

DEPARTMENT OF THE ENVIRONMENT  
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NOTE N 70/79

THE PIT LATRINE UPGRADED

by R F Carroll      C Eng M I Mech E

SUMMARY

The most widely used domestic excreta disposal system in developing countries today is the pit latrine. They are often installed in low income housing schemes as the only acceptable system that available resources can provide.

If pit latrines are to be installed then the best technology should be employed to ensure acceptable standards of hygiene and comfort, at economic cost.

This paper introduces the concept of permanent double pit latrines, suitable for mechanised or manual emptying; construction is rationalised and includes pit ventilation. These prototype latrines, designated 'PIP latrines' (Permanent Improved Pit latrines), are being developed in Botswana by a BRE collaborative experimental project with the Botswana Ministry of Local Government and Lands.

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## THE PIT LATRINE UPGRADED

by R F Carroll C Eng M I Mech E

### 1 INTRODUCTION

The pit latrine is the most widely used excreta disposal system in developing countries today, although still taking second place to indiscriminate defaecation in fields or bush.

Badly constructed pit latrines lacking effective ventilation can become very offensive due to bad odours and fly and mosquito nuisance. Also very real health hazards exist with some installations, resulting from access to the pit contents by insects and animals. If disease organisms are present then they can easily be transmitted over a wide area by these carriers.

Pit collapse is a serious problem in lots of low cost housing areas, particularly where heavy superstructures are built and the supporting ground is unstable. This has led to a fear of collapse by some would-be users of pit latrines and therefore care in adequately supporting pit tops is important to minimise the risk of pit collapse and consequent subsidence of the superstructure.

Shortcomings of pit latrines are frequently reported, but improvements can be made in design and construction to radically improve the comfort, safety and effectiveness while at the same time achieving an economical unit cost.

### 2 EFFECTIVE SANITATION

The main conscious community expectation of a sanitation system is simply the disposal of excreta without contact with or nuisance to members of the community. The almost universal practice in developed countries of flushing away the contents of the toilet pan with copious amounts of water has become the objective of many developing communities.

The fundamental criterion however, in order to preserve public health and comfort, is the isolation of human excreta from other people, insects and animals until it is rendered harmless and inoffensive. This is achieved in all really effective sanitation systems, from simple but properly designed pit latrines to fully waterborne systems that are so much desired. However, in waterless systems, which are generally the cheapest and simplest systems, care is required to ensure that this fundamental criterion is satisfied.

In a properly designed pit latrine, offensive and often harmful excreta are collected and retained in a pit where they are broken down (digested) by anaerobic bacteria. Because the pit environment, unlike the human gut, is unfavourable to prolonged survival of pathogenic bacteria and parasites, not only will the volume of material be reduced during retention but harmful organisms also will be reduced. The resultant humus-like material is very suitable as a soil conditioner and fertiliser.

### 3 POLLUTION FROM PIT LATRINES

There is some recent evidence (1) that groundwater pollution can occur from pit latrines installed in certain ground situations. In areas with fissured rock or other types of highly permeable ground and where pits penetrate the groundwater, high nitrate levels and high bacterial counts can occur, which could present dangers to human health. In areas where it can be shown that the hazards exist, it is important that a safe water supply is made available from an uncontaminated source if pit latrines are the only affordable method for excreta disposal.

It has however been shown by authorities such as Baars (2) and Caldwell (3) that the passage of harmful organisms through soil generally has a filter effect in removing organisms that may contaminate boreholes and wells.

Possible sources of groundwater pollution, such as pit latrines and soakaways from septic tanks and aqua privies, should be sited with care in relation to water sources and recommended safe distances should be observed (4).

### 4 A NEW APPROACH TO PIT LATRINE TECHNOLOGY

It is not intended to try to persuade a development authority to select pit latrines as the sanitation system for a particular site, but if cost constraints, social preferences, etc decide the choice to be a form of pit latrine then the following argument is presented for a radical approach to produce a rationalised design, based on double pit technology linked with a mechanised pit emptying service.

As new housing plots tend to be smaller as time goes on, due to a growing shortage of land, particularly in the semi-urban areas created by development of land for 'site and services' schemes, the traditional practice of digging a new pit when the first one is full will not be practicable. Also if standards of design and construction improve, giving greater comfort conditions with improved stability of pit and superstructure, then the rebuilding of the latrine every few years is wasteful of effort and material resources.

The practice of emptying pits for reuse is not entirely new. In some countries single pits have been emptied by first flooding the 'full' pit with water and then extracting the diluted contents by cesspit emptier (vacuum tanker). There is considerable health hazards in this practice, since the top layers of the pit contents will not be decomposed and are likely to contain viable organisms harmful to health.

By employing double pits, used in turn for a three year period before closing off, the contents then left for a further two years before emptying will be harmless and inoffensive when extracted.

Emptying should be without the addition of water, since water is normally a scarce resource and its addition will also increase the volume of material to be extracted and transported to disposal.

If double pits are employed with an emptying service at around three year intervals smaller excavations will suffice, with correspondingly reduced labour and material costs for the supporting structure. At a designed capacity of 1.5 m<sup>3</sup> effective volume per compartment, ~~two~~ compartments (pits)

will last a family of five persons for around three years. This calculation is based on two thirds of 'actual' pit volume being used as 'effective' volume in accordance with recommendations by the Ross Institute (5). The same authority gives an approximate deposition rate of  $0.06 \text{ m}^3$  per person per year for calculating pit life (filling rate).

By constructing shallower pits there will be less risk of penetrating the groundwater, less side area for percolation of contaminated liquids into the ground and indeed less stored material that is possibly a pollution source.

## 5 EXPERIMENTAL DOUBLE PIT LATRINES

To develop the concept of permanent, emptyable double pit latrines, the UK Building Research Establishment is collaborating with the Botswana Ministry of Local Government and Lands, to construct and monitor the use of 48 latrines for site and services' plots in Botswana.

Prototype designs have been prepared, designated 'PIP latrines' (Permanent Improved Pit latrines); figures 1 to 5 give details of four designs for experiment. Figure 1 shows the sequence of construction of a type A PIP latrine:

- 1 shallow excavation
- 2 insitu cast concrete liner on undisturbed ground
- 3 pits excavated within liner (1.2 m deep beneath liner)
- 4 precast concrete floor units and access covers assembled
- 5 finished PIP latrine
- 6 mechanised emptying at 3 year intervals.

