PRECAST FIBROUS FERROCEMENT

SANITARY UNITS

BY

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FORWARD:

The technology of fibrous ferrocement in the South Pacific region was pioneered by the World Health Organization principally thru the efforts of Eli Dekel and Todor Vidinov in Fiji and the WHO consultant Douglas Alexander of Auckland, New Zealand. The real push was by Mr. Videnov who relentlessly pursued the conviction he held about the quality of the product and future possibilities of the technology. If it wasn't for his zeal and push the branch of the technology reresented in this publication would not have been developed.

It is the author's sincere belief that the precasting of fibrous ferrocement components, as described in this publication is an exact construction procedure. As in any concrete operation, for really outstanding results all conditions must be closely controlled. When the techniques described herein are followed the result is an extremely high quality product. The result of the use of these high quality components is a properly engineered prefabricated unit which can be succesfully built in the villages by the people of the villages. However there is no way that the exacting conditions required for the casting of these units can be exchanged for any amount of enthusiam or compensated by any amount of community participation on the part of people inexperienced in concrete operations.

Credit must be given to Ms. Tamaleti Vakasiuola and her village womens groups who were precasting sanitary units, utilizing coconut fiber reinforcement, before Tonga was discovered by the author. The extremely important contribution of this previous work was the fact of the expressed need for improved sanitary units and the prior acceptance of the precast component, village assembled concept.

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INTRODUCTION

The need for a precast septic tank that could be constructed in high ground water, even below ground water led to the state of the art described herein. Holes, when dug for the tank construction, filled so fast that there was no time for forming or block laying. It was desireable therefore to develope the precast system that could be erected within an hour or so. Later the poor performance of wood materials as a shower house lead to the development of the precast houses where the longlasting quality of concrete makes this an excellent application.

The engineering design approach to precast ferrocement sanitary units can only be pseudo-scientific at best. The loading is always unknown and variable. Materials and processes lack consistant dicipline. Therefore most attempted calculations of loadings, moments and stresses demonstrate a simple lack of understanding of the problems. There still remains however a need for the optimization of steel and concrete.

What then can be the design philosphy ? The development of economies in the use of materials can best come through engineered guesses, failures and experience. The controlling criteria should be to get the very best both in the resultant product strength and appearance from the materials used. The engineered cut and try or the empirical approach is probably then the only practical approach.

It is easy, especially for engineers, to allow their training and habits to cloud the end objective. The real objective is not the production of optomized precast ferrocement pieces but to improve the health of the people through the furnishing of sanitary units of a standard that will make their use preferable to the bush and that will fullfill reasonable public health requirements.

One of the more important objectives of the original program was to upgrade the concept of what an excreta disposal unit looked and smelled like. In the development of a nation the health of the people is definitely and directly affected by the attitudes toward and procedures used in the disposal of human wastes. The disposal of human wastes, will as the population densities in the developing nations become higher and higher, become more and more of a problem. In the ultimate stages it may become more critical than food. New generations must change and adopt attitudes and practices that allow coexistance under extremely high population densities. The arithmetic of this problem is presently in action.

THE PRECASTING OF FIBROUS FERROCEMENT SANITARY UNITS

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THE THEORY AND ITS APPLICATION A GENERAL DISCUSSION

Ferrocement and fibrous ferrocement are a form of reinforced concrete but with some major differences. The handling of imposed stresses is much the same in either. The differences occur in the way the minute cracks develope when the material is stressed. In ferrocement cracks appear more often but smaller and by design can be controlled so that the material can bend further than reinforced concrete. This extra bending allows greater stressing of the steel thus the use of high tension steel and greater economies since steel is in essence sold by the kilogram. Corrosion of the steel will occur when water penetrates thru stress cracks and reaches the steel. Ferrocement is designed so that the cracks which appear when the material is stressed are so small that water will not penetrate into the cracks far enough to damage the steel.

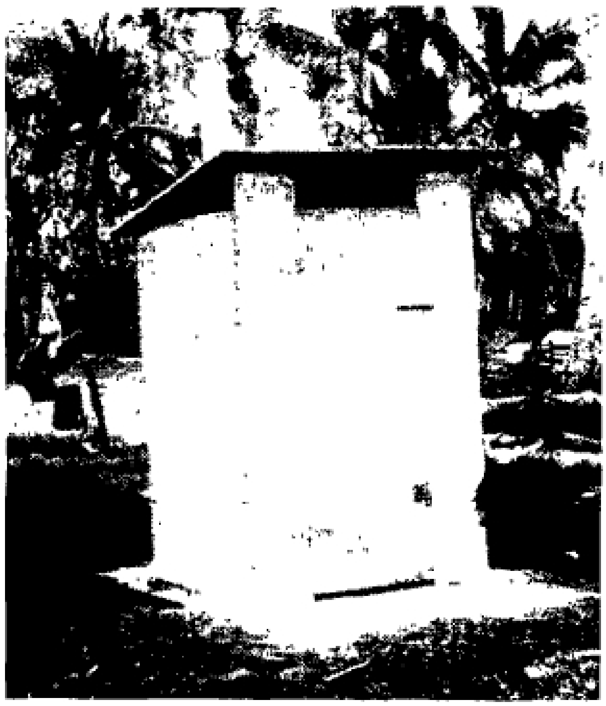
The technical aspects of the material are best left to the experts, there are several consultants and universities that specialize in the material. Our interest here is to utilize a well developed, quite complicated, technology in such a way that its' use in the field can be handled by ordinary craftsmen and so that the economies from the latest technical developments are available to the developing countries where they are so badly needed.

The application of the fibrous ferrocemt technology, as represented here, is a well developed and thoroughly field tested technology. Sanitary units constructed in the development of this technique have been in operation in Tonga since 1981. They have been carefully monitored and have proven satisfactory.

The material in this booklet represents the state of the art in Tonga in 1985.

THE VENTILATED PIT LATRINE:

General:
The ventilated pit latrine or the VIP is a highly improved version of the old pit latrine. It was developed in Africa principally by the World Bank. Thousands of these units have been built with every conceivable type of material, yet all must employ the same principals. In 1985 there were a total of approximately 40 being used in Tonga, some for as long as 4 years. The improvement over the old style pit latrine is amazing. Flies in the house are practically non existant (even though there is some fly breeding in the pit). The usual pit latrine smell doesn't exist and the general atmosphere in the unit makes it more comfortable and acceptable to use.



Principles of operation:
The ventilation pipe and the air tight pit are the most important components. The ventilation pipe must be thought of more in terms of a chimney than a plumbing vent pipe. It must be sized large enough to work on temperature differences, like a chimney. As the air goes up the vent pipe it is pulled down through the seat and riser pipe. The full and exact reasons why air goes up the pipe are not yet known but it may be partially heat makes the air rise or it may be the wind blowing across the top of the pipe sucks it out. The reasons matter little as except for a few weeks in the year the air going up the pipe keeps the air and smell from the pit from the air is forced to go down through the seat and riser pipe.

It is easier for the air to go through any hole in the pit than down the riser pipe so if the pit is not absolutely air tight the VIP ventilation won't work right and it becomes no better than the old fashioned latrine.

Flies have two weaknesses that are taken advantage of with the VIP. They are attracted by light and they will not fly down and away from light if they are trying to escape. Any flies in the pit see the light through the vent pipe as the brightest light, since the light from the seat and riser pipe is protected by the house. Therefore they fly up the pipe and once there encounter the screen. Since they will not fly down they stay next to the screen and eventually die and fall back down into the pit. The fly-tight screening of the top of the vent pipe is of course an absolute must and the maintenance of this screen so that flies cannot escape is critical.

Construction:
The precast ferrocement construction kit contains everything that is needed to completely assemble the unit except for the labor. There is no need to search the stores for materials that have been sold out. The precast concrete will last indefinitely, there will be no rot, no mold, in fact the concrete will gain strength every year that passes.

If ground water is encountered while digging the pit the VIP should not be used but a pour flush type, which is even better, should be used. A well can be dug and the water can be used to flush the latrine.

Construction is started by digging the form for the foundatior ring. This ring reinforces the edge of the hole to help prevent caving in and makes the pit absolutely sealed air tight to the ground. When the foundation is poured the riser boards are set in the fresh concrete to receive the main slab after the concrete has hardened. The riser boards must be set perfectly level and square. Level must be checked by the use of a carpenters level and square should be checked by measuring and adjusting so that distances between the two diagonal corners are exactly the same. If there is any question of the builder's ability to do this it is better to gently set the main slab on and adjust while the concrete is fresh. The main slab must be carefully sealed to the riser boards using a sticky mortar. This is best done by a man standing inside the pit. The seal may be made air tight by mortaring all places where light from the outside can be seen while standing in the pit. See picture showing this final inspection.

The house is then assembled using the stainless steel tie wire. The riser pipe is mortared on the outside only which is sufficient to hold it in place. The door, which has been custom prefitted with the hinges on the side piece, is installed. The earth is slightly mounded near the walls so that any rain will flow away from the unit and aggregate, small rocks or some form of protection is placed where the rain will fall from the roof so it will prevent any washing or erosion.

The inside surface of the house is made with a perfectly smooth surface that can be painted if desired.

Provisions should be made for hand washing after using the VIP even though this is difficult where there is no piped system. It is important that the woman in charge of the of the home see that this be done.

