have fecal pollution of the groundwater than fecal pollution of the soil immediately adjacent to people's houses which would result from an absence of sanitation facilities and which would cause extensive transmission of fecally-related diseases;
- (b) If the groundwater is being used as a source for supply, is it possible to modify the design of the latrine so that the groundwater is not polluted or the extent of pollution is acceptably low?^{26/} The use of a shallow twin-pit VIP latrine, rather than a deep single-pit latrine, may leave a sufficient depth in the unsaturated zone. Alternatively, a raised VIP latrine, which is provided with an "artificial" unsaturated zone of fine sand (less than 1 mm) to a depth of at least 800 mm may alleviate the pollution to an acceptable level (Figure 19);
- (c) If the groundwater is being used as a source of supply, but it is not possible to adopt the solutions indicated in (b) above, is it cheaper to use VIP latrines (or any other form of on-site sanitation) and supply water from elsewhere? In most cases the answer will be that on-site sanitation and off-site water is much less expensive than off-site sanitation and on-site water. It may be possible to supply the water from the same aquifer but via a small reticulation system and public standpipes, based on a pumped borehole sited sufficiently far upstream of the latrines that fecal pollution of the supply is either non-existent or acceptably low.

Sociocultural factors

59. VIP latrines are especially suitable when bulky anal cleansing materials are used; other sanitation technologies have difficulty in coping

^{26/} "Acceptably low" is difficult to define precisely. In general, a fecal coliform count below 10 per 100 ml may be considered reasonable.

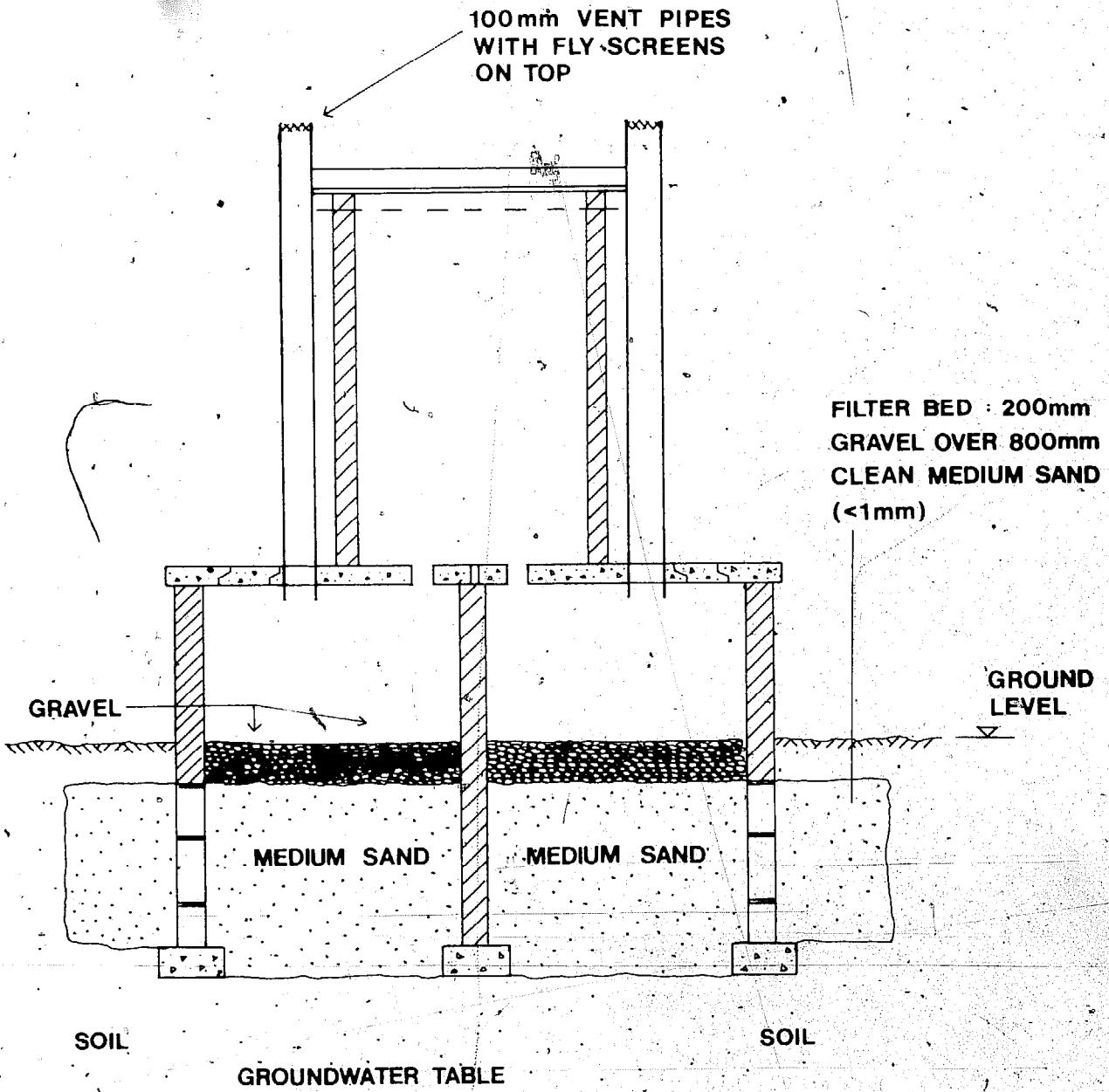


Figure 19. Raised alternating twin-pit VIP latrine with filter bed to reduce groundwater pollution (21/)

with such material. However, in areas where water is used for this purpose, usually a preferable sanitation option is the pour-flush toilet.^{27/}

60. VIP latrines can be designed for either a sitting or a squatting defecation posture (paragraph 21). The locally preferred posture should be ascertained and the latrine designed accordingly.

61. In societies where an in-house toilet is preferred, VIP latrines can still be used. Internal VIP latrines, with access to the pit from outside the house, have been built in Brazil (single-pit version) and Ghana (alternating twin-pit version); details may be found in Annex II.

62. If there is a local preference or requirement for separate facilities for male and female household members, then a design similar to that described in paragraph 40 should be adopted; sharing of this facility between adjacent households, to reduce costs, should be discussed with the community.

DESIGN SELECTION CRITERIA

63. Given that a VIP latrine of some type is the most appropriate sanitation technology for the community under consideration, the designer is faced with the question: which type of VIP latrine is the most suitable? This section discusses the selection criteria through which the designer can answer this question. The discussion assumes that all relevant sociocultural requirements have been assessed.

64. For convenience, this section is divided into two parts: Favorable and Adverse Ground Conditions. Favorable ground conditions refer to:

- (a) the soil being sufficiently permeable to permit infiltration of the liquid fraction of the excreta;
- (b) the absence of unpickable rock to the depth to which the pit is to be excavated; and
- (c) the groundwater table being sufficiently low so as not to make pit excavation and lining unduly difficult and expensive.

If these requirements are not all met, then the ground conditions are described as adverse.

Favorable ground conditions

65. Since single-pit VIP latrines of the kind shown in Figure 1 (see page 2) usually cost less than any other type, the designer will normally

^{27/} D.D. Mara, *The Design of Pour-flush Toilets*, TAG Technical Note (in preparation).

commence by assessing whether a design of this kind is feasible.^{28/} Assuming that a reasonable planning horizon is 20 years,^{29/} and that a single-pit VIP latrine can be expected to last for 10 years,^{30/} the designer must determine whether there is sufficient space available on each plot for two pit sites. If there is, then a single-pit VIP latrine system is normally the sanitation option of choice. One will be built initially and used for the first 10 years, after which a second one is built (re-using as much material as possible from the first) to serve for the second 10 years.

66. However, if the number of users of a single-pit latrine is high (say, more than 10), then the required pit volume may be unacceptably large, especially if the solids accumulation rate is high. Under these circumstances the designer should assess the comparative feasibilities--technical, social and economic--of the following options:

- (a) an "alternating single-pit" VIP latrine system; this assumes that there is space for two sites for single-pits with an effective life of, say, five years; a single-pit VIP latrine is built initially to serve for the first five years, after which a second single-pit latrine is built for the next five years; when this becomes full at the end of year 10, the first pit is excavated and put back into service; a similar operation is done at the end of year 15 with the second pit;^{31/}
- (b) one single-pit VIP latrine which is to be desludged mechanically every 3 - 10 years (several combinations of pit volume and emptying frequency should be investigated so as to arrive at the least-cost solution);
- (c) a single-pit VIP latrine with an individual or communal soakaway (paragraphs 42 and 44); and
- (d) an alternating twin-pit VIP latrine which is to be desludged, manually or mechanically, every two to three years.

28/ If separate facilities for each sex are required, then these should be provided. The ensuing discussion assumes, for ease of argument, that they are not required.