The type A is the main design incorporating the following features:

- (i) double pits
- (ii) pit tops and superstructure supported
- (iii) mechanised or manual emptying
- (iv) pits ventilated, to reduce odour and fly nuisance
- (v) 2 year minimum retention
- (vi) 3 year emptying cycle
- (vii) contents decomposed, inoffensive and useful as a fertiliser.

Some prefabrication is intended, for such components as floor panels and access covers. Superstructures can be designed to suit cultural and economic preferences, according to location.

Type B is basically the same as type A, with the difference that two separate pits are excavated within the concrete liner compartments. This design is intended for rocky or other stable ground. By maintaining a ground barrier between the two pits the partition wall is not needed.

Type C has the pits arranged side by side, instead of end to end as for types A and B. This means that some extra footings are required because part of the superstructure is offset from the liner.

Type D is similar to type C, except that twin asbestos cement inlet chutes are incorporated, similar to the Reed Odourless Earth Closet (ROEC), a type of offset single pit latrine in use in parts of Southern Africa. This type is included to provide comparative data to permit an assessment to be made of performance of PIP latrines relative to a double pit ROEC for the initial experimental development in Botswana.

Effective volume of each pit compartment is  $1.5 \text{ m}^3$  eg the storage capacity within the compartment up to the bottom of the 500 mm deep concrete liner.

The pit capacity is designed for a three year emptying cycle, based on an approximate deposition rate of  $0.06 \text{ m}^3$  per person per year. This rate will be verified during experimental trials over five years. It is expected that considerable variation of this rate could be found between countries and even between communities within countries due to diet variations and different personal cleansing materials deposited in the pits.

Organic refuse can be accommodated in the pits, but can of course affect storage capacity, particularly if of a coarse nature which would be slow to decompose.

## 6 PROTOTYPE CONSTRUCTION AT BRS

An example of a type A latrine is being constructed at BRS, details to drawing S.1005 (figure 2).

Superstructure walling and pit partition wall is 75 mm concrete blockwork.

Both pit compartments are ventilated by a common vertical pipe at the rear of the superstructure. This is sized at 150 mm at exit from the rear wall, with adaptors to allow 75 mm, 100 mm and 150 mm dia pipes to be tried for air flow performance. Alternative positions for vent pipes will be provided on both external side walls, by cast-in stub pipes, 150 mm dia, through the floor slabs. Again different pipe diameters will be tried, this time with individual straight pipe lengths rising vertically from each pit. This second vertical layout is probably the optimum for unobstructed air flow, but effectiveness will have to be considered in relation to cost of extra piping.

The top 500 mm of each pit top is supported by a concrete liner, 100 mm thick, cast in-situ within shutters in initial shallow excavation on undisturbed ground, figure 1. The excavation is 350 mm deep at the deepest point for a sloping site. This ensures a minimum of 150 mm step to prevent ingress of surface water into the pits. A single strand of galvanised fencing wire, 3 mm dia approximately, laid around the top edge of the liner is the only reinforcement.

The base of the initial excavation is levelled to receive the shuttering. After casting the liner, the excavation is backfilled with weak concrete (12:1 nom mix). It is important to excavate only the minimum amount of material for the liner to minimise the volume of backfilling. The concrete liner provides a bearing for precast concrete access covers and floor slabs, which in turn provide the foundation for the superstructure.

The pits are excavated within the internal rectangles of the liner. For this type A latrine design, both extreme end pit walls are sloped to the bottom and the soil removed underneath the separating central divider of the liner. A partition wall in 75 mm concrete blockwork is constructed up to the underside of the liner, to create the two separate pit compartments.

## 7 EFFECTIVE AIR MOVEMENT

So that odour nuisance is a minimum in service as well as to reduce the attraction to insects to enter the system, it is desirable to create a flow of air in through the inlet hole and out through the ventilation pipe/s. By siting a black painted pipe on the sunny side of a superstructure, solar heat should encourage an upward flow of air through the pipe. This movement will draw air in through the inlet hole.

Experiments in various tropical countries have shown that this air movement does work and is further assisted by wind movement across the upper end of the vertical pipe. Experience is required however to determine the effects of varying pipe sizes and locations for optimum effect while at the same time maintaining an economic construction cost. Both the single BRS prototype latrine and the larger experiment being mounted in Botswana (48 latrines) will be used to measure air flows during a 24 hour cycle and over several seasons.

As another simple measure against insect nuisance, applicable to the Botswana scheme, the inside of the superstructure should be darkened. The internal surface of the profile sheet roofing should be finished mat black. Any flies present in the pits would be attracted toward light and if a direct vertical pipe is provided to ventilate each compartment, this would provide a small patch of light visible to flies within the pit. By covering the outlet end of the vertical pipe with a fly proof mesh, flies attempting to move up the pipe are prevented from emerging by the mesh, resulting in a high fly kill.

The tops of the superstructure side walls are finished at the last horizontal course of blocks. In providing a 100 mm fall to the roof a triangular space is left between both side walls and the roof. It is hoped that this will provide sufficient ventilation to the superstructure while maintaining a small amount of illumination; experience in the 1976-8 Botswana Sanitation Study showed that this simple arrangement was satisfactory. User assessment will be an important feature of the proposed PIP latrine experiment in Botswana.

## 8 PIT EMPTYING

A major departure from traditional pit latrine practice is that PIP latrines are designed to be emptied. Double pits are used so that a minimum of 2 years can elapse before the last deposited material is excavated. This retention period means that the bottom layer of pit contents will be at least 5 years old, reducing through the depth of material to the topmost layer which will be at least 2 years old.

Pathogenic organisms that may contaminate fresh human excreta will die-off during the long retention period in the pit, due to dissimilar conditions to those in the human gut. The gut of course is the ideal host environment for survival and breeding of pathogenic bacteria and parasites that are the cause of much poor health, particularly in the developing countries.



Because of the shallow depth of PIP latrines it is feasible to empty the compartments manually, using long-handled shovels. However in many cultures, including Botswana, this is unacceptable to many people, even though the decomposed material in the pit will be almost odourless and inoffensive, similar in texture to friable soil.