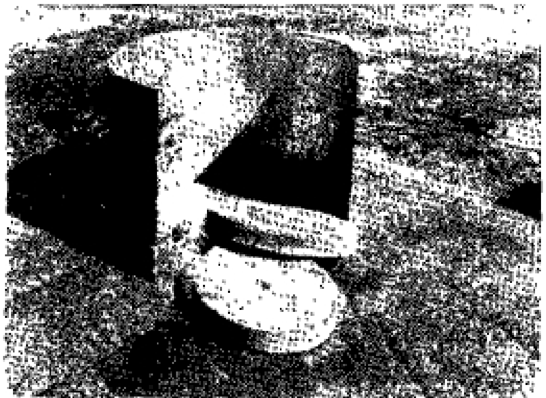
The pit should be dug as deeply as experience has shown the surrounding ground to safely stand over a period of time. The depth of the pit directly affects the expected life of the pit. The years expected life of the pit using the standard size unit may be computed by the following equation:

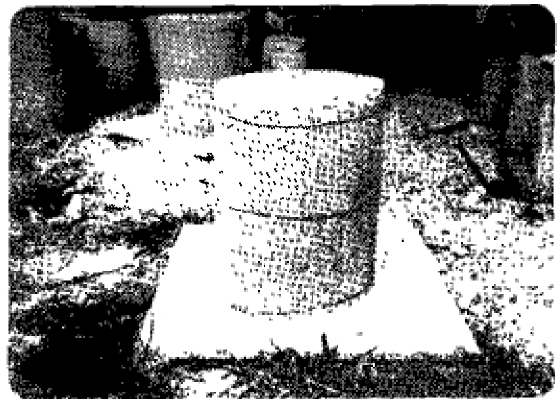
$$\text{Years pit life} = \frac{1.370 \times \text{depth meters}}{0.050 \times \text{number of people using}}$$

THE CONVERTIBLE RISER PIPE:

The convertible riser pipe allows the conversion of a VIP latrine to a pour flush or vice versa by the installation or removal of a plastic liner. This feature was found necessary because of the inconsistancy of the water supplies in the villages. Water may be on or off depending on many things including breakdowns, nonpayment of bills so diesel can be purchased, or sometimes how busy the operator gets with other interesting things. On one visit to an outer island in the Ha'apai group in mid 1985, to the village of Falemea, the water was found to have been off for 6 months. This is certain to create a problem in pour flush latrines which are not equiped with the convertable feature.

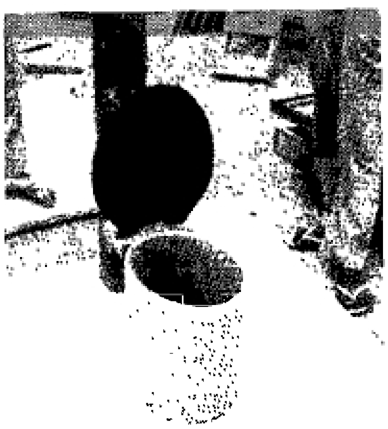
The convertible riser pipe employs the ultimate in simplicity in the forms required. Two sawn pieces of wood and a flat sheet of metal is all that is required. The thickness of the riser pipe being produced is controlled by the worker making the piece. While it takes several attempts to achieve a good product the skill level is achievable by the average construction worker.


A COMPLETE MOLD

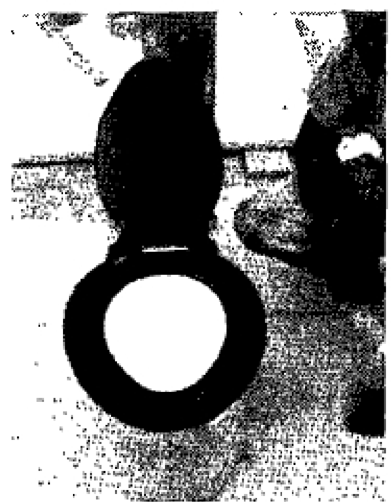

THE MOLD ASSEMBLED


PLASTERING THE MOLD


A PURCHASED PLASTIC LINER


AS A V.I.P.


AS A V.I.P.


AS A POUR FLUSH


AS A POUR FLUSH


THE COMPLETED PRODUCT

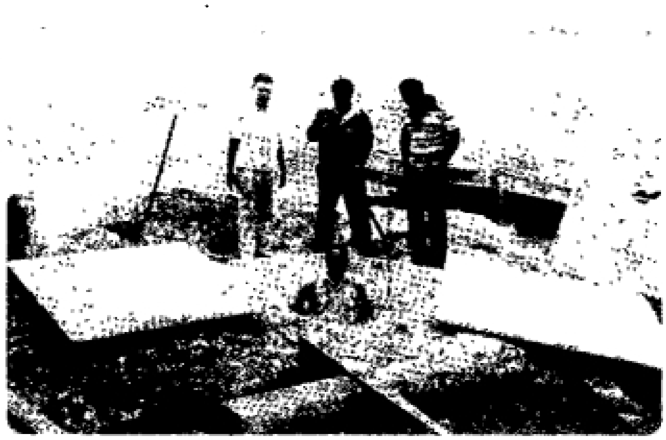
DIGGING AFTER THE RISER BOARDS ARE INSTALLED

THE MAIN SLAB IN PLACE

FINAL INSPECTION FOR AIR LEAKS

THE NEW AND THE OLD

A NEW V.I.P. FOR A NEW SCHOOL



A BEACH SAND UNIT UTILIZING SAND SLABS

THE POUR FLUSH LATRINE:

General:
The pour flush latrine is also known as a "Philippine" and a "cup and saucer". It provides all of the advantages of any water seal toilet without the complications required in the maintenance of a flush tank. There are no flies, no odors and no fear of children falling through the seat as with the VIP. The unit can be constructed next to or inside the house which will encourage its use. It should be noted that the best latrine in the world is of no use if not used. Children especially should be encouraged to use the latrine.

Water should always be piped to inside the pour flush latrine house.

High ground water:
If the groundwater is within 0.6 meters from the top of the ground the high ground water model should be used. See the special section in this report that discusses this problem. Models of this type have been succesfully tested where the groundwater was within 0.1 meters from the surface of the ground.

Construction:
The precast ferrocement construction kit contains everything that is needed to completely assemble the unit except for the labor. There is no need to search the stores for materials that have been sold out. The precast concrete will last indefinitely, there will be no rot, no mold, in fact the concrete will gain strength every year that passes.

If ground water is encountered while digging the pit a well can be dug and the water can be used to flush the latrine.

Construction is started by digging the form for the foundation ring. This ring reinforces the edge of the hole to help prevent caving in and makes the pit absolutly sealed air tight to the ground. When the foundation is poured the riser boards are set in the fresh concrete to receive the main slab after the concrete is hardened. The riser boards must be set perfectly level and square. Level must be checked by the use of a carpenters' level and square should be checked by diagonal corners are exactly the same. If there is any question of the builders' ability to do this it is better to gently set the main slab on and adjust while the concrete is fresh. The main slab must be carefully sealed to the riser boards using a sticky mortar. This can not be done from inside the pit as with the VIP but must still be done well to keep flies from entering the pit.

The house is then assembled using the stainless steel tie wire. The seat and riser pipe is mortared on the outside only which is sufficient to hold it it place, or if a ceramic bowl is used it is bolted to the main slab. The door, which has been custom prefitted with the hinges on the side piece, is installed. The earth is slightly mounded near the walls so that any rain will flow away from the unit and aggregate, small rocks or some form of protection is placed where the rain will fall from the roof so it will prevent any washing or erosion.

The inside surface of the house is made with a perfectly smooth surface that can be painted if desired.

Piping water inside the house ensures that water is available for hand washing. This hand washing after use is very important and the woman in charge of the of the home should see that this is done.

The pit should be dug as deeply as experience has shown the surrounding ground to safely stand over a period of time. The depth of the pit directly affects the expected life of the pit. The years expected life of the pit using the standard size unit may be computed by the following equation:

$$\text{Years pit life} = \frac{1.370 \times \text{depth meters}}{0.040 \times \text{number of people using}}$$

HOUSES FOR VIP'S, POUR FLUSHES AND SEPTIC TANK SHOWER HOUSES:

Precast fibrous ferrocement houses cost more than a house made of salvage materials, but only very little more than a house made of new materials. Houses made of wood or made with wooden framing material will start to rot within a few years, sooner if the unit includes a shower or if the floor is flushed out with water to clean it. The precast concrete house presents an acceptable appearance and can be placed nearer the home. This materially increases the probability of use.

The precast ferrocement construction kit contains everything that is needed to completely assemble the unit except for the labor. On the septic tank shower house unit complete prefabricated piping and all fixtures are included. There is no need to search the stores for something that always seems to be "finished". The entire house is constructed of precast fibrous ferrocement parts except the door which is timber. The inside surfaces of the walls and roof are cast on formica which creates a surface smooth as the formica on which it was cast and cleanable as only a perfectly smooth surface can be. Paint can be applied to the surface as desired. Mold or rot cannot happen. Concrete will not rot or mould unless something foreign is on the surface. In fact the concrete will gain strength every year that passes.

The house is assembled using the stainless steel tie wire. The door, which has been custom prefitted with the hinges on the side piece, is installed.

SEPTIC TANKS:

General:
The purpose of the original prefabrication of the fibrous ferrocement precast septic tanks was to have a tank that could be erected in high ground water conditions. The pictures show typical situations in the Nuku'alofa area. The hole can be dug, usually some pumping or bailing is necessary, but if left overnight, the hole fills with water and repumping is necessary (see picture showing this). The prefabricated units allowed rapid construction and completing the job within hours overcame the water problems.

When these tanks are installed in these conditions, where the effluent discharges directly into the groundwater, treatment of the effluent in the "unit operations" sense is not possible. Preventing exposure of the effluent to humans or animals is possible and is the only alternate, found to date, that is both possible and practical. The object of the "treatment" thus becomes preventing exposure of the effluent while nature does its work and the pathogens die a natural death. It is believed that the resultant biological activity will mature into a system which will give full treatment but this has not been investigated. Further study of the happenings in this type of system is recommended.

The tanks are manufactured in two sizes 128 cu.ft. (3622 l) and 200 cu.ft. (5660 l). The 128 cu.ft. size is for the normal single family dwelling. The 200 cu.ft. is for commercial and school use. At least 20 small tanks are sold for every large tank. This fact is making the continued manufacture of the large tank questionable as the unit costs for the molds are therefore high.

The tanks are sized on the basis of the time in years before pumping out is required in the average home. Smaller tanks could be used and some mathmaticians could show them to be more economical. We believe the larger tanks, with around 10 plus years pump out periods are warranted. Since no inspections of the tanks are made the first sign of trouble is that the toilet won't flush properly. Unfortunately by this time solids have carried over into the soil absorption system and have lowered its capacity, probably forever. Fortunately experience shows that the capacity will recover enough to function properly. The "pump out problem" is that once the owner realizes that the tank requires pumping out there are a series of events that must occur. The first event is the decision that the tank requires pumping out, then he has to go to the Ministry of Works, pay a sum of money, wait sometimes up to two days, remove the concrete lid on his septic tank, wait while the pumper operates, remortar the lid back on the tank and clean up the mess. These events are difficult and the value of not repeating them oftener than absolutely necessary is difficult to estimate. A guide to size of the tank cannot be found in the literature as there is no reasonable agreement of the sizes required by codes in different places in the world nor the pumpout times desirable.