29/ After 20 years (possibly less) water supply service levels may have improved so that other sanitation technologies become more appropriate.

30/ This is not always possible, due to adverse ground conditions or a large number of users. On the other hand, single-pit VIP latrines may last for 20 years, as in Zimbabwe (Annex II).

31/ This solution is likely to have a lower present value than the other options as listed below, but it should be discussed carefully with the community at the design stage to determine its acceptability and to clarify responsibilities (e.g., are the householders themselves required to do all the work involved in latrine relocation?).

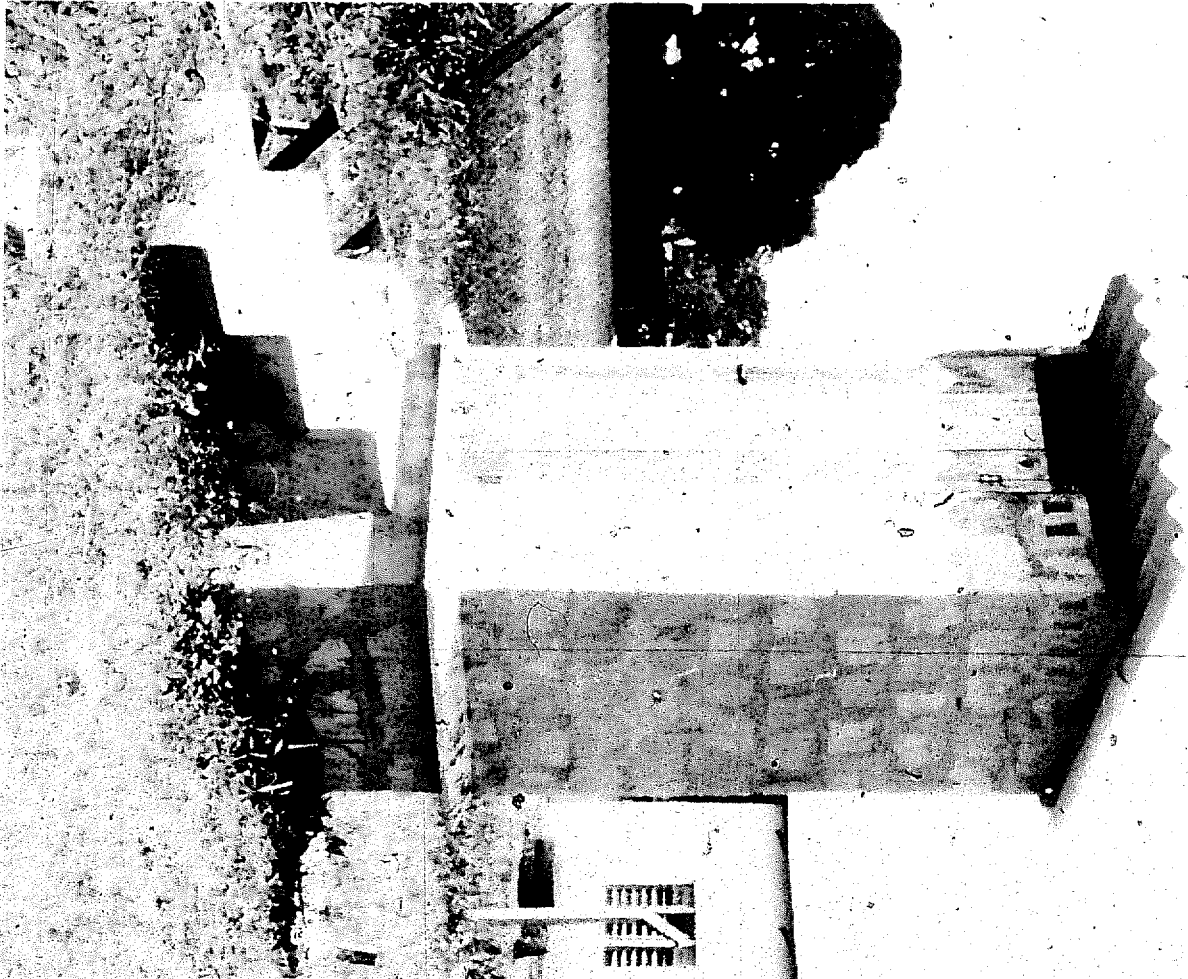


Figure 20. Raised VIP latrine in high groundwater table area (Tanzania).

Adverse ground conditions

67. **Low soil permeability.** If the soil is insufficiently permeable for VIP latrines, then on-site excreta disposal of any type is infeasible^{32/} and off-site technologies, such as small bore sewerage,^{33/} must be considered.
68. **Shallow unpickable rock.** Options (a) through (d) in paragraph 66 should be evaluated. In many situations option (d) - alternating twin-pit VIP latrines - will be the choice.
69. **High groundwater table.** In areas with only a seasonally high groundwater table, it is generally possible to excavate and line the pit during the dry season; under these circumstances the ground conditions may be considered as favorable and the designer should follow the advice given in paragraphs 63 - 66. The only additional design feature, which is necessary in areas where the groundwater table reaches to within 300 cm of the ground surface, is the raising of the cover slab some 300 cm above ground level (Figure 20).
70. In areas with permanently high groundwater levels pit excavation in stable soils may be relatively easy; a portable pump can be used to remove water from the pit as excavation proceeds. In unstable soils deep excavation may be totally infeasible; the use of shallow twin-alternating VIP latrines, with a raised cover slab, may often be the only feasible onsite solution.

Design examples

71. **Design example #1.** A new communal village for 200 households is being designed. Each household comprises eight people and is to receive a large plot measuring 30 m x 40 m. Ground conditions are favorable (the soil is a silty sand) and the groundwater table is 10 m below the surface. The water supply is from communal wells and hydrogeological investigations have shown that the groundwater pollution hazard is low. Cement, reinforcing steel and locally burnt bricks are readily available at reasonable cost. Local experience indicates that solids accumulate in pit latrines at a rate of 0.03 m³ per person per year.
72. **Solution.** Single VIP latrines are clearly the sanitation option of choice. The designer has to design the substructure and, after consultation with the villagers, the superstructure.

(a) **Substructure design.** First, the required effective pit volume (V, m^3) must be calculated from:

^{32/} Compost toilets are theoretically feasible but, in urban areas especially, they are unlikely to perform well as they require an extremely high level of user care in their operation and maintenance.

^{33/} R.J. Otis and D.D. Mara, **The Design of Small Bore Sewers**, TAG Technical Note (in preparation).

$$V = PSN$$

where

P = number of users (here 8)

S_s = solids accumulation rate (here 0.03 m^3 /person/year)

N = pit design life, years

For $N = 10$ years, $V = 2.4 m^3$. Thus, for a 1.2 m diameter pit, the effective depth is $(4V/\pi d^2)$, = 2.1 m; so, allowing 0.4 m for the free space, the total depth of excavation is 2.5 m. This is perfectly acceptable, so the design is adopted: the pit dimensions are 1.2 m dia. x 2.5 m deep. The soil is unstable and so the pit must be lined in open-joint brickwork.

- (b) **Superstructure design.** A brick design, including a brick vent pipe, is clearly the obvious solution. The designer needs to determine whether a round or "square" spiral design is acceptable; if a floor is required; if a pedestal seat or squat-hole is preferred; if the superstructure is to be large enough to permit "bucket-showers" to be taken in it; and whether a simple thatched roof is feasible (several examples of superstructure design are given in Annex II). Provision must be made for the supply of sufficient flyscreens, preferably of stainless steel.

73. **Design example #2.** A low-cost "sites and services" scheme is being developed for 1000 households in an urban peripheral area. Each household comprises six people and the plot size is 10 x 15 m. Ground conditions are adverse as the groundwater table is permanently 1.5 m below the surface, although there is no unpickable rock and the soil is sufficiently permeable. The water supply is from public standpipes connected to the city's reticulation system. There is no shortage of good building materials. The local solids accumulation rate is known to be 0.06 m^3 per person per year.

74. **Solution.** Alternating twin-pit VIP latrines are likely to be the most appropriate sanitation option, since the plot size is small. The main design problem is to calculate the size of each pit; the superstructure design procedure essentially follows that described above for design example #1.

75. The effective volume of each pit (V, m^3) is given by:

$$V = PSN$$

$$= 6 \times 0.06 \times N = 0.36 N$$

Thus for $N = 3$ years, $V = 1.08 m^3$. For an effective depth of 0.75 m, the pit cross-sectional area is 1.44 m^2 . Thus the pit could be 1.2 m square or, say, 1m x 1.5 m; the latter option is likely to lead to an overall design with easier access for desludging. Allowing 0.5 m for the free space, the

internal dimensions of each pit are 1 m x 1.5 m x 1.25 m. The pit depth (1.25 m) is less than 1.5 m--the position of the groundwater table--so the pit will be dry and construction straightforward.