Therefore mechanised emptying of pit compartments is planned for the Botswana experimental scheme. As part of the research programme an emptying machine will be supplied to provide a three year emptying cycle for these double pit latrines. The machine envisaged will work on a high volume air flow principle, that will draw all types of material from the pits, from light dry material down to wet sludge, according to the groundwater conditions in the pit at the time of emptying. The suction unit is simply a centrifugal fan, passing only filtered air. No abrasive material will pass through the rotor of the fan, thus ensuring a long life. Trials with such a machine, lorry mounted, will be carried out at BRS, using the original prototype (type A) latrine and removing simulated 'pit contents' material, to ascertain maximum horizontal distances over which the material can be pulled by the machine. The suction hose is 200 mm dia and will pass all the common materials likely to be deposited in a pit latrine.

#### 9 RE-USE OF DECOMPOSED EXCRETA

It is hoped that, as a long term benefit, the decomposed pit contents will be used as a fertiliser and soil conditioner, so vitally needed in arid areas with poor soil. In Asia and the far east generally raw human excreta has been recycled to the land producing food crops for many hundreds of years. The practice has been accepted as a normal re-use procedure for a waste material even though until recently the health risks were not generally understood. Considerable progress has been made in recent years with composting techniques (6) so that the material being handled is considerably safer for direct application to land producing crops for direct human consumption.

Pit latrine contents, when properly broken down by anaerobic bacteria and sufficiently matured to remove pathogens, is ideal for re-cycling, not least because of its inoffensive nature which it is hoped will encourage its application in gardens and possibly on a larger scale to farmland. Large scale collection would be necessary for farm use, since only small amounts would be available from domestic pit latrines at widely spaced intervals eg for the PIP latrines a three year cycle is planned.

The volume of fertiliser produced from an original  $1.5 \text{ m}^3$  compartment would probably be less than one quarter of the original volume. The final amount must depend very much on the nature of materials other than excreta going into the pit. Coarse woody vegetable material would take a lot longer to completely break down than say light leafy material. Other materials such as stones and plastics if they are put in will not reduce at all, but will add to the stored bulk.

#### 10 DATA TO BE OBTAINED FROM LATRINE TRIALS

Information is required that will help in the design of more effective, simple and economic latrines, that are culturally acceptable to the people for whom they are intended.

Information sought:

- (i) excavation problems and costs with reference to ground type
- (ii) construction costs and alternatives
- (iii) comparison of ventilation methods - effectiveness and costs
- (iv) required skills - availability and costs
- (v) suitability for prefabrication of components
- (vi) role of self help labour in 'site and service' schemes
- (vii) mechanised emptying - costs and problems
- (viii) user reactions and comments
- (ix) user maintenance
- (x) ground and water pollution
- (xi) comparative costs and acceptability of PIP latrines with existing latrines.

From this information preferred designs can be prepared for wider application not only in Botswana, the host to the first trial development, but on a wider front, by introducing the system to other developing countries who are interested.