Our pumpout times are based on a yearly storage requirement of 40 liters per person contributing adult and half of this for a child. Additionaly one day's flow volume is reserved to make the case ideal. The latest census indicates an average family of 6 persons, two of which may be considered children or an equivalent storage requirement for 5 adults. (Our original calculations were based on 7 persons per family.) The average pumpout time in years is for an outside unit:

$$\text{Pumpout time in years} = \frac{(3622 - (5 \times 82)) \times .8}{5 \times 40} = 12.8 \text{ years}$$

The 3622 is the total volume of the tank which is reduced to 80% of this to allow for air space. One daily flow volume at 82 liters per day per person is subtracted from this. This calculation is about as rough as a calculation can get but yields a concept at least. Time of testing has not allowed this pump out time calculation to be varified.

In the larger unit for schools and commercial use the daily flow is the controling parameter. The sizing formulas need not be discussed in this paper.

THE SEPTIC TANK SHOWER HOUSE:

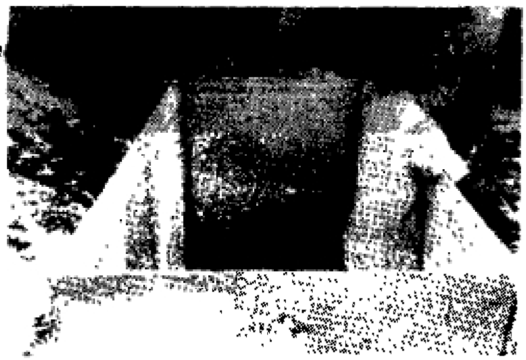
General:
The septic tank shower house is an ideal unit for Tonga, particurlarly Nuku'alofa for the following reasons:

1. It is an all concrete structure, will last indefinitely.
2. It can be kept clean.
3. It is economical to build. Units constructed of concrete block are considerably more expensive. Further contributing to its economy is the fact that the septic tank forms the foundation and floor for the structure. In late 1985 the cost of the erected unit ready to use was $750.00T ($520.00 US) using government prices and castings from the MOH plant operated under the National Sanitation Program.
4. It can be constructed in any location desired, attached to the house or, as is more often preferred, may be erected away from the house.
5. It has a high ground water adaptation. For a few extra loads of quarry material and labor to build the soil absorption system it has proved itself to be ideal for the high ground water areas around Nuku'alofa.
6. It can be ready to use only a few days after the order is made.
7. It is an engineered unit. All worry about working properly, or working at all, has been taken from the hands of the individual plumber building the structure.
8. It is as modern a toilet block as the ones in New Zealand. A flush type toilet may be used, even though the pour flush bowl uses less water and has less maintenance. Also included are a porcelain handbasin and a shower.

Features of construction:
The entire unit is constructed of precast fibrous ferrocement parts except the door which is timber. The inside surfaces of the walls and roof are cast on formica which creates a surface smooth as the formica on which it was cast and cleanable as only a perfectly smooth surface can be. Paint can be applied to the surface as desired. Mould or rot cannot happen. Concrete will not rot or mould unless something foreign is on the surface.

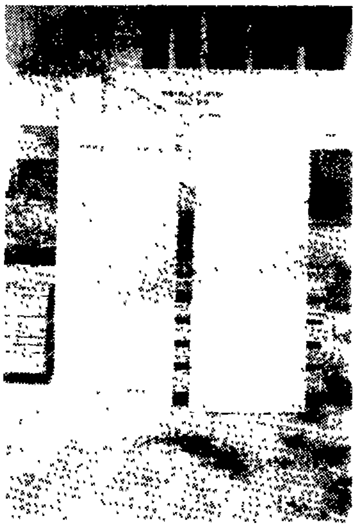
No drainage plumbing in the usual sense exists. The floor is formed in two shower pans which drain directly into the septic tank. The toilet flushes directly into the tank through a vertical pipe extending to the center of the tank.

The soil absorption system utilized in normal soil conditions is the seepage pit type. This is formed when drain gravel is used under the base slab of the tank to level it and used to fill the excavated space around the tank up to just under the surface of the ground. The standard soil absorption trench system could also be used in case there is only a limited distance from the bottom of the pit and the ground water and the ground water in the area is to be used for drinking. This



READY TO MORTAR THE CORNERS

LEVELING THE BOTTOM SLAB



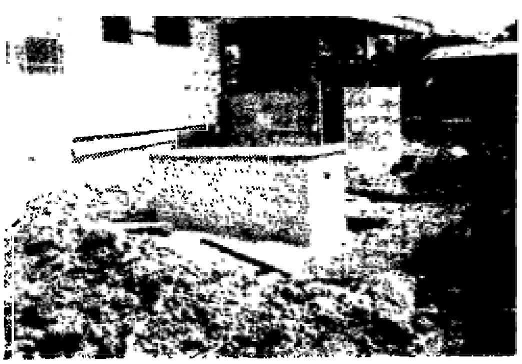
PREFABRICATED DOORS

PREFABRICATED WATER PIPING

EFFLUENT DISTRIBUTION

HOUSE ASSEMBLY

THE COMPLETED TANK



AN INSTALLATION IN A FLOOD PRONE AREA

IN THE RAINY SEASON THE WATER WILL RISE TO THIS MANS FEET costs a little more construction labor and in Nuku'alofa is not necessary; therefore the seepage pit type is normally used.

In high groundwater areas the dose rate of the effluent to the absorbing soil is lowered to one quarter the dose rate for normal soil. In Tonga a high groundwater area is anywhere the groundwater, which is the top surface of the freshwater lens, is encountered during the excavation of the tank. In some locations being settled the groundwater is at or even above, in exceptional cases, the surface of the ground. The recent raintalls and tides also affect this water level. Note the pictures of construction of the units paying particular attention to the groundwater level which is visible even in the pictures. The methods and reasons for the construction features of the high ground water adaptation of this unit are discussed elsewhere in this paper.

THE HIGH GROUND WATER POUR FLUSH:

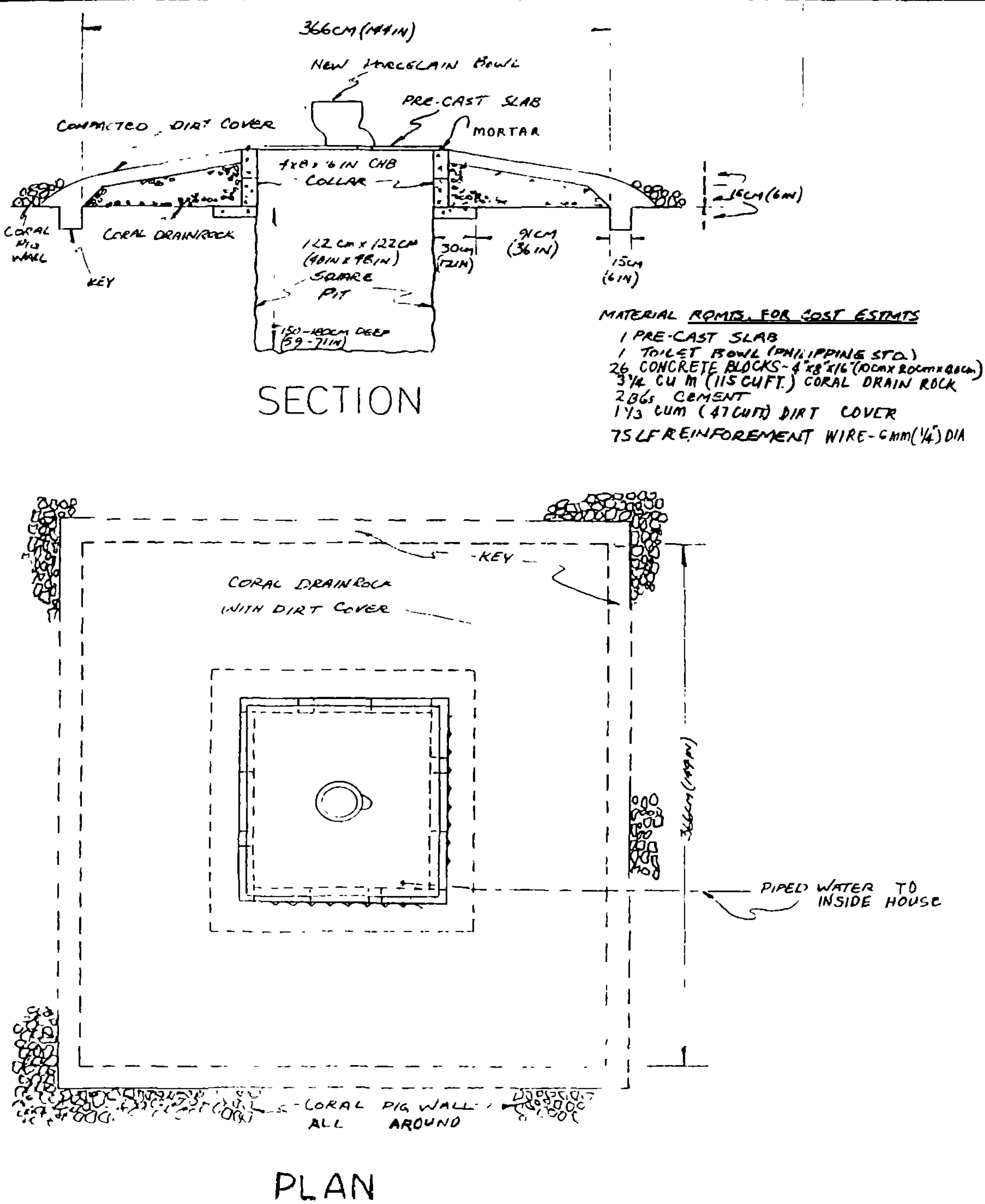
The high ground water pour flush was developed to provide a unit that could be used in the swampy areas currently being settled by the Government of Tonga. Observations of failures in these areas with the standard pour fush systems indicated, as usual, that the ground was unable to absorb the sewage produced. This was because of too high a dose rate or, said in another way too much water is being applied too to small an area. The high ground water pour flush allows a lower dose rate and has proven successful in these difficult areas. The dose rate used is 10 liters per day per square meter (0.25 gallons per day per square foot) in this design as oposed to the 40 liters per day per square meter (1.0 lpdpsf) normally used.

Note the drawing showing this construction. Special riser boards are used or concrete blocks with the lower layer laid without mortar in the vertical joints. The key with its dirt dam is utilized to confine the effluent to the soakaway area and to prevent contamination of flood waters when they rise above the ground level.