76. The desludging interval of three years leads to the requirement for a vacuum tanker for only six months every third year (this assumes that 10 pits can be emptied each day and that there are 200 tanker-working days per year). Thus one tanker would be able to service 6000 alternating twin-pit latrines of the above size. Since a 5000-litre vacuum tanker costs around US\$ 60,000 (c.i.f.), its capital cost per household served is only some US\$ 10. Even assuming a tanker life of only three years and operation and maintenance costs as high as US\$ 30,000 per tanker per year, total costs to each householder for servicing his latrine would be only US\$ 8 per year.

COSTS

77. Two types of costs are used in the evaluation of VIP latrines and other sanitation systems. They are economic costs and financial costs. Economic cost is the cost that is borne by a country or a community as a whole. It measures the value of all resources used up by a sanitation project such as land, labor and capital, whether a cash outlay is involved or not. It is used for making a least-cost comparison among alternative technologies. The economically favored technology is deemed to be the one which yields full benefits at the lowest economic cost.

78. Economic costs have two components: investment cost and recurrent costs. Each component should be expressed in a way that reflects its real opportunity cost to the economy; this will normally involve shadow pricing of inputs such as labor and foreign exchange. The stream of investment and recurrent costs should then be converted, using a discount rate reflecting the opportunity cost of capital, into a total annual cost per household (TACH). The techniques for this form of analysis lie outside the scope of this paper, but are covered in any standard text on the economic analysis of projects.^{34/}

79. Financial costs are the sum of investment and recurrent costs, without any adjustment to reflect economic considerations. They are relevant in selecting a technology which the consumer can afford. The financial burden on the individual consumer will be heavily influenced by the local conditions for each project: for example, the loan/grant mix used to make the initial investment more affordable (including hidden subsidies in below-market interest rates on loans), the extent of community participation, and the use of local materials produced by the consumers themselves. The design of the project financing and cost recovery systems should be directed towards making the economically-optimal solution affordable by consumers, both in terms of the proportion of their cash incomes which they can reasonably be expected to spend on sanitation and of the self-help or other inputs assumed in the project design.

^{34/} See also John M. Kalbermatten et al. **Appropriate Technology for Water Supply and Sanitation: Technical and Economic Options.** World Bank. December 1980.

80. One major component of sanitation project costs which is often omitted in cost analysis is institutional and project delivery cost. This includes the cost of such activities as community mobilization and development, information dissemination, training and financial delivery; it also includes monitoring and evaluation and technology delivery activities such as logistic support and engineering supervision. The institutional and project delivery cost may constitute 15 to 50% of the total cost of a sanitation project. It is therefore an important cost component, and it must not be ignored. In the absence of adequate information, the institutional and delivery cost may be assumed to be 30% of the total cost of a project, or about 45% of the sum of material and labor costs.

81. Table 1 gives investment costs of five-user VIP latrines from two countries. Excluding institutional costs, the range of cost is from US\$115 to US\$167. The cost range becomes US\$164 to US\$240 when institutional costs are estimated and included. A breakdown of material and labor costs is given in Annex III for rural and urban VIP latrines in Zimbabwe. The costs are seen to range from US\$70 to US\$245 depending upon the nature of the settlement (rural or urban), soil stability and choice of construction materials. The cost of VIP latrines relative to the cost of conventional sewerage varies from one country to another. In a recent World Bank study, the mean value of the total annual cost per household (TACH) for sewerage was found to be about 13 times higher than it was for the VIP latrine, as Table 2 shows. However, in Botswana the TACH of conventional sewerage was found to be only two and a half times the TACH of the VIP latrine. It may be noted that the TACH for sewerage in Botswana was found to be the lowest of eight sewerage systems studied in the World Bank research project; the highest value of TACH, \$641.30, was found in Kyoto, Japan, compared to \$142.2 found in Gaborone, Botswana.

TABLE 1

COSTS OF 5-USER VIP LATRINES

(in US Dollars; relative proportions are given in parentheses)

	Materials (M)	Labor (L)	Total M+L	Institutional ^{1/} (I)	Total M+L+I
Tanzania (1983) (Twin-pit)	58 (35)	57 (35)	115 (70)	49 (30)	164 (100)
Zimbabwe (1983) (Single-pit)	86 (36)	81 (34)	167 (70)	73 (30)	240 (100)

Note:

1. Estimated to be 30% of total costs.

TABLE 2

AVERAGE ANNUAL INVESTMENT AND RECURRENT COSTS

PER HOUSEHOLD FOR VIP LATRINES AND CONVENTIONAL SEWERAGE^{35/}

(1978 US Dollars)

Technology	Observations (number)	Mean TACH	Investment Cost	Recurrent Cost
VIP latrines	7	35.0	31.3	3.7
Sewerage	8	400.3	269.9	130.4

^{35/} Based on: John M. Kalbermatten, et al. "Appropriate Technology for Water Supply and Sanitation: Technical and Economic Options." World Bank. December 1980.

SOIL STABILITY CRITERIA

1. This Annex describes three alternative simple field tests for soil stability, on the results of which the designer of VIP latrines can decide whether a pit needs to be fully lined, as described in paragraph 18 above, or not.

Test A

2. This is the simplest test. Soil samples are taken by hand-auguring; one sample should be taken every 50 cm to a depth of 3 m. Each sample is then hand-rolled to form a rough cylinder of approximately 2 cm diameter and 5 cm long. After sun-drying for two days or, preferably, oven-drying for two hours at 100°C, the sample is gently crushed between one's thumb and fingers. Unstable (cohesionless) soils crush easily, whereas stable (cohesive) soils do not. This test requires some experience, and it is therefore a good idea to practise the test on soils of known particle size distribution and undrained shear strength.

Test B

3. This is the standard soil mechanics measurement of particle size distribution^{1/}. A soil can be considered stable if it contains more than 30 per cent clay (< 0.002 mm). It is simpler to measure the combined sand and silt fraction (> 0.002 mm) which should not therefore exceed 70 per cent.

Test C

4. This test is the measurement of the undrained shear strength of soil samples and is thus applicable only to cohesive soils. It is done in the field by the standard soil mechanics vane test procedure.^{1/} Soils with an undrained shear strength of less than 15 kN/m² are unlikely to be able to support normal superstructure and coverslab loads (which may exceed 20 kN). As a reasonable precaution pits excavated in soils with an undrained shear strength of less than 20 kN/m² should be fully lined.

^{1/} This is described in, for example, British Standard BS 2004:1972.

CASE STUDIES

1. This Annex briefly describes some VIP latrine types that have been constructed in Zimbabwe, Botswana, Tanzania, Ghana and Brazil^{1/}. Full design details can be found in the references quoted herein.

A. ZIMBABWE

"Pole and dagga" design^{2/}

2. These are single-pit VIP latrines made almost entirely out of local materials and are especially suitable for rural areas (Figure II:1). The pit dimensions are 1.5 m x 0.6 m x 3 m. Once the pit has been excavated, the cover slab is formed. This is done by placing two logs, measuring 2.1 to 2.3 m long and approximately 100 mm in diameter, along the pit 300 mm apart, so that their upper surface is flush with ground level. Logs measuring 1.2 m long and roughly 100 mm in diameter are then placed across the longitudinal logs without gaps and nailed or tied to them; apertures for the vent pipe and squat-hole are left by using pairs of shorter logs which come to the inner edge of the longitudinal logs. The wooden logs used should be resistant to termite and fungal attack; in Zimbabwe mopane (*Colophospermum mopane*) and mususu (*Terminalia sericea*) are commonly used.

3. Once the logs are in position, the superstructure is then built. Some 30 to 40 timber poles, 1.8 m long and 50 to 80 mm in diameter, are erected in a spiral shape, nailed to the coverslab and tied together with wire. The lower ends of some of the poles should be roughly cut to a point so that they may be firmly wedged between and nailed to the coverslab logs. The upper sections of the poles are kept in place by fastening rings of green saplings around them. The roof is then made from gum poles about 30 mm in diameter which are pliable and can be easily shaped to the desired circular form. The diameter of the roof base is 2 m and its apex 0.5 m above the plane of the base. The roof is made by weaving and tying 1.2 m long gum poles between five circles of green saplings 225 mm apart. The roof is then thatched with straw or rye grass and placed on and tied to the superstructure. This procedure was adopted as it is the traditional method for making roofs in rural Zimbabwe. The thatching has to be very dense to keep the superstructure sufficiently dark for good fly control.

1/ TAG is always interested in novel VIP latrine designs. Readers with information on VIP latrine developments are asked to write to the TAG Project Manager at the address given on page (viii).

2/ "Pole and dagga" is the local term for mud and wattle; dagga is soil taken from termite hills.