11 REFERENCES

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# PIP

latrines

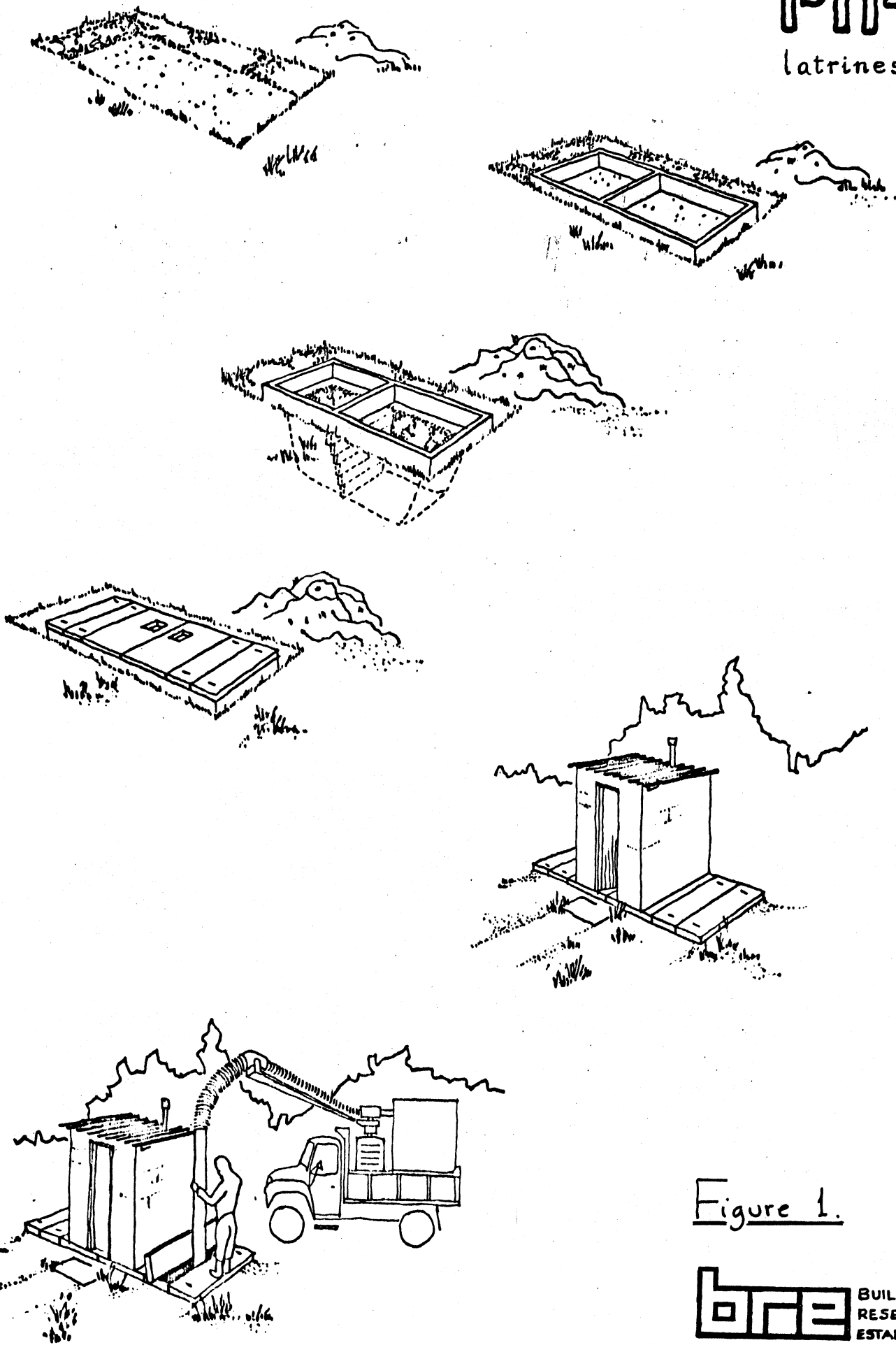
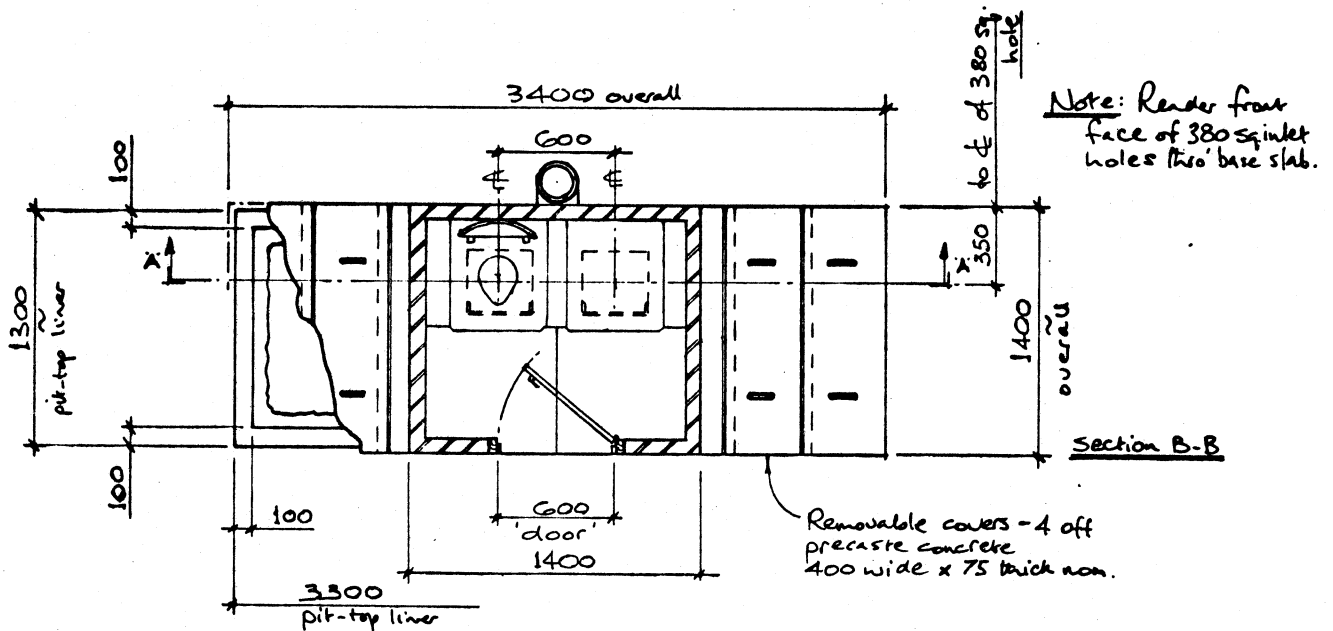
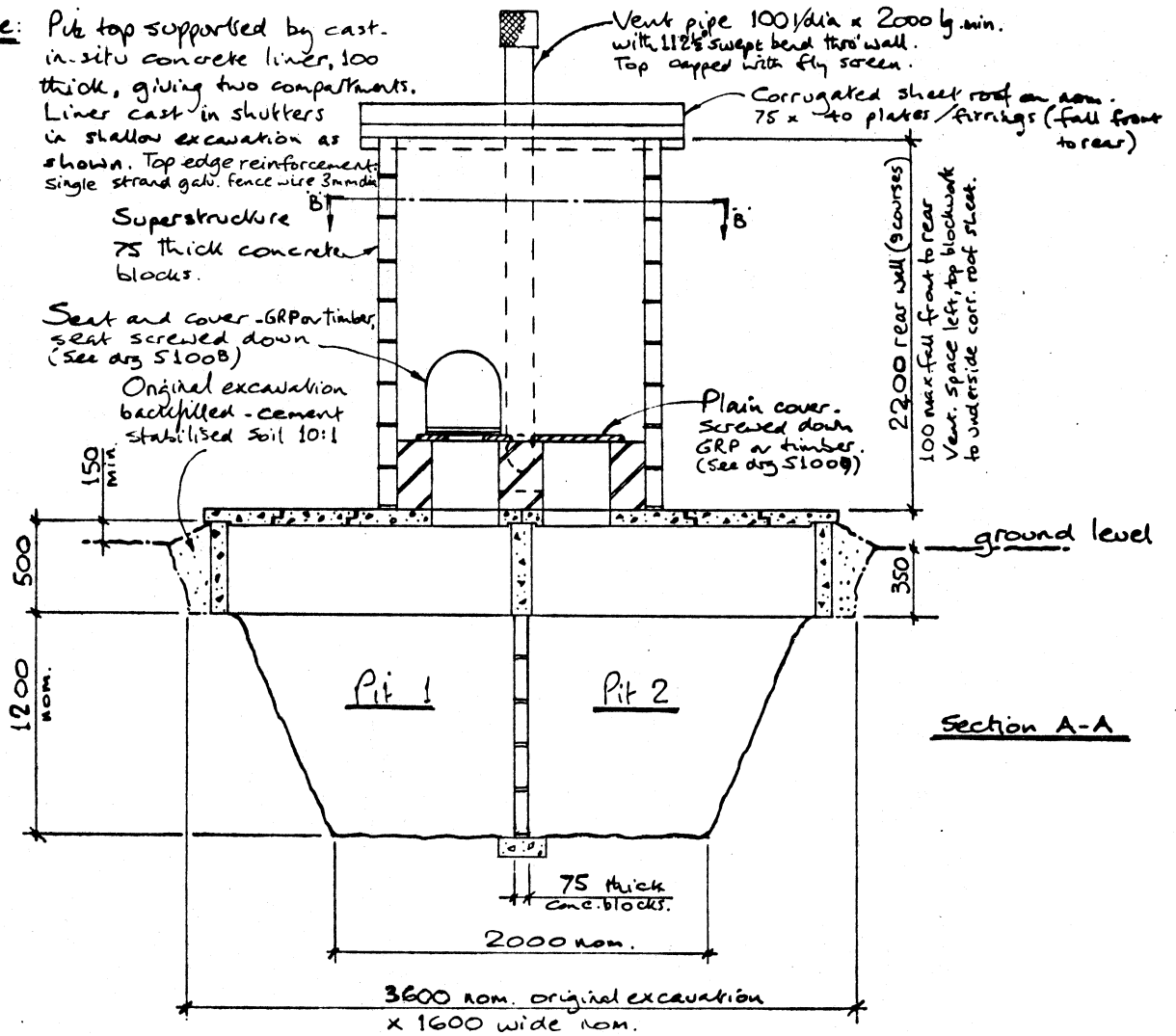