THE HIGH GROUNDWATER SEPTIC TANK SOIL ABSORPTION SYSTEM:

The high groundwater septic tank soil absorption system is exactly the same as the standard system except for the soil absorption system. The difference in the high groundwater soil absorption system is that the dose rate is calculated at 10 liters per day per square meter instead of 40 lpdpsm (.25 gal per day per square foot v.s 1.0 gpdpsf). This requires an area about 6 meters by 6 meters (19.7 ft. x 19.7 ft.) for the average home in Tonga and is used as the standard.

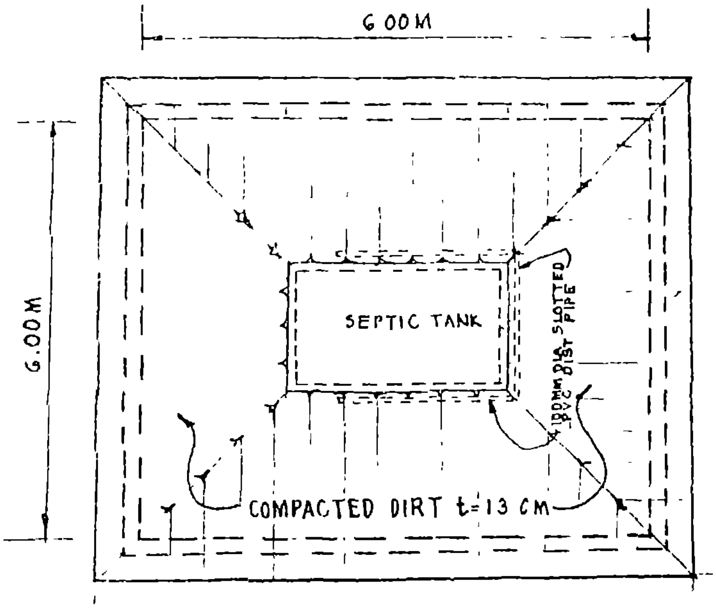
Because this style of soil absorption system is used in swampy areas subject to periodic flooding a dam is constructed around the drainfield to the flood waters on the outside of the dam.



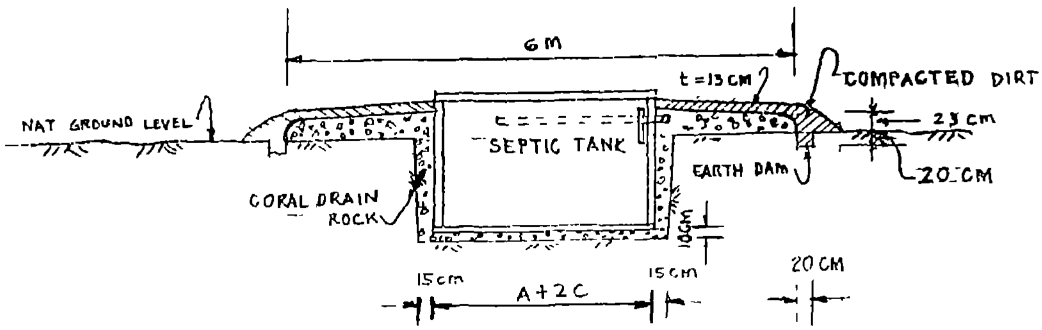
NEW POUR FLUSH LATRINE	
HIGH GROUND WATER AREAS	
APPROVED (MIN OF HEALTH):	DATE: 23 - 8 - 83
L.BELZ	SHT 1 OF 4

The construction of this dam or dike is clearly visible in the pictures. First a ditch is dug to sever all roots and possible root channels. Then clay or topsoil is used to fill the ditch and fill up to the future top of the drain rock level. The area within the dam which forms the soil absorption system. It has been necessary to armor the outside edge of the dam with hand placed rock to prevent damage from pigs. Pigs go straight for this soft dirt, as water starts to rise during a storm or flood, and root for food. As a test fluorscene dye was added to several units on a weekly basis to determine if it could be observed, with the naked eye, escaping from the damed off area particularly during flooding. On one unit, which had suffered pig damage at the dam, dye was observed. No other escape of the dye was seen on any other units.

The top of the drain rock was originally covered with a blanket of cut grass as in a normal drain trench. The thought on this is that by the time the grass rots the soil has enough structure to prevent the dirt from falling into the drain rock thus preventing the free flow of water through it. This is the case if 30mm (1 ft.) is applied but where we are aplying only a few inches when the grass rots the dirt will fall into the drain rock when walked on. We now make a filter on the top layer with rock before the application of the dirt. A filter is constructed by adding rock of a smaller and smaller size in layers until the size of sand is reached. The total thickness of this filter need not be over 4 to 6 inches (100mm to 150mm). The dirt blanket forms a barrier for any smells and furnishes a place for grass to grow.



PLAN



SECTION

SEPTIC TANK SOIL ABSORPTION SYSTEM - SINGLE FAMILY	
HIGH GROUND WATER AREAS	
APPROVED (MIN OF HEALTH):	DATE: 23 8 85
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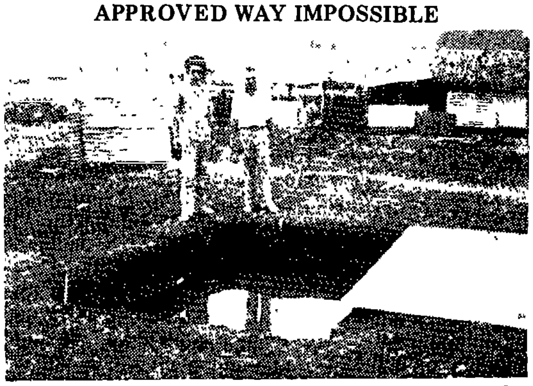
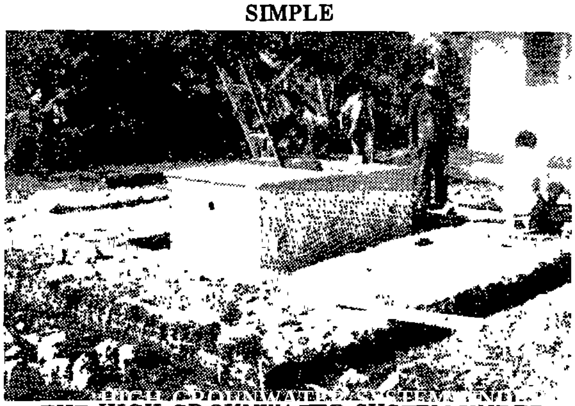
HIGH GROUNDWATER AREAS SUCH AS THIS MAKES EXCRETA DISPOSAL IN THE APPROVED WAY IMPOSSIBLE

THIS HOLE WILL FILL WITH WATER BY MORNING

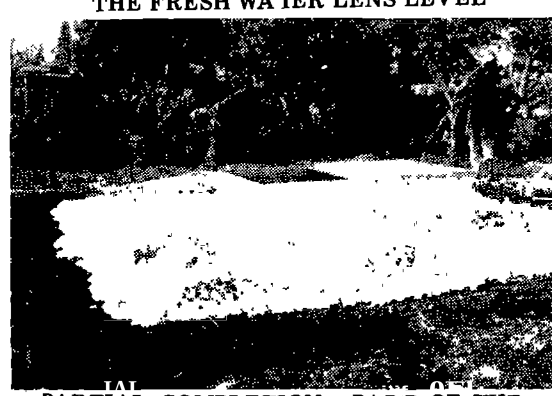


PRECASTING MAKES THIS INSTALLATION SIMPLE

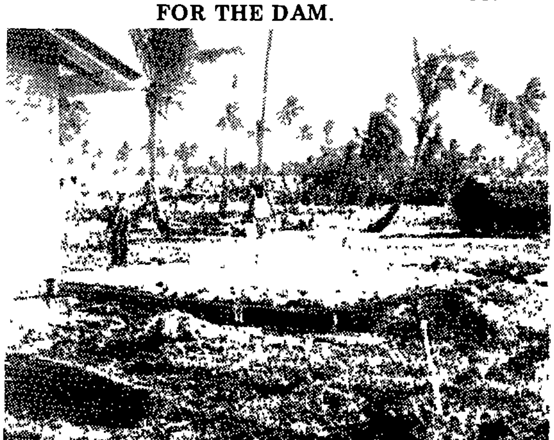
THE NEXT MORNING. THE WATER IS NOW AT THE TRUE GROUNDWATER LEVEL THE FRESH WATER LENS LEVEL



THE HIGH GROUNWATER SYSTEM UNDER CONSTRUCTION. NOTE THE EXCAVATION FOR THE DAM.



PARTIAL COMPLETION. PART OF THE DRAIN ROCK AND PART OF THE DAM HAS BEEN COMPLETED



THE DAM HAS BEEN COMPLETED

THE COMPLETED SEPTIC TANK SHOWER-HOUSE UNIT. NOTE THE PIG PROTECTION ROCKS AROUND THE PERIMETER OF THE MOUND

THE 5000 LITRE RAINWATER STORAGE TANK:

The 5000 liter rain tank is an adaption of the "Cook Island Modular" tank. The design and methods were used directly but with some modifications.

The corners as described demanded a degree of carefulness that required careful and constant supervision. This was overcome by a change in the corner design. The vertical corners are poured using 6" (150mm) drain pipe that has had one quarter cut out. One piece is placed inside and one piece outside the tank. The two pieces of pipe are held in place by continously threaded bolts and nuts. approximately 8" (200mm) long, spaced at about 50cm intervals.

The bottom joint is made using board forms inside and out that allows pouring this joint also.

Alternate design tanks currently being constructed which use wire only for reinforcement (no fiber). They are made in a cylindrical shape and can be produced for a unit cost of storage of about one half of the costs of the fibrous ferrocement tanks. The fibrous ferrocement tanks, which are cast under controlled factory conditions and assembled with experienced supervision are of a considerably higher quality.

It appears that, given the current zeal for village participation without limiting it to quickly achievable skills, only time and experience will prove the superiority of factory production, and even possibly the economies of a rain water storage tank with a higher initial cost.