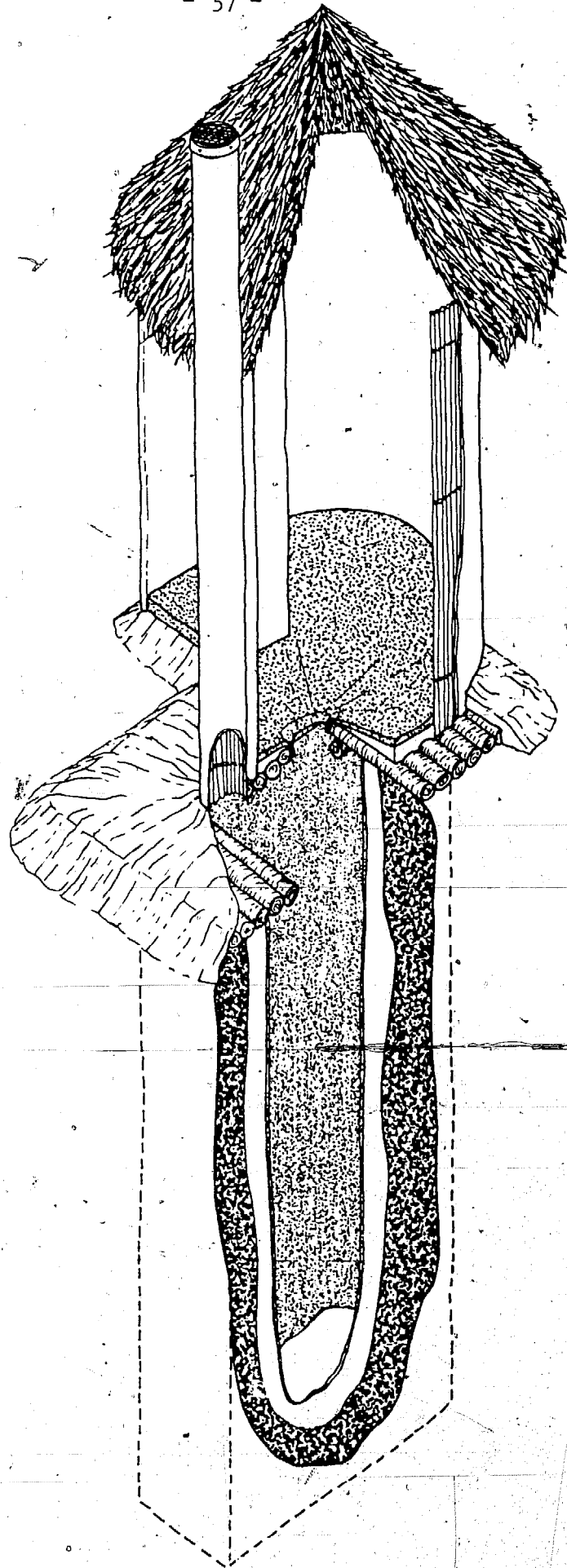


Figure II:1. Rural spiral VIP latrine (Zimbabwe).

4. Once the superstructure and roof is complete the application of mud begins; in Zimbabwe traditional practice in the rural areas is not to use soil from the ground but from termite hills, as this is found to have better adhesive properties and greater durability. The superstructure is first plastered with mud, both inside and outside. The coverslab is then also plastered with mud so that the floor slopes in all directions to the squat-hole. As the mud dries, cracks appear and the surfaces are plastered with mud again to fill these cracks and to provide increased strength. The mud is allowed to dry out and all surfaces are then plastered with a thin coat of cement mortar (1 part cement, 6 parts sand). The coverslab is then painted with black bitumastic paint.
5. The vent pipe is constructed from a 2.4 m x 0.9 m mat of local reeds woven with string or wire. The mat is rolled up around four or five 280 mm diameter rings of green saplings to form a vent pipe of approximately 280 mm internal diameter, and the flyscreen is wired on the one end. The vent pipe is then plastered around half its circumference with cement mortar; when this has dried it is placed in position and tied to the superstructure, and then the rest of the vent pipe is plastered.
6. Finally, the exposed parts of the coverslab are covered with soil which is placed so as to slope gradually away from the latrine to the surrounding ground level. Grass is then planted to provide protection against the rain.

Reference: P.R. Morgan and D.D. Mara, **Ventilated Improved Pit Latrines: Recent Developments in Zimbabwe**, TAG Working Paper No. 2, The World Bank, 1982.

Brick design

7. These are also single-pit VIP latrines, but made with more permanent building materials (Figure II:2). The pit dimensions are 1.2 m diameter x 3 m depth; in stable soils the pit is lined with cement mortar (1 part cement, 8 parts sand), or in open-joint brickwork in unstable soils. A circular collar of bricks is laid in cement mortar around the pit circumference at ground level. The reinforced concrete coverslab (1.5 m diameter, x 50 mm thick) is then mortared on to the brick collar.
8. The superstructure is built in a round or "square" spiral shape to a height of 1.8 m. Only part of the superstructure is over the pit; this is done so that there is sufficient space inside to enable "bucket showers" to be taken. The part of the superstructure built on the surrounding ground is supported on a foundation of a single course of bricks laid in cement mortar at right angles to the superstructure. The inside of the superstructure is plastered with cement mortar to give a smooth finish.
9. The roof is made from either thatch or ferrocement. Once it is in place and a brick step (to keep out rainwater) has been made at the latrine entrance, soil is used to raise the level of the exposed ground within the

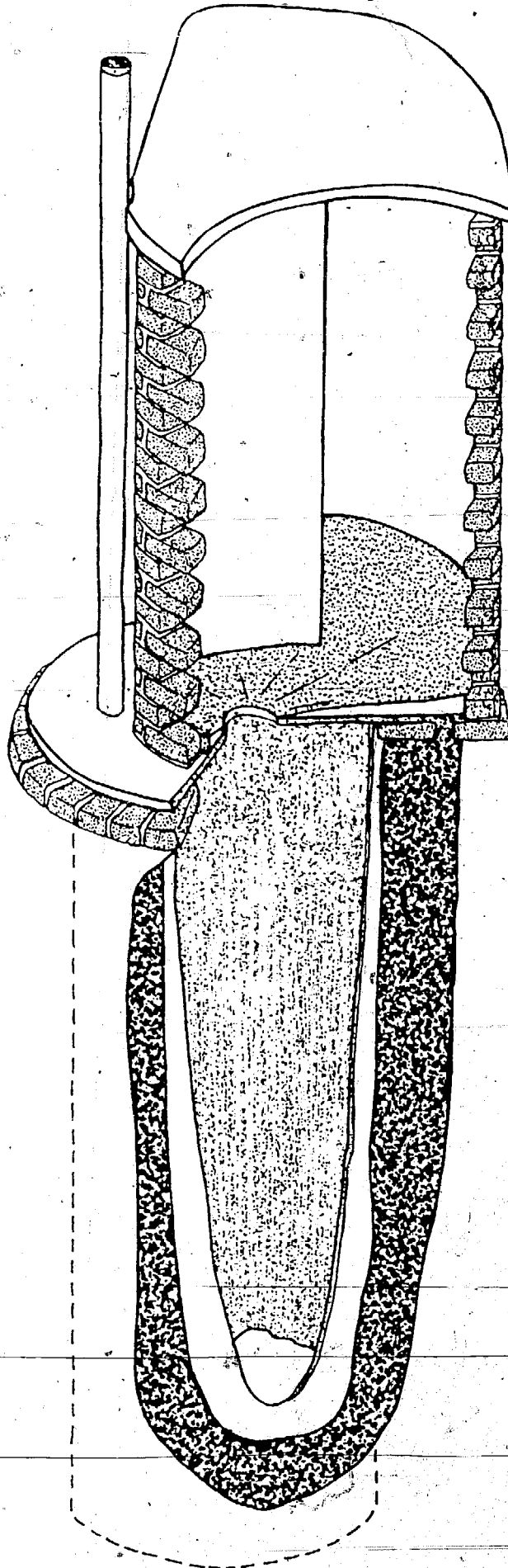


Figure II:2. Brick spiral VIP latrine (Zimbabwe).

superstructure to that of the coverslab. When this has been well compacted by tamping, cement mortar (1 part cement, 3 parts sand) is laid over the compacted soil and the coverslab to a sufficient depth so that the latrine floor slopes towards the squat-hole all round. The vent pipe is made in brickwork using the superstructure as one side of it and is built six courses higher; and its internal dimensions are 230 mm square. Alternatively, commercially available PVC vent pipes (110 mm diameter) may be used. The fly-screen is stainless steel mesh.

Reference: P.R. Morgan and D.D. Mara, **Ventilated Improved Pit Latrines: Zimbabwean Brick Designs**, TAG Discussion Paper, TAG/DP/01.