Figure 1.

**bre** BUILDING  
RESEARCH  
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**Note:** Pit top supported by cast in-situ concrete liner, 100 thick, giving two compartments. Liner cast in shutters in shallow excavation as shown. Top edge reinforcement: single strand galv. fence wire 3mm dia.



**Note:** effective volume of each compartment 1.5 m<sup>3</sup>  
(upto underside of liner)

**Figure 2.**

'Permanent Improved Pit' Latrine - type 'A'

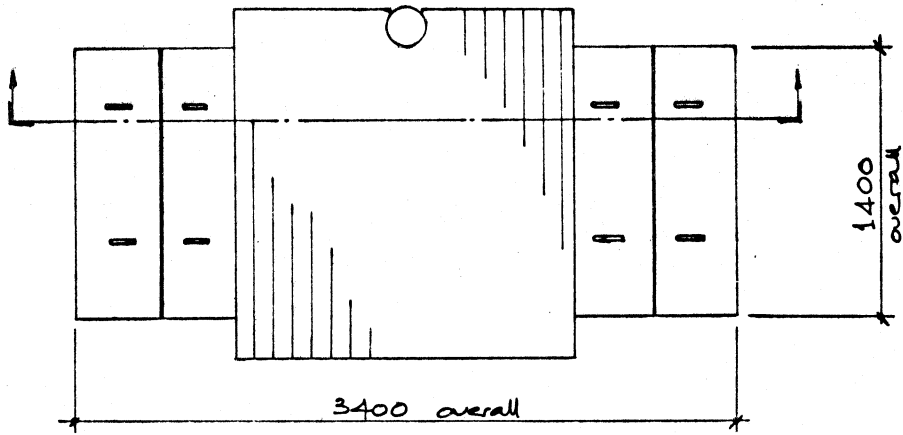
Drwg. N<sup>o</sup> S.1005

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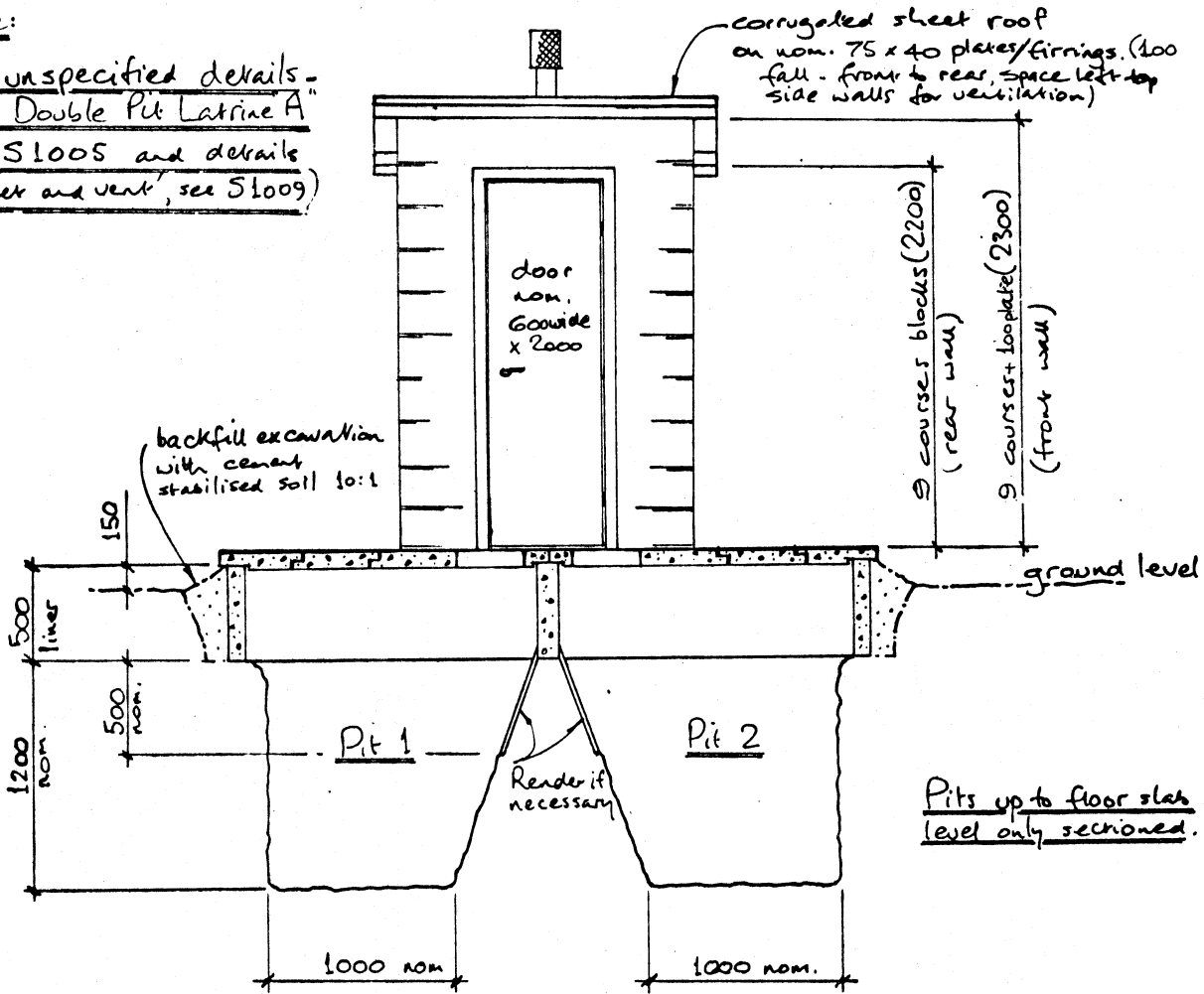
Scale 1/40

K.M. Connell 13.2.79  
2 9.4.79  
3 30.5.79

Dimensions in mm



Note:  
 For unspecified details -  
 see Double Pit Latrine A  
 drg. S1005 and details  
 of 'inlet and vent', see S1009)



Note: effective volume of each compartment 1.5 m<sup>3</sup>  
 (up to underside of liner)

'Permanent Improved Pit' Latrine - type 'B'

Figure 3.