THE RAINWATER STRAINER:

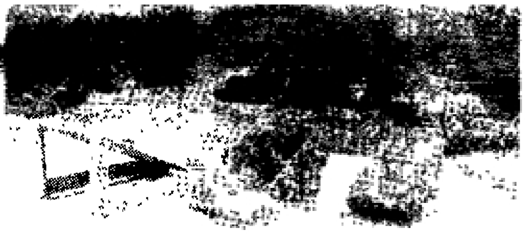
The development of a suitable rainwater strainer was a long overdue event. For years people have realized that rainwater is the cheapest and best source of water for the smaller Pacific islands. This is particulally true where the rainwater can be supplemented with ground water. Rain water storage was not as easily done in times past as it is today. The introduction of several kinds of construction techniques for ferrocement rainwater storage tanks has finally opened the door to the harvesting of this perfect resource. It is shameful that such a wonderful resource is, in its harvesting, so often degraded by ignorance and neglect. Most rainwater storage tanks are not mouse proof, none observed before the installation of this strainer have been mosquito proof. Water with dead mice floating in it and mosquito larve swimming around in it should not be accepted as suitable for human consumption. Straining systems which are not at least to some degree self cleaning may serve as a retainer for any garbage that may have found its way from the roof to the strainer. Fresh rainwater will have to pass through this garbage. Periodic cleaning is required for any strainer but some degree problem on new ferrocement tanks is as simple as supplying and installing the strainer as described herein coupled with an educational program. The older tanks may be more of a problem, especially the large village tanks, but they certainly should be corrected.

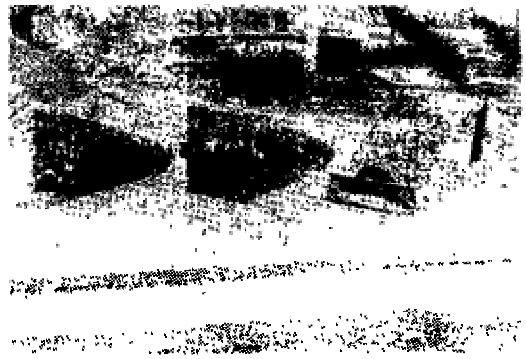
The materials cost of this strainer, utilizing stainless steel screen, is under $15.00T ($10.40 US). The useful life of the strainer which utilizes only stainless steel and concrete should be indefinite. The addition of fiber to the mix makes the strainer more resistant to cracking and is desirable, however any wire may be substituted for the fibre. There is little further excuse for drinking substandard rainwater.

An educational program should accompany the installation of the screen. The roof must be regarded as a catchment area and kept clean and free of vines which harbor mice and rats. Mice and rats can transmit Weils' disease, through their urine, to humans. Chickens that walk around on the roof should be killed. The screen, while mostly self cleaning, will require an occasional assist and inspection. The plate on which the screen is installed must be properly sealed with mortar to the tank itself. Any holes in the tank must be plugged or screened. Health inspectors during their village inspections should be particularly observant of these points.

The strainer is constructed in two operations. First the strainer body and screen are cast using the metal mold. The use of the steel mold makes the casting nearly fool proof and good dimensional control is obtained. The screen is preformed and placed in position then held there by wooden pins during the initial placement of the mortar. When in use there are essentially no stresses expected except thermal stresses so minimal reinforcement is necessary. We use steel fibre but any steel wire may be used, placing it along with the mortar. Second the completed strainer body is cast into its base. The baseplate must be designed to fit the exact tank onto which the strainer is to be fitted. Sloping tops and varing horizontal angles of pipe delivery must be accomodated but are easily within the skills of a clever workman. Note that the hole through which the screened water will flow is only approximately 2 inches by 5 inches (50 mm x 250 mm). This is done for two reasons. The first, is to keep sunlight out of the tank since this will produce green alge, the second is for strength.

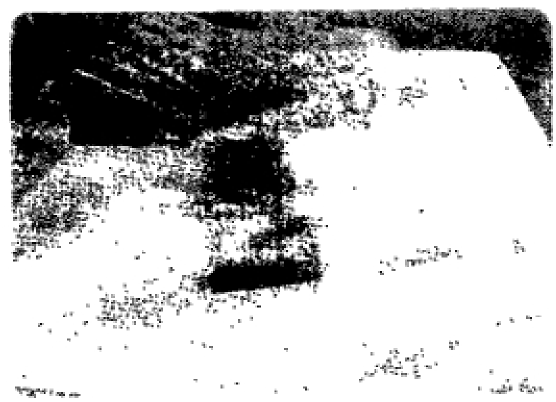
Stainless steel screen is used for the rainwater strainers. The cost is about 7 times as much as aluminum wire but the stainless screen is much heavier and should last indefinitly, even under the corrosive island atmosphere. It is ordered in 48" width so it can be cut to the 8 inches (200mm) width as required for the individual screens without waste. This wire can be ordered cut to size, the cut size is 8" by 14" inches(200 mm x 356mm). It should be specified as "stainless steel standard grade wire cloth-type 304, 16x16 mesh per lin inch, .018 inch wire diameter.





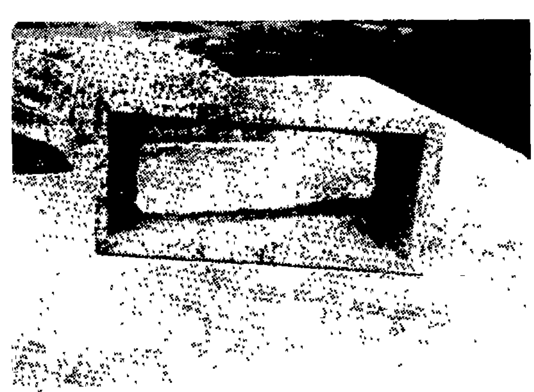
THE THREE PIECE STEEL MOULD. THESE MOULDS COST $100.00US

THE STRAINER MOUNTED ON A PLATE READY TO INSTALL



AS PULLED FROM THE MOULD

A COMPLETED INSTALLATION



AS PULLED FROM THE MOULD

THE LAYOUT OF THE PRODUCTION PLANT:

The precasting of ferrocement products is in reality a series of material handling problems. The equipment selected to efficiently handle the heavy products through their production paths must be related to the volumes to be handled and are limited only by the ingenuity the designer can employ. For our combination of budget, labor costs, and capital available the monorail system seems to be the best. For the design of other new plants some original thinking and study will prove very rewarding. One of the controlling factors is how often a fork lift is available. In our plant the fork lift is normally used only for loading out pallets of components onto trucks for transport to the erection site. Other than this it is used only about every two months to rearrange or transport to storage the full pallets.

The flow pattern can be seen by looking at the pictures. The aggregrate is dumped at one end where it may be screened if required. The aggregrate is then measured by volume and dumped into the mixer. From there it is cast on the vibrating table and transported by monorail for overnight curing. After removal from the forms the pieces are stacked on individual pallets. Each pallet stores only identical pieces. When the pallets are full they are transported by fork lift to a less active part of the yard for storage and further curing until needed.

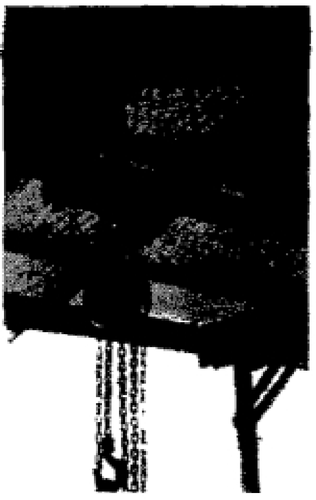
All other materials to be used are brought from storage and stacked adjacent to where they will be needed on the production line. Only the amounts that can be easily transported are taken at one time and never more than one days supply.

Mold repair requires a section of it own and once the plant is in operation is something that must be continued almost every day. The mold maintenance shed is not visible in the picture of the overall plant. The same shed is used for prefabricating piping, constructing doors and other minor tasks.

The storage section where the pallet loads are stored for curing and use requires a sizable area. The layout should be carefully planned.

CASTING PROCEDURES:

In the typical casting the cleaned and prepared mold is placed on the vibrating table. Reference is made to a formula book, the proper volume of materials are measured into the mixer and the high tensile wire as required is cut. In all flat castings one half of the total volume is mixed at one time, side, end or bottom. According to the piece the placement of