B. BOTSWANA

Alternating twin-pit design

10. Alternating twin-pit VIP latrines (Figure II:3) are widely used in urban Botswana, where they are generally known as "Revised Earth Closet Type II (REC II) latrines". Each pit (internal dimensions: 1.25 m x 3.7 m x 1.25 m) is lined in open-joint concrete blockwork supported on reinforced concrete footings; a dividing wall in fully mortared blockwork is built at mid-length and is similarly supported. The reinforced concrete coverslab (80 mm thick) is made in eight sections: two permanent central sections, each with apertures for the vent pipe and pedestal seat, which support the superstructure; and six removable sections, three at each side, to permit desludging.

11. The superstructure is built in blockwork with a sloping roof of corrugated asbestos cement supported on timber rafters. An outward-opening door is provided. The vent pipes are 2.5 m lengths of 110 mm diameter PVC pipe. A glass-fiber reinforced plastic pedestal seat unit is provided, and a concrete cover cap is placed over the aperture to the pit not in use. An L-shaped "privacy wall" is often added to the superstructure by the householder.

Reference: J. van Nostrand and J.G. Wilson, **The Ventilated Improved Double-Pit Latrine: A Construction Manual for Botswana**, TAG Technical Note No. 3.

Single-pit design

12. Various single-pit VIP latrine designs are used in rural Botswana. They are in many ways similar to the Zimbabwean designs in Section A above. Here a design suitable for use in stable soils is described (Figure II:4).

13. Before the pit is excavated a rectangular concrete ring beam (1.8 m x 1.25 m overall) is cast in a trench measuring 125 mm wide and 75 mm deep; the top of the ring beam is 50 mm above ground level, and it is reinforced by a single central 8 mm diameter mild steel bar. After the ring beam has been

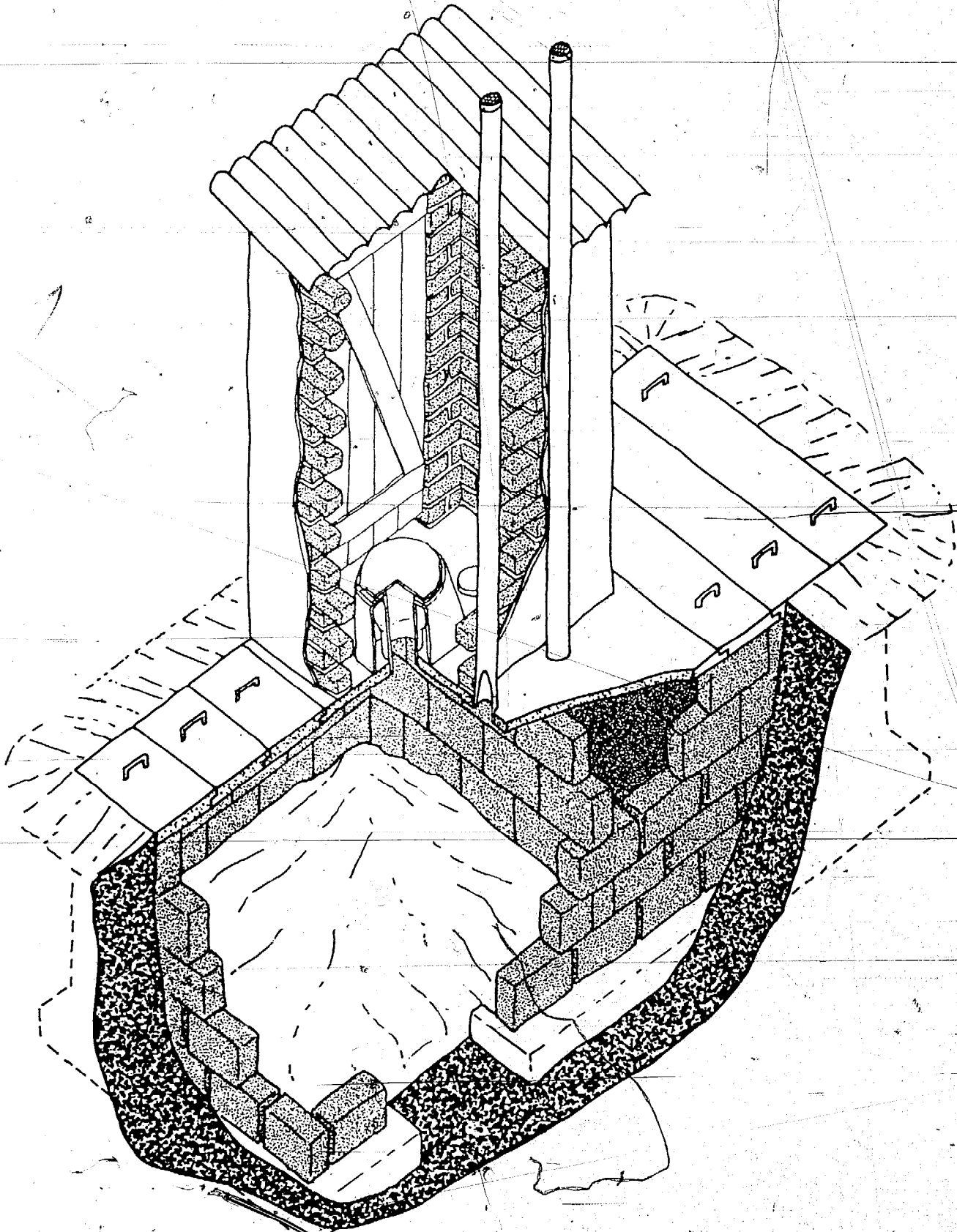


Figure II:3. Urban alternating twin-pit VIP latrine (Botswana).

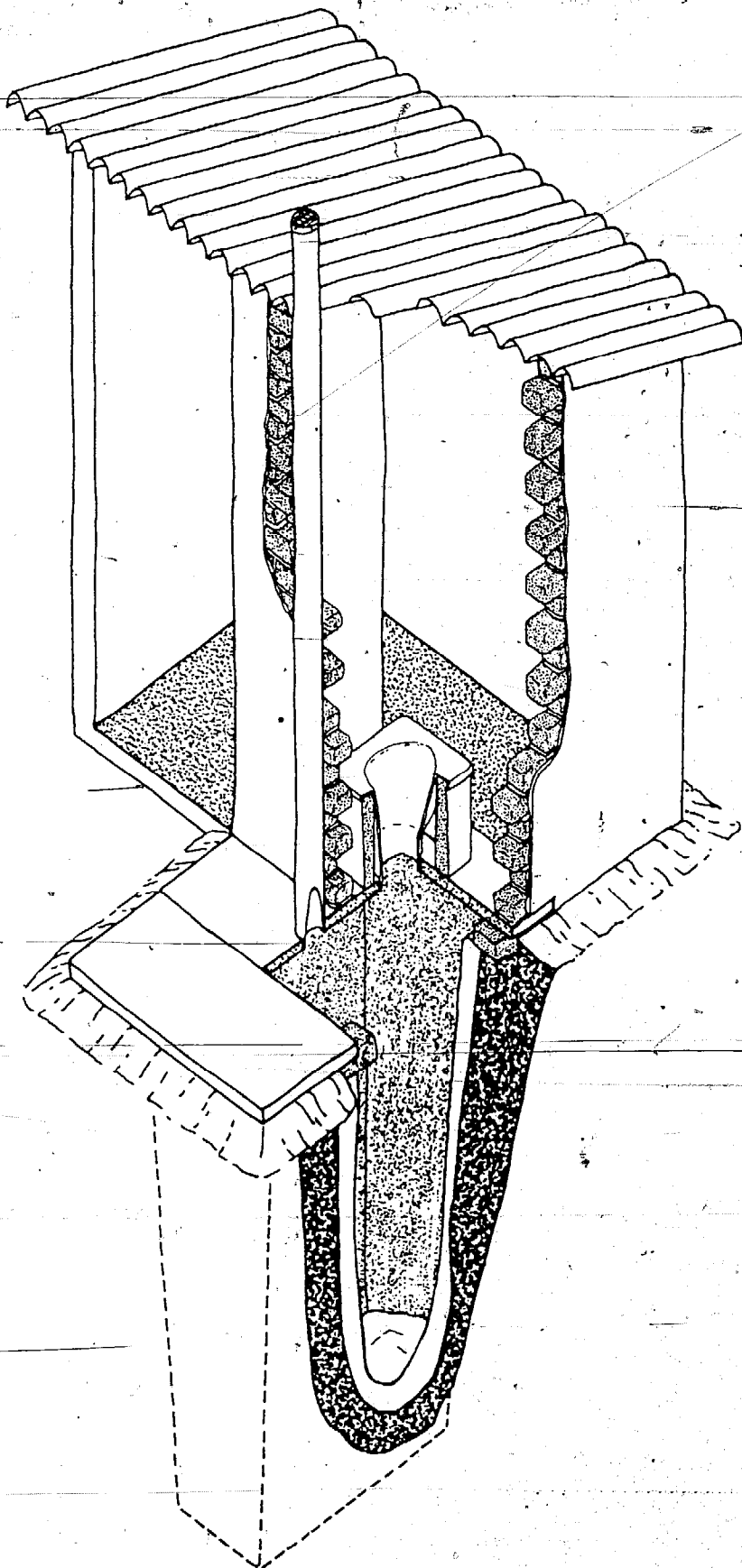


Figure II:4. Rural single-pit VIP latrine (Botswana).

cured for at least three days, the pit is excavated 125 mm within the ring beam to a depth of 2 m or more; the pit walls slope inwards at about 1 in 20. The coverslab is made in three reinforced concrete sections: one end-section has a hole for the pedestal seat; the central section has the vent pipe hole; and the other end-section is removable to allow access for emptying.