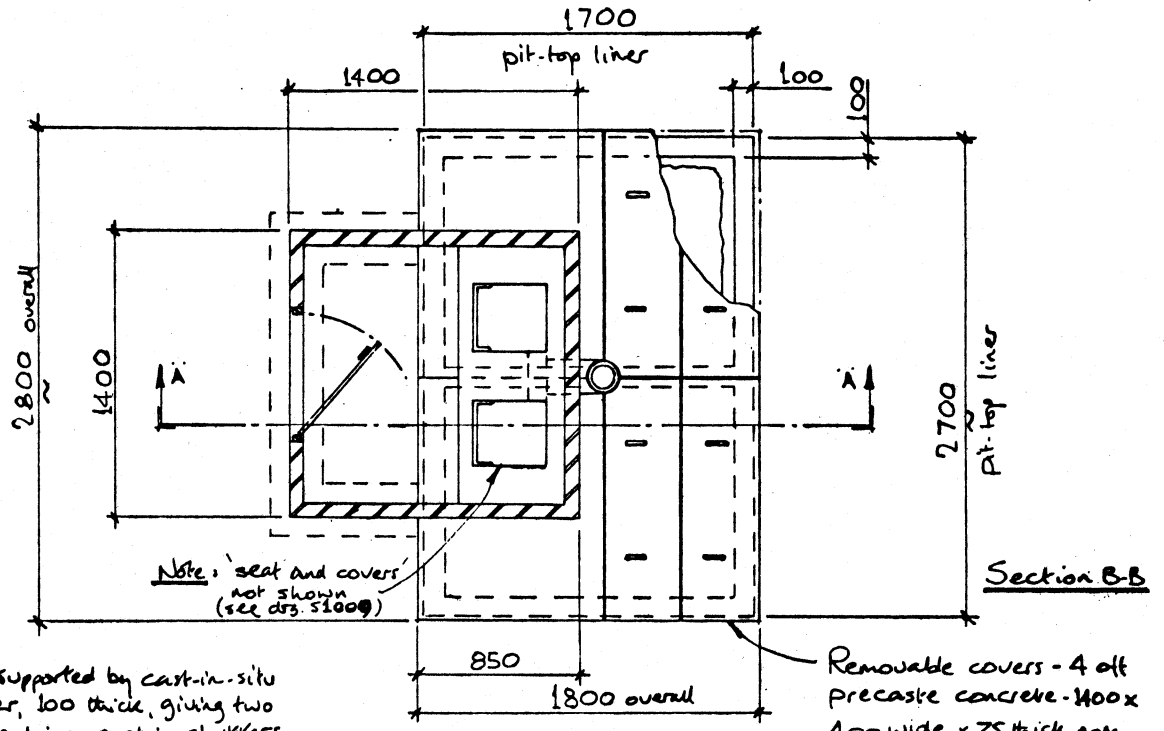
Drg. N<sup>o</sup> S.1006

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9. 4. 79

Dimensions in mm

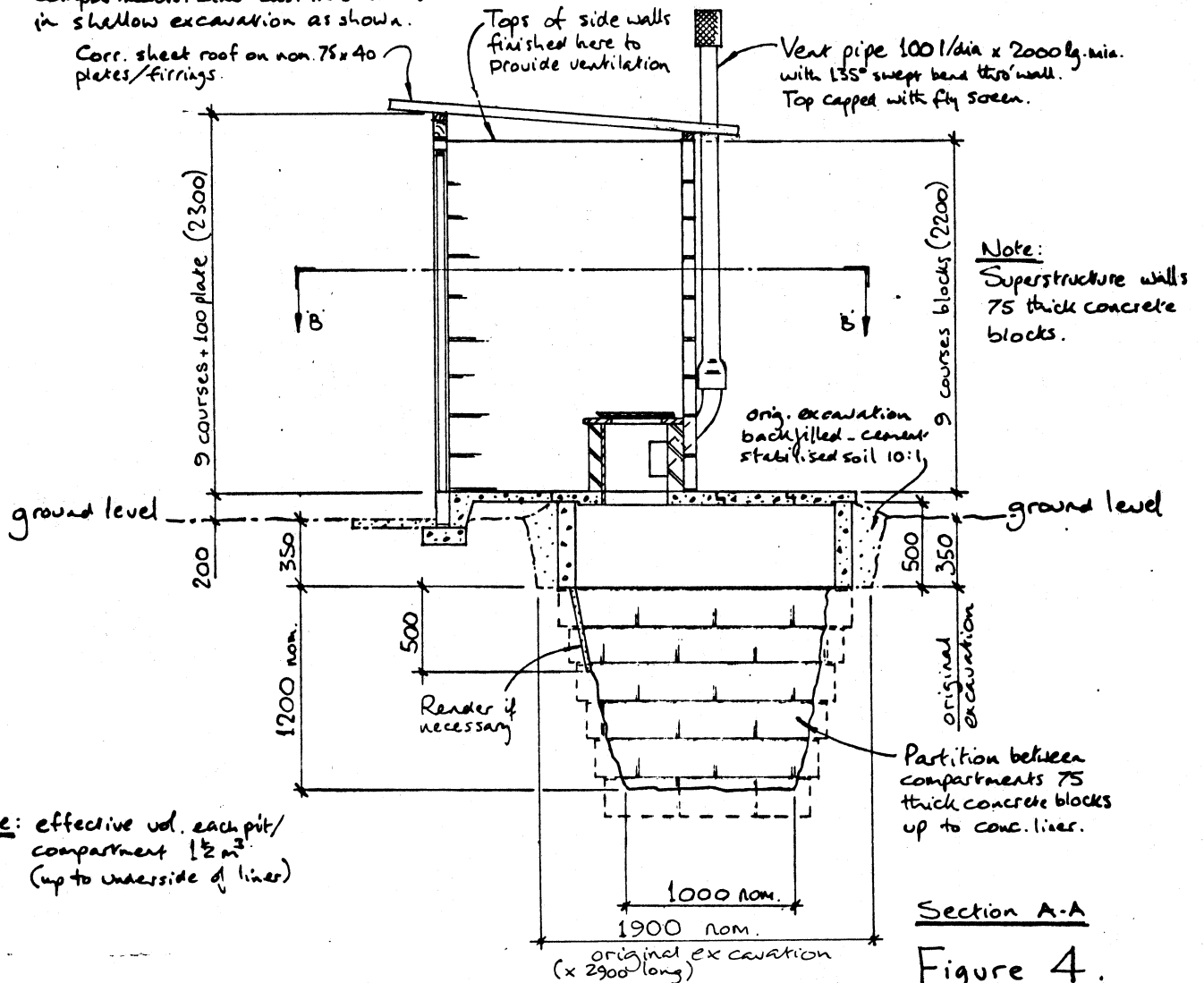


Note: Pit top supported by cast-in-situ concrete liner, 100 thick, giving two compartments. Liner cast in shutters in shallow excavation as shown.

Corr. sheet roof on non. 75 x 40 plates/firings.

Tops of side walls finished here to provide ventilation

Vent pipe 100/dia x 2000g. min. with 135° swept bend thro' wall. Top capped with fly screen.



Note: effective vol. each pit/compartment  $1\frac{1}{2} m^3$  (up to underside of liner)

Section A-A

Figure 4.

Permanent Improved Pit Latrine - type 'C'

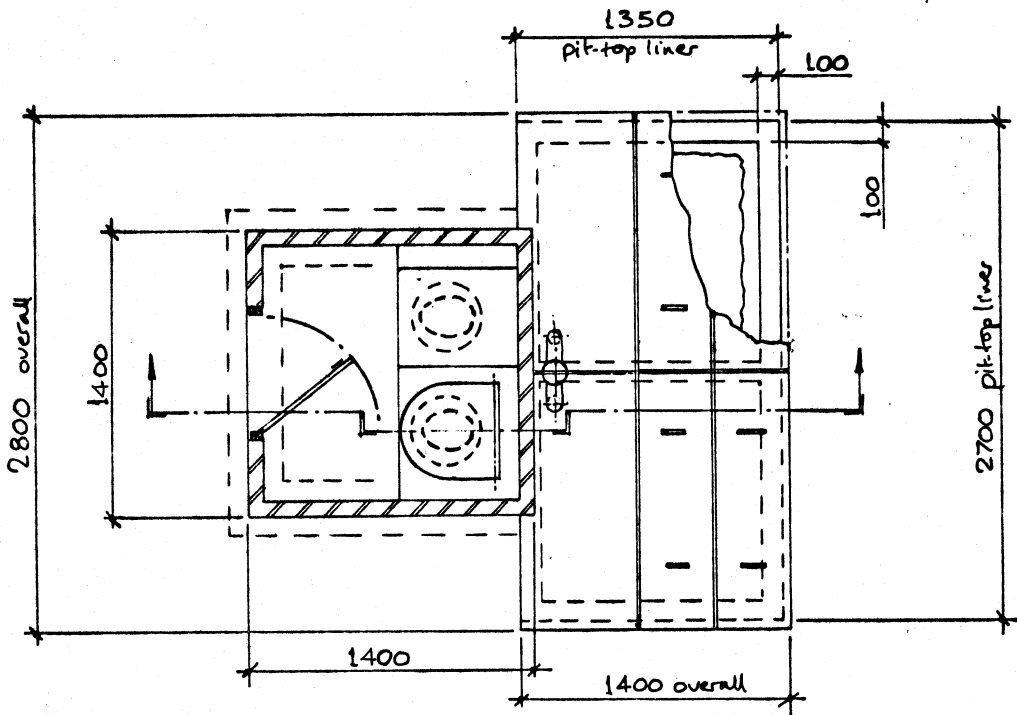
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Scale 1/40

R.M. Carroll 13.2.79  
3.9.4.79

Dimensions in mm



Corr. slat. roof on non.  
75 x 40 plates/irrigations

Tops of sidewalls  
finished here to  
provide ventilation

Vent pipe 100  $\phi$  dia x 3000 lg  
Top capped with fly screen.  
Pipe divides, Y piece, to vent each pit.

Twin inlet holes (use  
'chute' only of proprietary  
ROEC units) similar det.  
as det. S.1009, one hole  
in use at a time with  
hinged cover; other hole  
closed with fixed cover

Note: Superstructure  
walls 75 thick  
concrete blocks

Removable covers (4 off)  
precast concrete 1400  
x 400 x 75 thick non.

9 courses blocks (2200)  
100 fall, roof, frame to back wall

ground level

ground level

Partition between  
compartments 75 thick  
concrete blocks up to liner

Original excavation  
backfilled - cement  
stabilised soil 10:1

Note: Pit-top supported by cast-in-situ  
concrete liner, 100 thick, giving two  
compartments. Liner cast in shutters  
in a shallow excavation as shown.

1400 min.

1800 (to suit)

1000 non.

Note: effective vol. each pit/  
compartment  $1\frac{1}{2} m^3$ . Level of  
pit contents not to exceed  
centre of chute to enable  
vent to be effective.