HOIST AND TROLLEY

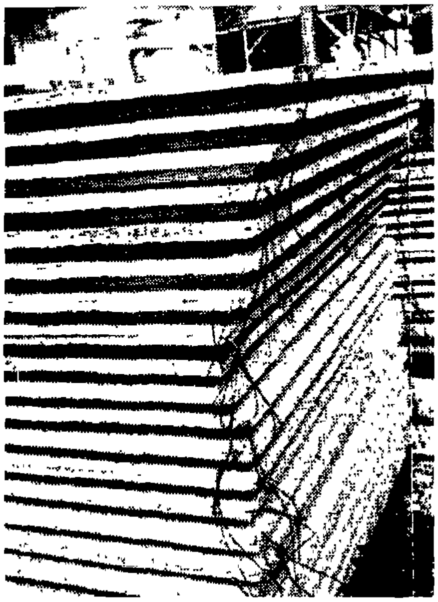
CASTING YARD

FEEDING MIXER

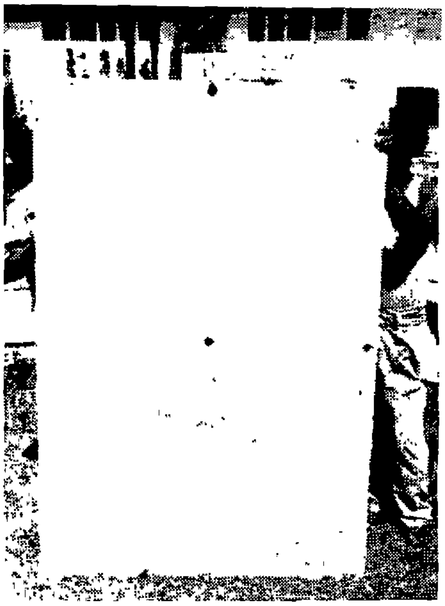
MOVING MOLD TO CURING STACK

STACKING PANEL AFTER REMOVAL FROM MOLD

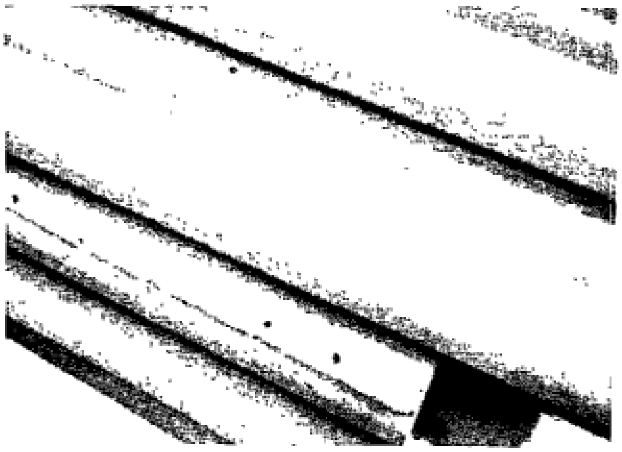
TRANSPORTING PIECE FROM MOLD TO YARD



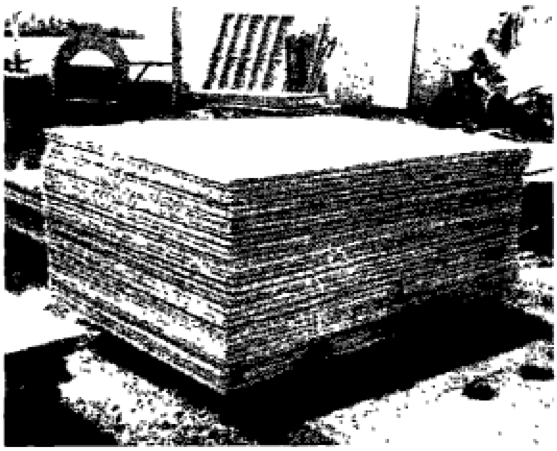
SEPTIC TANK SIDES.
NOTE CONSTRUCTION TIE WIRES



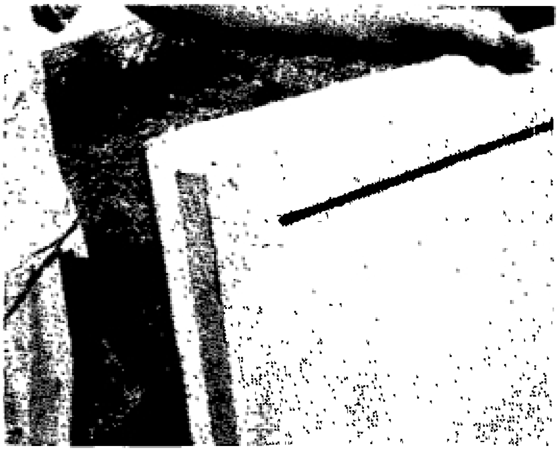
BACK PANEL SHOWER HOUSE



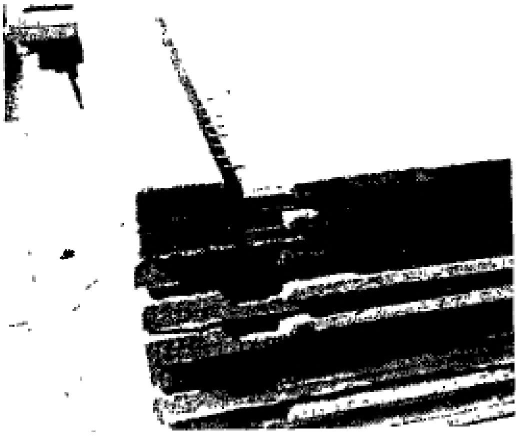
FENCE POSTS



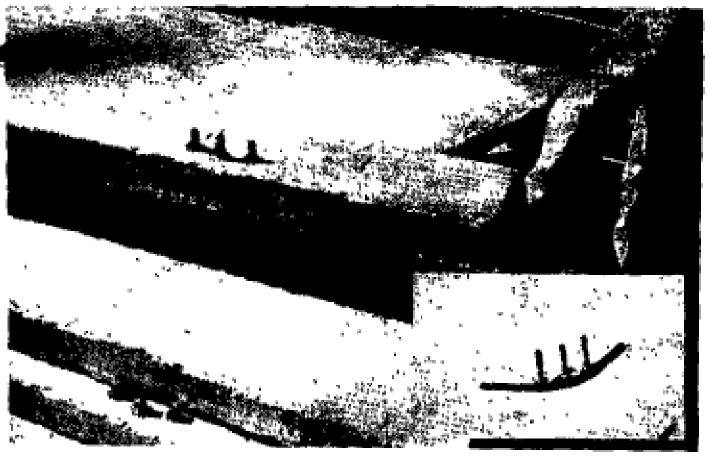
V.I.P. SIDES



SEPTIC TANK END PIECE



SHOWER HOUSE ROOFS

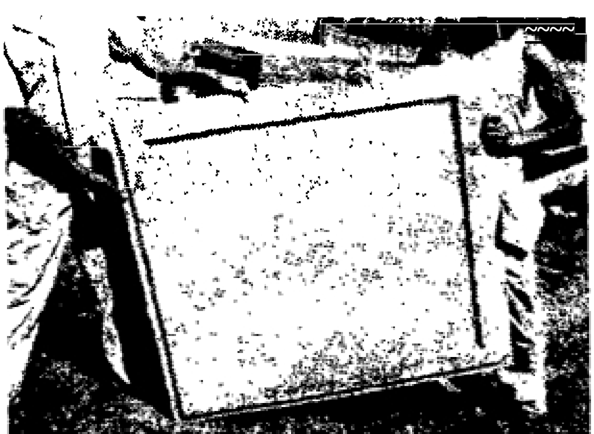


DOOR PANEL. INSET SHOWS BOLT ASSEMBLY

FRONT PANEL FOR SHOWER HOUSE

CONVERTIBLE RISER PIPES

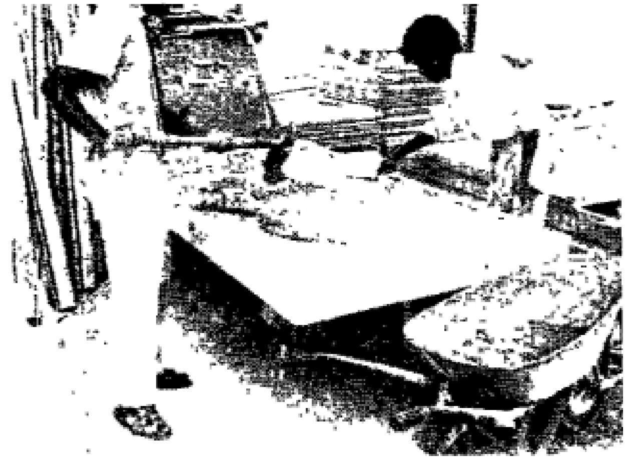
WOODEN SEAT ATTACHMENT BLOCK



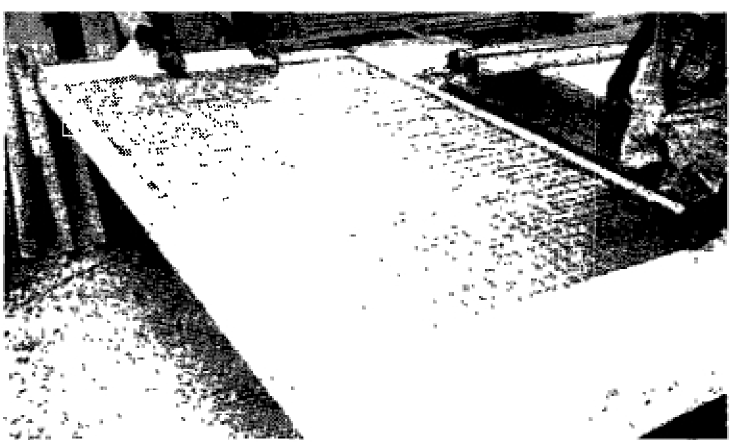
SEPTIC TANK END PIECE

SHOWER HOUSE FLOOR PAN.
HOLES ARE FOR DRAIN
AND TOILET PIPES

THIS IS FIBRE STEEL



PLACING SECOND LAYER

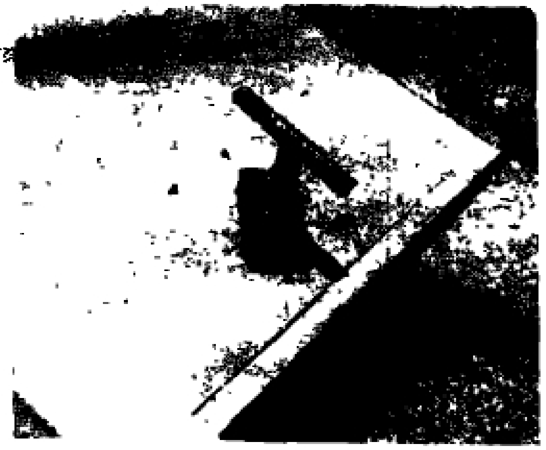


PLACING WIRE ON FIRST LAYER OF MORTAR

MAKING HOLES FOR ASSEMBLY TIE WIRES

HOLDING MOLD WHILE VIBRATING

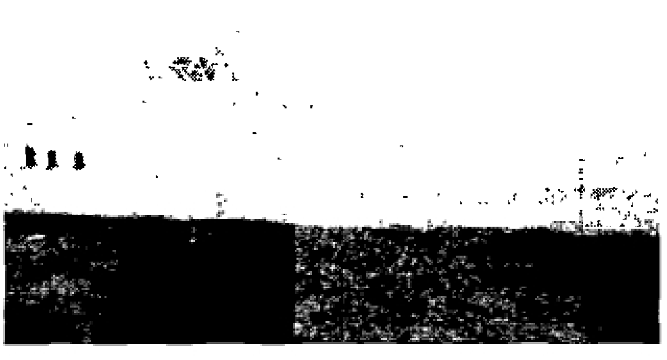
PLACING WIRE IN FENCE POSTS. THREE LAYERS ARE USED



THE RISER BOLT. A BASE PLATE WITH 4 SCREWS IS BETTER

NOTE THE EDGING FOR THE WATER TANK SLAB, THIS ALLOWS THE WIRES TO PROTRUDE

THE RISER BOLT AFTER USE



NOTE THE SURFACE QUALITY FROM THE WAXED FORMICA

THE UNDERSIDE GROOVE MOULD FOR THE SHOWER PANS the concrete to the level of the first high tensile wire is made, smoothed with a trowel and vibrated. The wire is placed and the process repeated until finished. Vibration must be thorough, there is no need to worry about overvibrating as nothing can be harmed since nothing is going to move as far as we have been able to determine. The exposed surface is finished with a steel trowel. If the exposed surface will be an exterior surface exposed to view as in the VIP house it is rolled with a 150mm pipe to provide a dippled surface. This is more pleasing to the eye than a steel troweled finish, especially if not perfect. At this point holes are put through the wet concrete with a piece of wire. These holes will eventually be used for the stainless steel tie wire which will bind the assembly together. The mold is then left to cure until the next day.