14. The superstructure is made in blockwork in a square spiral shape which is partially offset from the coverslab; a foundation of two courses of blockwork is laid to the level of the coverslab. The roof is made from corrugated iron or asbestos cement sheets. A PVC vent pipe is used with a glass-fiber (or, preferably, stainless steel) flyscreen.

Reference: J. van Nostrand and J.G. Wilson, **Rural Ventilated Improved Pit Latrines: A Field Manual for Botswana**, TAG Technical Note No. 8.

C. TANZANIA

15. The single-pit VIP latrine design shown in Figure II:5 has been constructed in several low-income areas of Dar es Salaam. It contains several novel features. The pit (approximately 1.3 m x 1.3 m x 2.5 m) is lined in special blockwork: each block has two rectangular openings in it for infiltration, and thus the blockwork has fully mortared joints. The blockwork superstructure is not offset from the pit but, to allow access for desludging, the central part of the reinforced concrete coverslab, which contains the squat-hole, is removable. The vent pipe is built up internally in one corner of the superstructure from 400 mm square blocks which have a central 150 mm diameter hole. The roof is made from fiber reinforced cement sheets and the vent pipe passes through it and projects 400 mm above it. PVC-coated glass-fiber (or, preferably, stainless steel) flyscreens are used.

D. GHANA

In-house alternating twin-pit design

16. A pilot-scale program in Ghana has shown that it is possible to convert in-house bucket latrines to in-house alternating twin-pit VIP latrines, thus providing a modern, permanent sanitation facility (Figure II:6).

17. The conversion procedure is as follows. First, the external parts of the twin-pits are excavated and lined in open-joint brickwork and the dividing wall built. The pits are then extended some 45 to 60 cm inside the house, passing below the foundation of the house wall; timber is used to support the foundation during this excavation. The pit lining and dividing wall are then completed and the old bucket latrine access door bricked up. The reinforced coverslab sections are placed in position.

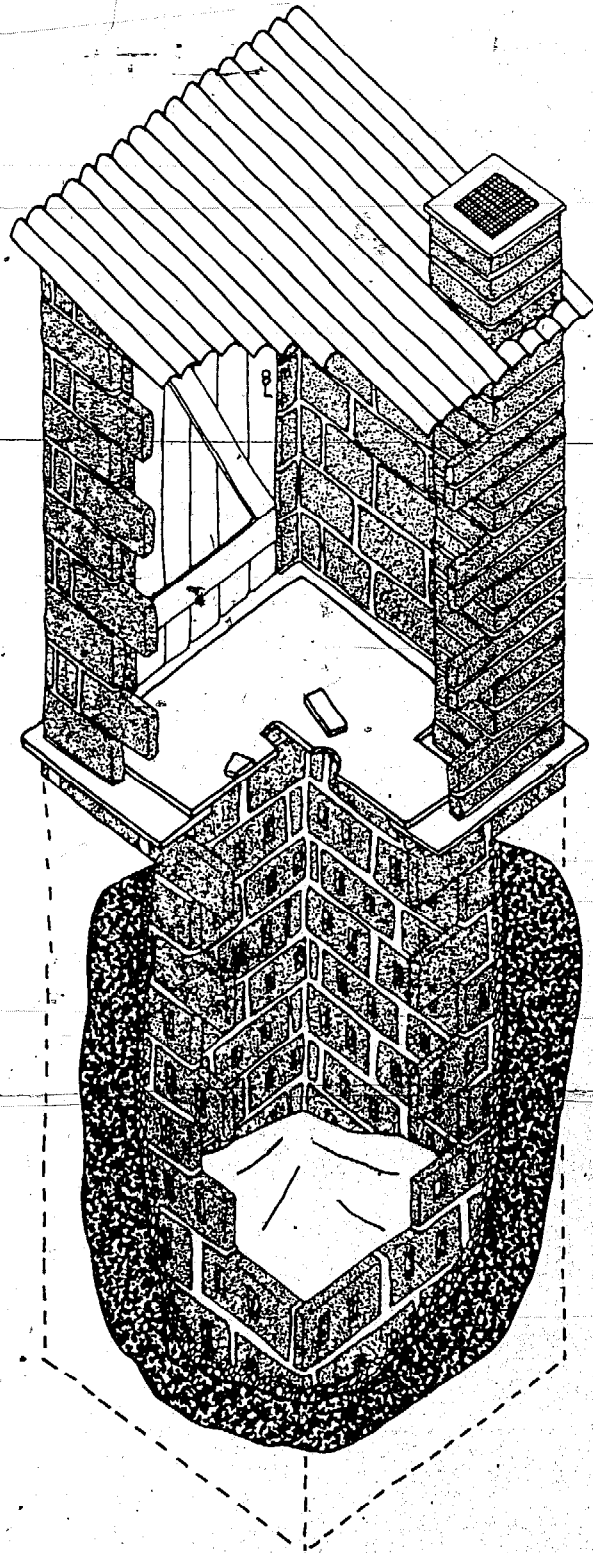


Figure II:5. • Urban VIP latrine (Tanzania).

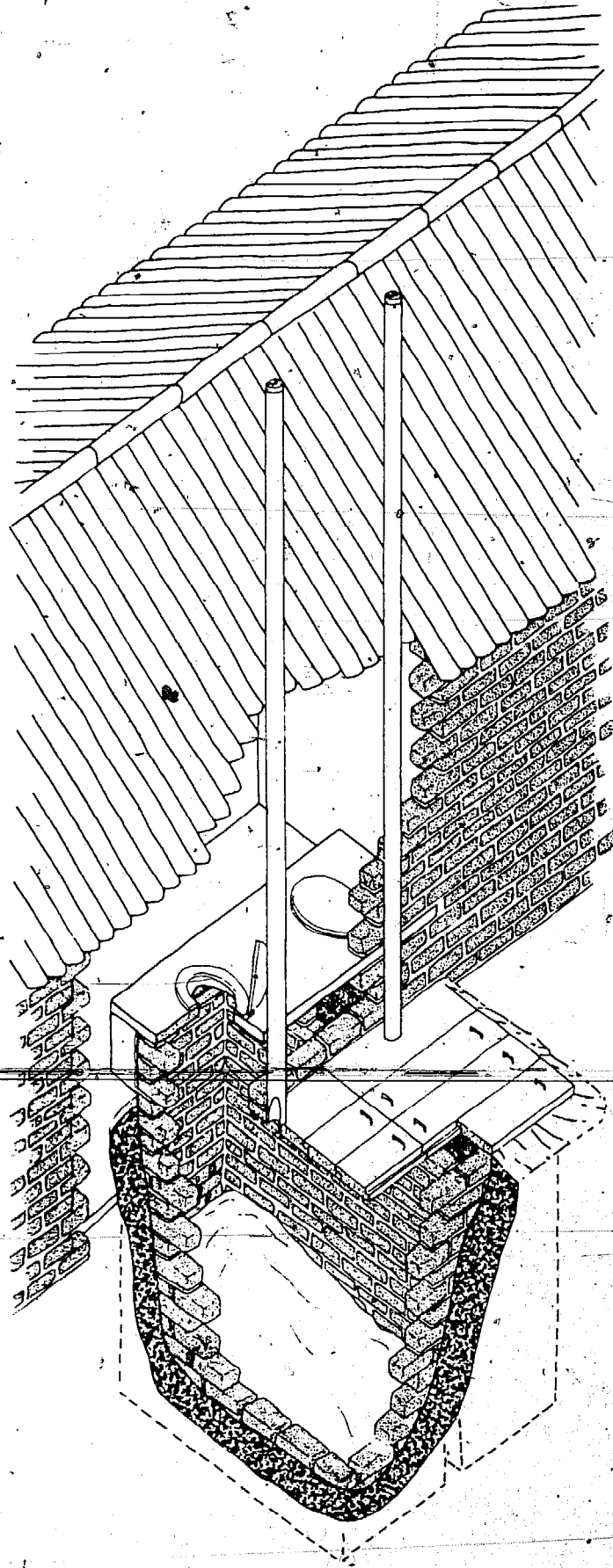


Figure II:6. In-house alternating twin-pit VIP latrine (Ghana).

each pit has one section with apertures for the squat-hole and vent pipe and, depending on the pit size, two or more removable sections to allow access for desludging. The pit size depends on the number of users and is determined as described in paragraph 13 above. Since the internal room is normally small, the longitudinal axes of the squat-holes (or, in urban areas, the pedestal seats) are located along the diagonals of the room to provide greater comfort. The vent pipes are 3 m lengths of 150 mm diameter PVC pipe, and they are fitted with PVC-coated glass-fiber flyscreens.