Permanent Improved Pit' Latrine - type 'D'

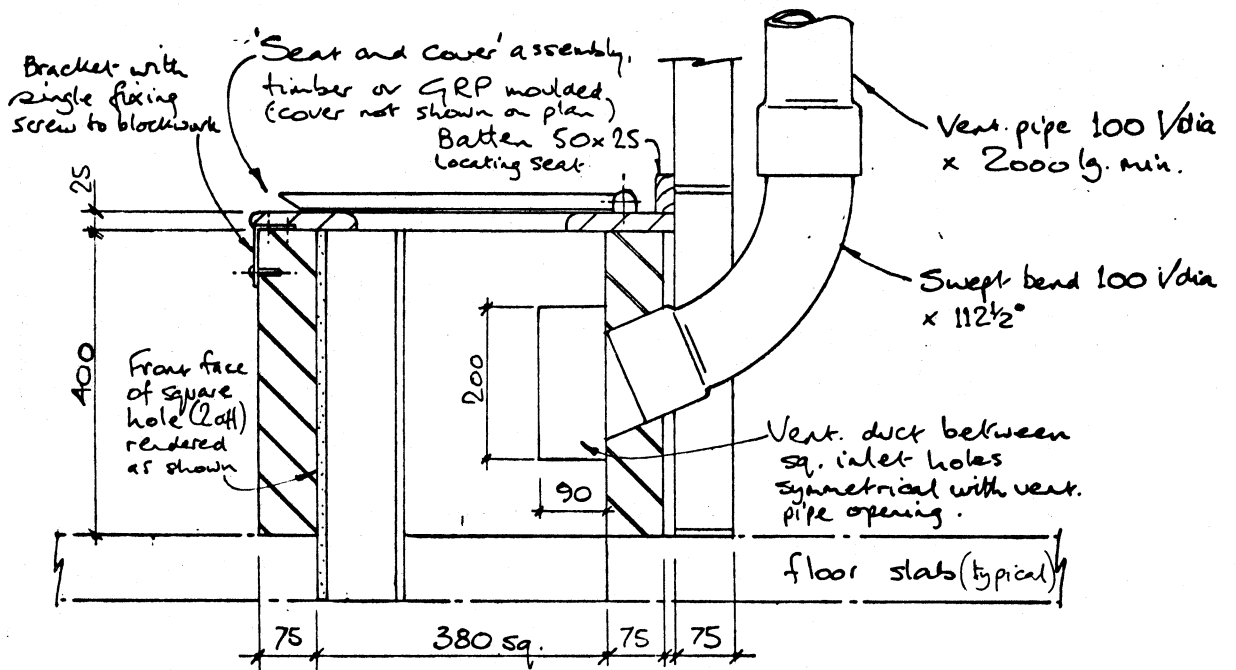
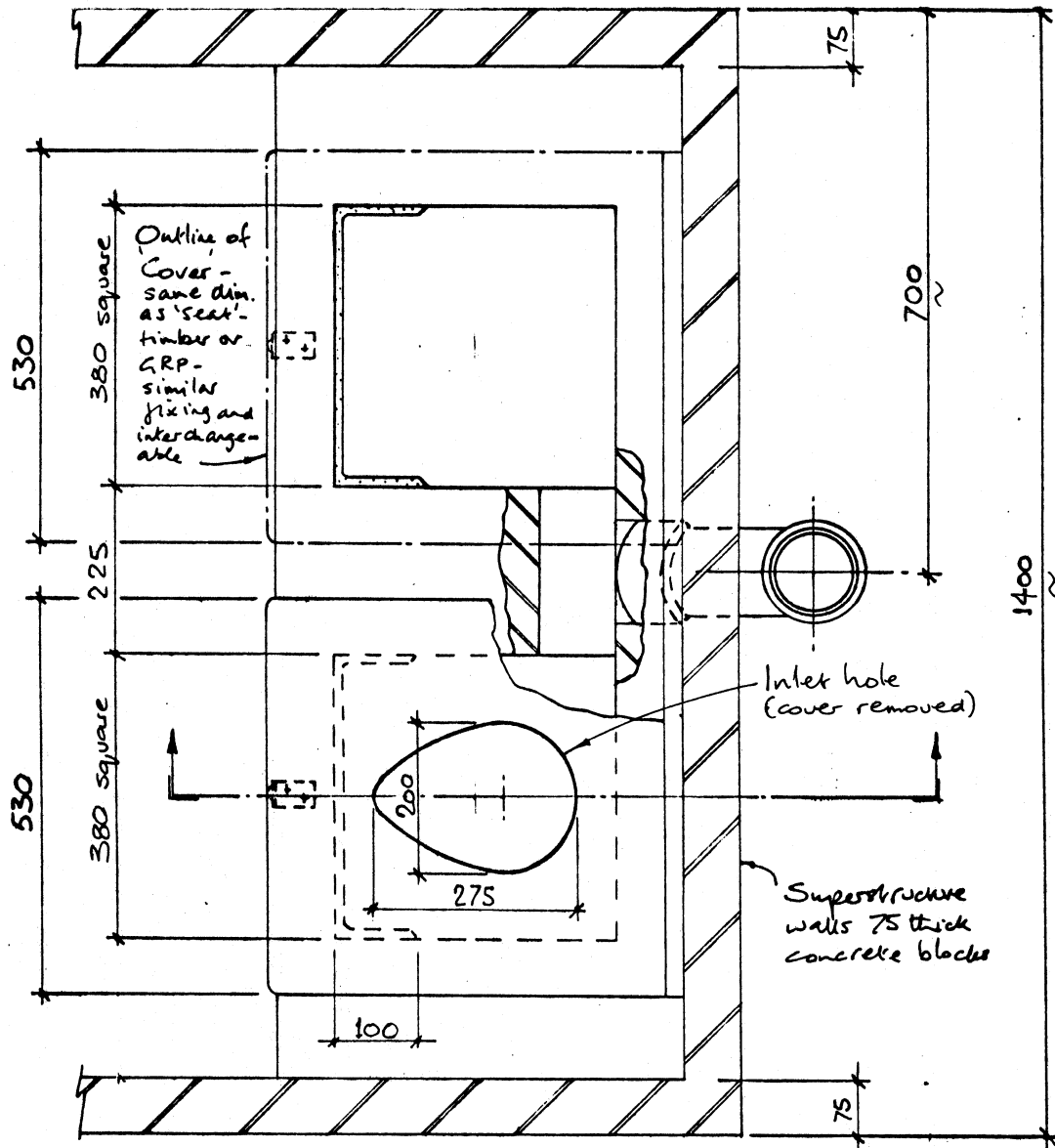
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Dwg. No S.1008 Figure 5.

Scale 1/40

Dimensions in mm



'Permanent Improved Pit' Latrines - inlet & vent. details

Figure 6.

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3 9. 4. 79  
3 30. 5. 79

Dwg. No. S.1009

Scale 1/10

Dimensions in mm