The following day the lifting screws are used to break the piece away from the mold and the piece is lifted and stored on a pallet with others of the same size. The curing time at this point is usually about 16 to 18 hours.

The mold is then cleaned, waxed or oiled and the process is repeated.

STORING AND HANDLING CASTINGS:

Castings are transported to stacks utilizing a specially constructed truck. This truck was made using two pneumatic tire wheel barrow wheels. Transport of these pieces can easily be done by one man even over the rough surface of our yard.

Castings are stacked on wooden pallets for handling by fork lifts. Our cement comes stacked on pallets which are used for this purpose.

MOLDS:

The stressed skin type plywood molds currently being used are the end result of many trials, improvements, and developments. The principle is directly copied from the stressed skin plywood structural system developed in the United States by the Plywood Research Institute. Before the materials handling systems improvements the molds were set up so that three 1 1/2 inch galvanized pipes could be threaded through the mold base and six strong Tongans could lift and move the loaded mold. Some molds were tried with plywood only on the top side but were floppy compared to the same molds with plywood on both sides. The plywood on the lower side does not increase the mold cost more than 10 to 25%. It does give a solid surface to set the mold down on both for the vibrating table and to store, even as stacks of molds, for curing.

All of our new molds are being built the same way. A frame like studs and plates for house construction. It is recommended that all joints be glued before nailing. The completed frame which is constructed to the size of the finished mold, is then checked for flatness by laying on a perfectly level floor and using a straight edge to locate any high spots. These high spots are planed off, the frame turned over and the process repeated. Unto this flattened frame 5/8 inch (16mm) plywood is glued and nailed to both sides. The plywood used is not critical. We have used marine, exterior, 5/8 inch, 1/2 inch, and 3/4 inch but find the 5/8 inch about the best. Whether marine or exterior was used has been determined by price at the time of construction and what is available in the Government Stores at the time. We have experienced rotting of the plywood necessitating the replacement of the mold after two years when using untreated plywood. Because of this the use of plywood treated to prevent rot is recommended, unfortunately it has not always been available nor has the paint on types of treatments such as pentachlorophenol.

The filler panels to produce the thinner sections are constructed of plywood of the proper thickness. The most critical point in the assembly of these panels is the absolute watertightness at the point where the panel joins the base plywood. If any concrete can start to gain access to the opening the opening will "grow" larger and larger until the mold must be repaired. When the concrete can flow into a crack the breaking out of the finished piece gets very difficult and the quality of the piece suffers.

The edges are usually constructed of a 1 x 6 (25mm x 150mm) screwed or lagged to the 2 x 4 mold edge. These edge pieces will gradually warp away from the mold at the joining point allowing concrete to penetrate the crack making breakaway of the piece from the mold very difficult. We find it necessary to reverse these pieces every two or three weeks. This puts the warped curve tight against the edge so that no mortar can penetrate the crack. Placing a small filler strip at the lower edge of the 1 x 6 will force the top edge tightly to the mold.

EQUIPMENT SPECIFICATIONS:

Concrete Mixer:
Bowl capacity: Upright position 5.375 cu. ft.(150 l), Mixing position 3.0 cu. ft.(85 l), delivering 3.0 cu ft. mixed concrete. This size mixer has proven satisfactory for all our formulas. We use a steel wheeled, electric motor driven model.

The mixer is a Model Number E302-PW supplied by:

Fowler Industries Ltd.
557 Rosebank Road
P.O. Box 19050
Auckland 7, New Zealand

Vibrating table:
A well engineered commercial standard vibrating table is an absolute necessity. The table presently being used does a good job but the small size of the table (620 mm x 1250 mm), when carelessly loaded, allows the piece being cast to become something less than perfectly level and thus the concrete flows to the low end giving a varing thickness. This necessitates rotating the piece during the vibration process. The piece must be cast absolutely level to say within 10 mm variation in 1500 mm. Were a new table to be purchased the size of the table should be carefully studied with the larger table being considered better. The actual strength of vibration is sufficient with the model currently being used.

The table being used is a Model 302, Series 85.
It was manufactured by (direct purchase is recommended):
Triton Engineering Co., Ashford, Kent, England.
It was supplied by:
Crown Engineering Co., P.O.Box 18/294, Auckland 6, New Zealand.

Monorail, trolley and hoist:
The handling of the heavy precast pieces in their molds was at first done by hand but to be done properly required 6 strong men and even then, as in any heavy lifting operation, was hazardous. Further there were times that 3 men were all that were effectively needed for the casting operation. This was overcome with the monorail system but one weakness with our present plant is that we do not have sufficient length to the rail to allow the handling and storing on sorting pallets of the cast pieces as they are being removed from the molds. Doubling the existing length of the rail would be advantagous. The monorail was constructed from angle iron to match with the trolly which was obtained from salvage locally. The beam design for each installation will be an engineering problem as to the space between the supports and the size of the beam. The hoist is a standard one ton chain hoist.

PROBLEMS AND PRECAUTIONS:

Simplicity:
Simplicity is the number one requirement. Complicated procedures are guaranteed to fail, whether the resultant failure is serious or not is a matter of luck. Habit and repetition are the best allies. If there is no provable, obvious reason for a step eliminate it. Be harsh on this point.

Mold maintenance:
There is a natural tendency to try and get another pour out of a deteriating mold. What results is an inferior product. Close watch must be kept on the molds and when they need

repair they must be pulled from the production line and fixed.

The most common mold problem is the creeping of mortar into cracks either between the filler panels and the base sheet or along the edge boards as they become warped. Also, if the formica is not properly glued and beveled at the edges the mortar will be vibrated into the crack, make a bulge and make pulling the precast difficult. Perhaps in time a solution to this problem will be figured out but for now prompt mold repair is all that can be done.

Erection site storage of precasts:
There seems to be a tendenancy, when unloading the precasts at the erection site, to lay each piece by itself and for people to want to walk on the newly unloaded pieces. This will usually crack the thinner pieces. The unloading crews must be instructed to pile the pieces in no more than two or three piles. Also care must be taken in the instruction of the unloading crews to instruct them not to stand the pieces against posts or trees as children playing can easily push the pieces over with possible tragic results.

Water piping:
P.V.C. water piping is used exclusively. It was noted in followup inspections, which were made every year for three and sometimes more years, that about one joint in three was leaking to some degree. This varied from just enough to grow alge to drips. Investigations showed that the workman joining the pipes had never been instructed in the proper joining techniques as recommended by the manufacturer. Typically the workmen were just doing what they had seen someone else do. No particular care was taken that the joint was clean and dry and that the glaze had been removed or that at least several hours passed before turning on the water. Study of this matter showed that it was extremely difficult to get dry, clean, properly glued joints in the field. Extremely difficult means it simply won't be done. This then indicated that the prefabricating of the plumbing assemblies in workshop conditions was warranted. Jigs were constructed, tradesmen instructed and all piping was prefabricated. The pipes must fit the holes cast into the panels where the pipes are to pass through the panels. The field made joints are kept to the absolute minimum of 3. With properly trained erectors the problems associated with the water piping system are now expected to be over.

Shower and floor drain piping and trapping:
Standard sink or basin fittings are used in the precast floor pans. The hole to receive these fittings are cast into the pans, (see pictures of the floor pan mold ready to pour). Initially half of a standard "S" trap was used as an air seal. This seemed satisfactory but again on follow up inspections trouble was found. The half trap had been broken off the drain fitting which allowing gasses to come up into the room. Small rocks are invariably carried into the house on peoples

feet and end up in the trap which after a few months will become restricted and a few more months become plugged. The owner then, with any stick or rod in the attempt to clear the trap, breaks it off. The solution to this problem was to eliminate the trap completely and replace it with a straight pipe glued into the floor fitting and extending to the half depth point on the septic tank. This is actually the clear zone in the tank so no resistance to flow from the contents should occur and any rocks can fall directly to the bottom of the tank. There will be a few weeks until the tank fills to the halfway point before a seal will be obtained but during this period the drain is kept plugged. The outside of the pipe is a little small for the inside of the hole but the pipe is expanded slightly by heating and a satisfactory joint can easily be obtained.

THE MYTHS ABOUT GASSES AND LEAKAGE:
The effect or importance of gasses and leakage is mostly a figment of someones imagination. There will be gasses and there will be leaks but in the units described in this booklet it is not important to release the gass nor prevent the leaks. Attempts to accomodate these points which are problems only because of someones over active imagination simply serves to create real problems.

Consider the gas problem. A septic tank does generate gasses but in what quantity ? It is not a seathing caldron belching out gases that must be vented to prevent the whole thing from blowing up. The small amount of gases produced, which has been quantified by work with biogas plants, can easily escape through the open pipe to the soil absorption system. There the filtration of the gasses through the earth furnishes an ideal disposal system. The best way to put this problem in perspective is to think of trying to construct such a unit that is gas tight -ridiculous and impossible. The venting of this unit would only convert it into a perfect mosquito breeding station.

Consider the nesessity for a bottle tight septic tank. The construction of an absolutely water tight septic tank would double the cost of a simply assembled precast ferrocement unit. How much difference in system performance will result ? Sewage leaking through a corner or bottom crack would have soon gone via the outlet pipe to the soil absorption system. If this happens to be to a soakaway as deep as the septic tank the difference will be nill. Tests have shown that it takes up to two months to fill a new septic tank of this type. This is because of leakage. Plugging occurs from the contents of the tank trying to escape with the water. Again if the object was to construct a tank that constantly exfiltrated through the cracks it would be impossible to achieve without mechanical cleaning.

AUXILLIARY MATERIALS:

DOORS AND HINGES:

Doors:
Several types and styles of doors were experimented with. Initially precast concrete slabs 3/4 inch thick were tried. These proved much to heavy since in a wind storm if the concrete door slammed shut it threatened the entire structure. The few that were installed were replaced with wooden doors. Next a masonite covered wooden frame was tried but proved weak and easily damaged. This style also was abandoned. Next a door constructed of New Zealand pine, or equivalent, 3/4 inch (19mm) by 6 inch (150mm) pieces was tried. This proved very satisfactory. The door is nailed together and given one coat of primer and one coat of exterior paint. The cost of this door is high but so is the quality. The construction may be seen from the pictures.