E. BRAZIL

Single-pit design

18. Ventilated improved pit latrines are a recent development in Brazil and currently exist only at demonstration-scale level. A single-pit design, developed by the Water and Sanitation Company of the State of Mato Grosso do Sul in conjunction with TAG-Brazil, is shown in Figure II:7. The pit dimensions are 1.5 m x 1.1 m x 2.5 m, and the pit is lined in open-joint brickwork. The reinforced concrete coverslab is in three sections: one with apertures for the vent pipe and pedestal seat unit (shown on page 18, and two which are removable to permit access for desludging. The superstructure is built in brickwork and has a corrugated asbestos cement roof. The vent pipe is a 2.5 m length of 100 mm diameter PVC pipe and is fitted with a nylon flyscreen. The superstructure, which is offset from the pit, is large enough (1.6 m x 0.8 m internal) to permit "bucket showers" to be taken (at a later stage a shower can be installed); the resulting sullage is drained away to a small adjacent soakaway.

In-house single-pit design

19. In the low-income area of Peixinhos in the city of Olinda in northeast Brazil a few in-house single-pit VIP latrines have recently been installed (Figure II:8). This area has a very high groundwater table and as a result only small volume pits could be provided. The pits, which are lined with 1 m diameter concrete rings to a depth of 1.5 m, are built just outside the house wall. The reinforced concrete coverslab is in one section with apertures for both the pedestal seat and the vent pipe. The house wall is demolished for a length of 1.5 m adjacent to the pit and an outwards extension built, with the inner edge of the new wall along the diameter of the coverslab. The vent pipe is a 3 m length of 150 mm diameter PVC pipe, fitted with a nylon flyscreen. To desludge the pit, the vent pipe is removed and a 100 mm diameter vacuum hose introduced through the vent pipe aperture in the coverslab; this works satisfactorily, as the pit contents, due to the high groundwater table, are very liquid and therefore easy to remove.

Further details: Available from the TAG Resident Adviser, PNUD/Banco Mundial. Caixa Postal 273, Rio de Janeiro, Brazil 20.000.

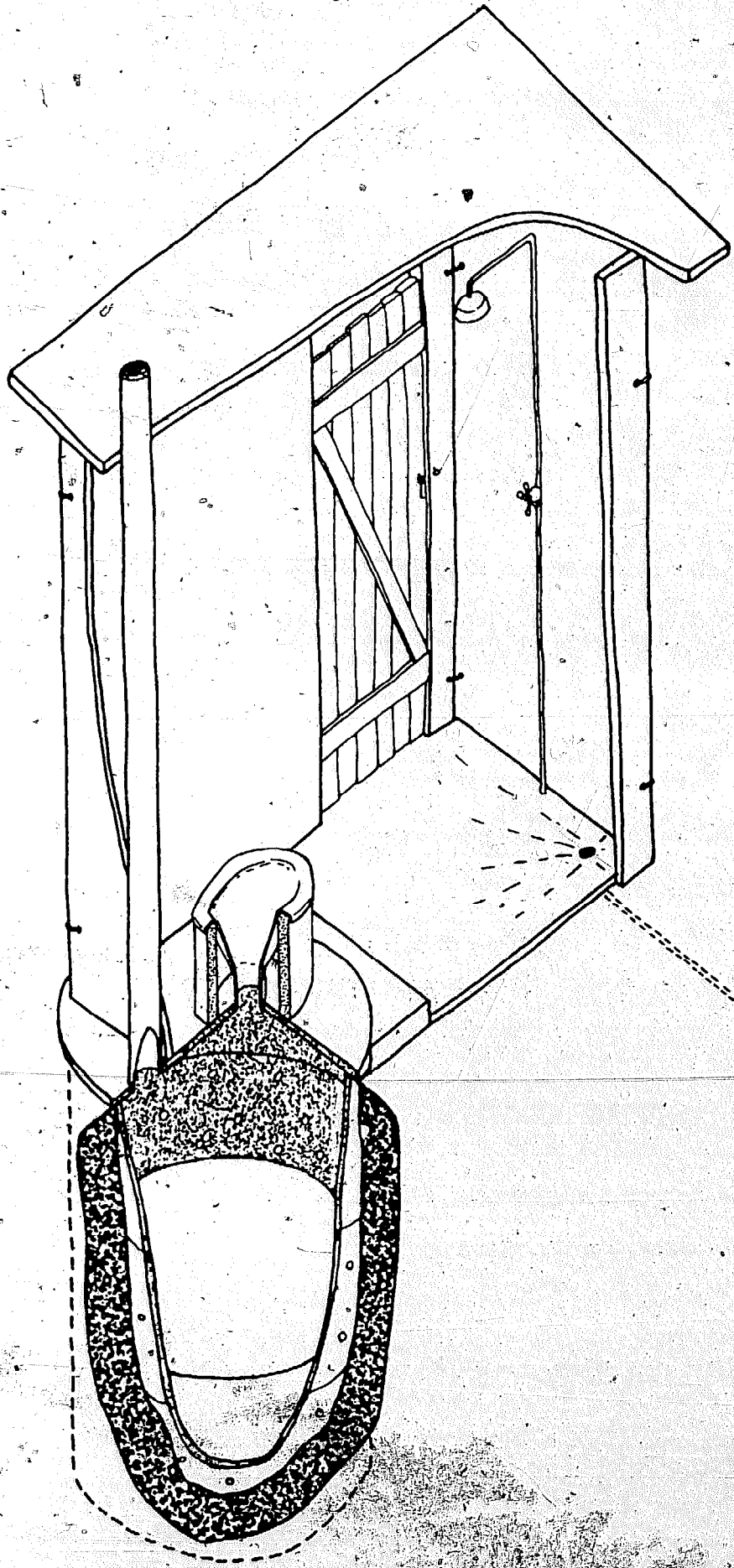


Figure II:7. Urban VIP latrine (Brazil).

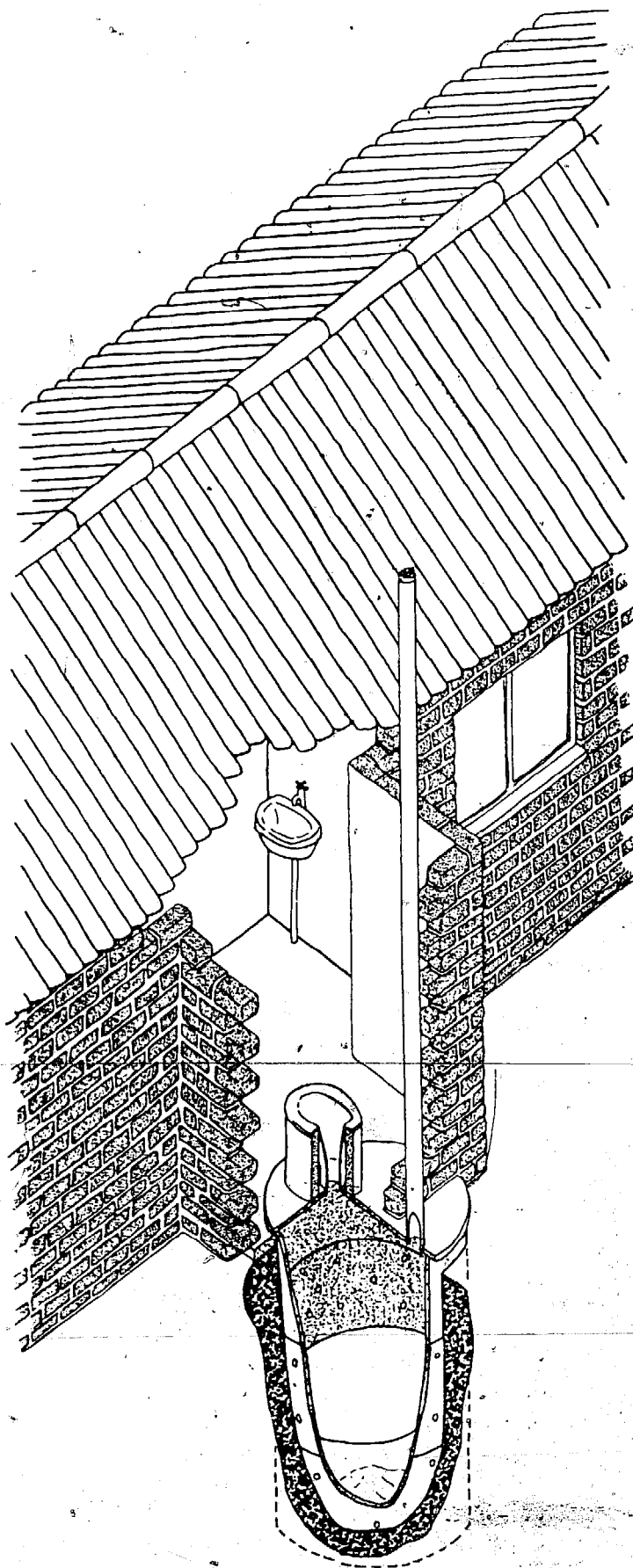


Figure II:8. Urban in-house VIP latrine (Brazil).

TABLE 1
COSTS OF ALTERNATIVE COMPONENTS FOR RURAL BRICK
VIP LATRINES IN ZIMBABWE

Item No.	Description	Unit	Rate (US\$)	Quantity	Cost ^{1/} (US\$)	Sub-total (US\$)
A. SUBSTRUCTURE						
(i) Stable Soils						
01	Cement	50 kg.	4.75	1	4.75	00.00
02	River sand	m ³	(free)	0.3	-	
03	Bricks	1000	19.00	30	0.57	5.32
(ii) Unstable Soils						
04	Cement	50 kg.	4.75	1.5	7.13	
05	River sand	m ³	(free)	0.5	-	
06	Bricks	1000	19.00	0.55	10.45	17.58
B. COVERSLAB						
07	Cement	50 kg.	4.75	0.5	2.38	
08	River sand	m ³	(free)	0.125	-	
09	Reinforcing steel (3mm dia.)	kg.	0.48	1.5	0.72	3.10
C. SUPERSTRUCTURE						
(i) Round spiral						
10	Cement	50 kg.	4.75	2.5	11.88	
11	River sand	m ³	(free)	0.7	-	
12	Bricks	1000	19.00	0.45	8.55	20.43

^{1/} Costs were converted from Zimbabwe dollars using an exchange rate of
Z1.00 = US\$0.95

Item No.	Description	Unit	Rate (US\$)	Quantity	Cost (US\$)	Subtotal (US\$)
(ii) Square spiral						
13	Cement	50 kg.	4.75	3	14.25	
14	River sand	m ³	(free)	1	-	
15	Bricks	1000	19.00	0.60	11.40	25.65
D. LATRINE FLOOR						
16	Cement	50 kg.	4.75	0.5	2.38	
17	River sand	m ³	(free)	0.1	-	
18	Bituminous paint	liter	2.28	0.5	1.14	3.52
E. ROOF						
(i) Thatch						
19	Thatching grass			8 kg)	
20	Timber poles (65 mm dia.)			12 m)	
21	Twine			0.5 m)	
(ii) Ferrocement for round spiral						
22	Cement	50 kg.	4.75	0.5	2.35	
23	River sand	m ³	(free)	0.1	-	
24	Chicken wire (40 mm; 1.8m wide)	m	1.90	1.5	2.85	5.20
(iii) Ferrocement for square spiral						
25	Cement	50 kg.	4.75	0.67	3.18	
26	River sand	m ³	(free)	0.1	-	
27	Chicken wire (as above)	m	1.90	1.5	2.85	6.03

Item No.	Description	Unit	Rate (US\$)	Quality	Cost (US\$)	Subtotal (US\$)
F. VENT PIPE						
(i)	PVC vent pipe, 110 mm. o.d. (with stainless steel flyscreen)					13.30
(ii)	PVC vent pipe, 160 mm o.d. (with stainless steel flyscreen)					25.65
(iii)	Asbestos cement vent pipe, 150 mm o.d. (with stainless steel flyscreen)					24.70
(iv)	Brick vent pipe (230 x 230 mm internal dimensions)					
28	Cement	50 kg.	4.75	0.25	1.19	
29	River sand	m ³	(free)	0.1	-	
30	Bricks	1000	19.00	0.120	2.28	
31	Flyscreen (stainless steel)	No.	3.80	1	3.80	7.27
G. LABOR						
32	Pit excavation	m depth	2.85	3	8.55	
33	Building (skilled labor)	man day	4.75	3	14.25	
34	Building (unskilled labor)	man	2.85	3	8.55	31.35

Notes

1. The cheapest option is an unlined type in a stable soil area with a thatch roof on a round spiral superstructure which has a brick vent. It costs US\$70.99.
2. The most expensive option is one located in an unstable soil, using a square spiral, a roof made of ferrocement slab and a PVC vent pipe with an outer diameter of 160 mm. It costs US\$112.88.

TABLE 2
COSTS OF ALTERNATIVE COMPONENTS FOR URBAN BRICK VIP LATRINES
IN ZIMBABWE

Item No.	Description	Unit	Rate (US\$)	Quantity	Cost ^{2/} (US\$)	Subtotal (US\$)
A. SUBSTRUCTURE						
(i) Stable soils						
01	Cement	50 kg	4.28	1.	4.28	
02	River sand	m ³	8.55	0.33	2.82	
03	Bricks	1000	85.50	30	2.57	9.67
(ii) Unstable soils						
04	Cement	50 kg	4.28	1.5	6.42	
05	River sand	m ³	8.55	0.5	4.28	
06	Bricks	1000	85.50	550	47.03	57.73
B. COVERSLAB						
07	Cement	50 kg	4.28	0.5	2.14	
08	River sand	m ³	8.55	0.125	1.07	
09	Reinforcing steel (3 mm dia.)	kg	0.48	1.5	0.72	3.93
C. SUPERSTRUCTURE						
(i) Round spiral						
10	Cement	50 kg	4.28	2.5	10.70	
11	River sand	m ³	8.55	0.67	5.73	
12	Bricks	1000	85.50	0.450	38.48	54.91
(ii) Square spiral						
13	Cement	50 kg	4.28	3	12.84	
14	River sand	m ³	8.55	1	8.55	
15	Bricks	1000	85.50	0.600	51.30	72.69
D. LATRINE FLOOR						
16	Cement	50 kg	4.28	0.5	2.14	
17	River sand	m ³	8.55	0.1	0.86	
18	Bituminous paint	lifter	2.28	0.5	1.14	4.14

^{2/} Costs were converted from Zimbabwe dollars using an exchange rate of Z\$1.00 = US\$0.95

Item No.	Description	Unit	Rate (US\$)	Quantity	Cost (US\$)	Subtotal (US\$)
E. ROOF						
(i) Ferrocement for round spiral						
19	Cement	50 kg	4.28	0.5	2.14	
20	River sand	m ³	8.55	0.1	0.86	
21	Chicken wire (40 mm; 1.8 m wide)	m	1.90	1.5	2.85	5.85
(ii) Ferrocement for square spiral						
22	Cement	50 kg	4.28	0.67	2.87	
23	River sand	m ³	8.55	0.1	0.86	
24	Chicken wire (as above)	m	1.90	1.5	2.85	6.58
F. VENT PIPE						
(i) PVC vent pipe, 110 mm o.d. (with stainless steel flyscreen)						13.30
(ii) PVC vent pipe, 160 mm o.d. (with stainless steel flyscreen)						25.65
(iii) Asbestos cement vent pipe, 15 mm o.d. (with stainless steel flyscreen)						24.70
(iv) Brick vent pipe (230 x 230 mm internal dimensions)						
25	Cement	50 kg	4.28	0.25	1.07	
26	River sand	m ³	8.55	0.1	0.86	
27	Bricks	1000	85.50	0.120	10.26	
28	Flyscreen (stainless steel)	No.	3.80	1	3.80	15.99
G. LABOR						
29	Pit excavation	m depth	3.80	3	11.40	
30	Building latrine (skilled labor)	man/day	9.50	3	28.50	
31	Building latrine (unskilled labor)	man/day	4.75	3	14.25	54.15

NOTES

1. The cheapest option costs US\$145.95. It applies to stable soils and round spiral structures with ferrocement roof plus a PVC screened vent pipe of 110 mm outer diameter.
2. The highest cost option costs US\$244.87. It applies to areas with unstable soils where square spiral superstructures are built with ferrocement roof and provided with screened vents of 160 mm outer diameters.

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