Hinges:
It seems in Tonga that doors are never shut unless someone is to be locked out. Doors on sanitary units are no exception. In the VIP the slightly darkened house interior is an important part of the fly control. Because of this the use of spring hinges or screen door hinges was started and eventually used for all doors. The spring hinges also make the doors a bit more resistant to wind damage since they can seldom be slammed hard.

The hinges we are using are: Number 464, Finish zinc, and are manufactured by: Lane Amalgamated Hardware Company, Sydney, Newcastle, Adelaide, Australia.

VENTPIPES:

The vent pipes for the VIP's must be large enough to do the job. We use only plastic (pvc) drain pipes 6 inch (150mm) diameter. These are cut to 8 foot (2438mm) lengths, the odd pieces being joined with the formed coupling that comes on each piece of pipe in order to use the entire length. At first much thought was given to getting enough additional screen area exposed to make up for the area occupied by the wire. The tops of some pipes were serrated with v notches but this made the screen more difficult to install and hold. On some the screen was "puffed up" a little. The best answer has yet to be arrived at but the natural looseness from installing without stretching must help. The inefficiency of ventilation caused by this factor has yet to be evaluated. We now simply cut a square end on the pipe and wire on aluminum fly screen with galvanized soft wire.

WATERPIPES AND DRAIN PIPES:

All water and drain pipes are plastic (pvc) pipes. The most important thing about the pipes is the trouble we experienced with breakage and leakage. Therefore see the previous section in this report entitled " Problems and Precautions".

TOILET SEAT ATTACHMENT BLOCKS:

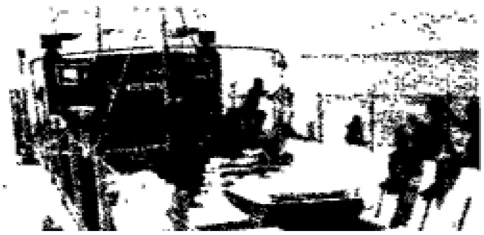
Throughout this report reference is made to wooden blocks. These were used with fair success until we were shown an improvement. (After this report had been prepared.)

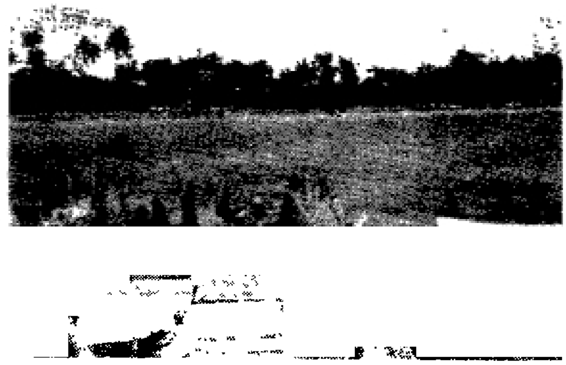
Mr. T. Magno an engineer working as a UNV in Lautoka, Fiji made a very clever and worthwhile improvement by casting the attachment block in mortar while plastering the riser pipe. The block is formed on the plywood being used as the base for the plastering. The size is the same exactly as the wood block. The block is held on by setting in several wires which run along the chicken wire for about 100mm. The holes for the seat attachment bolts are cast in using small pieces of plastic or rubber so they can be removed after the riser has cured.

The use of this mortar seat attachment block is recommended. A wooden block would not be nearly as satisfactory for many reasons.

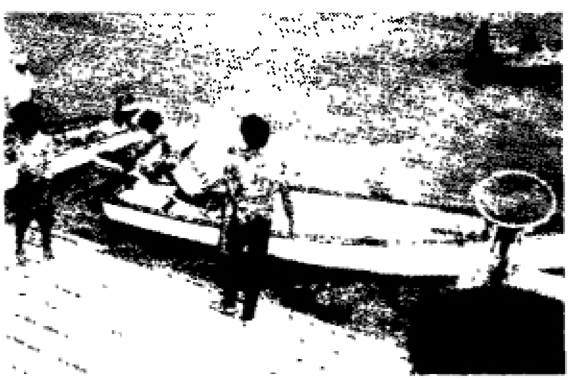
LOADING OUT AT THE CASTING PLANT

LOADING THE LANDING BARGE





APPROACHING THE ISLAND OF 'ATATĀ



SMALL BOAT TRANSFER AT 'ATATĀ

BARGE UNLOADING AT THE ISLAND OF 'EUAIKI

UNLOADING COMPLETED AT 'EUAIKI

UNLOADING COMPLETED AT 'ATATĀ

MATERIAL SPECIFICATIONS:

CEMENT:

Rapid hardening portland cement is used exclusively, (the delivered cost being about the same as regular cement). The use of rapid hardening cement is advantagous in the prevention of breakage at the two critical maximum stress times, first when the cast piece is removed from the mold and second when the piece is transported to the erection site. "Wilsonite" rapid hardening portland cement develops the 3 day concrete strength of normal cement in 1 day and a 28 day strength in the concrete in 7 days. This high early strength prevents untold breakage. There is still ample time to mold the fresh cement, as the initial set time for rapid hardening cement is 2 hours and 30 minutes while for regular cement is a comparable 3 hours and 30 minutes. Rapid hardening cement is a true portland cement, is as long lasting, durable, and as water tight.

The cement is ordered simply as rapid hardening portland cement. We are currently using "Wilsonite Rapid Hardening Portland Cement" manufactured by: Wilson's (N.Z.) Portland Cement Company, C.P.O. Box 1359, Auckland,1,New Zealand.

It is interesting to note that by volume this finer ground rapid hardening cement bulks 11% greater than regular cement. This means that for the same weight of cement in a mix if a volume measure is used it must be 11% greater than for regular cement. More interesting yet is the fact that we did not know this until researching for this paper. This means that we actually have been using 11% less cement than we thought, and still with very good results. Normal portland cement weighs 94 pounds per cubic foot or 1508 kg per cubic meter while this rapid hardening cement weighs 84.7 pounds per cubic foot or 1359 kg per cubic meter.

FIBRE:

Notes:
The steel fibre is weighed out per computation of quantities shown under Section 6 and sprinkled into the mixer by hand, after the aggregate and cement. Great care must be used in sprinkling the material into the mixer by hand to prevent any clumping of the material.

Specifications:
18.0mm x 0.4mm EE Fibresteel in 20 kg cartons.

Supplier:
Australian Wire and Iron
P.O. Box 53
Five Dock, New South Wales,2046, Australia

CONCRETE ADDITIVES:

Initially two concrete additives were used, superplasticiser and air entraining agent. Neither of these agents seemed to have any noticable effect. Yet there can be little doubt that they do have an effect on the ultimate strength and workability of the concrete. Also there is little doubt that their use presents several more problems. The material must be ordered and kept on hand, it must be measured out in varing doses for each mix by someone who is willing to accurately measure and dilute the product. Further it costs money. As pointed out earlier the variable nature of the crushed coral aggregrate, we are forced to use, makes precision in mixing impossible thus making casting experience and observation of the mixing the primary control. Therefore after comparisons of product with and without additives with no visible difference the use of the additives was discontinued. In some other location where different aggregrates will be used the use of these additives may be beneficial. Therefore the specification and supplier is shown:

Superplasticiser:Daracem-FL
Air entrainer:Daracel
Supplied by:
Grace, Industrial Chemicals Division
P.O. Box 17-177, Greenlane
Auckland, New Zealand

FORM RELEASE AGENTS:

Form release agents, parting compounds, and form oil are all different names for a material to provide the same function. In the initial phases of the development of the procedures we started using, as most every one else in the South Pacific, used motor oil. This was not a satisfactory operation. The oil was applied with a paint brush and most often unevenly. The resulting surface was of low quality with numerous air bubbles that were very difficult to reduce by vibration. Later it was discovered that new oil did a much better job, break out was easier and the surface was a better quality. No commercial compounds were tried but the low quality of the surface produced led to the use of formica as a form liner.

Formica mold surfaces produced a much higher quality cast surface but the new engine oil used was still not satisfactory. Eventually waxes were tried, leading to the polished wax procedure which produces the ultimate in surface quality.

Currently a silicone floor wax on the formica surfaces is being used. First the formica is scraped using the flat end of a trowel, then the paste wax is applied, allowed to dry, and then polished as if it were being used on a floor. This procedure is necessary each time the mold is used as some material seems to adhere or combine with the wax which ruins the quality of the next piece if the surface is not cleaned and repolished.

New engine oil is still being used on the wood surfaces with not completely satisfactory results. Perhaps if the wood surface is coated first with an epoxy resin or epoxy paint it too can be waxed and the resulting quality of the casting improved.

HIGH TENSILE STEEL WIRE:

Notes:
The high tensile steel wire is ordered in lengths as long as can be easily shipped, about 6 meters, and cut at the precasting yard. It may be ordered cut to length but keeping the lengths separate and arranged is more trouble than on site cutting unless a large quantity of one size is to be used.

Specifications:
2.0 mm bright, hard drawn, range 2, spring wire, phosphate coated.

Supplier:
Australian Wire and Iron
P.O. Box 55
Five Dock, New South Wales 2046, Australia

STAINLESS STEEL SCREEN AND WIRE:

Stainless steel screen is used for the rainwater strainers. The cost is about 7 times as much as aluminum wire but it is much heavier and should last indefinitly, even under the corrosive island atmosphere. It is ordered in a 48" width so it can be cut to the 8" (200mm) width as required for the individual screens without waste. This wire can be ordered cut to size.

Stainless steel wire is used for the assembly of the precast units. Galvanized wire could be used but the slightly added expense is considered worth the price. As an example in the assembly of the VIP unit 10 meters are required, the current price for stainless steel wire is approximately $1.55 US which is approximately 2 1/2 times the galvanized wire cost. Again considering the pacific islands corrosive atmosphere the cost is considered worth it even though we have no data on the actual life of galvanized wire under these conditions.

Specifications:

Stainless steel standard grade wire cloth-type 304,16x16 mesh per lin inch,.018 inch wire diameter.

Stainless steel wire,type 302,.047 inch diameter,soft temper.

Supplier:
McMaster-Carr
P.O.Box 54960
Los Angeles, Ca. 90054 USA

AGGREGATES:

Tongatapu is a coral island. The only aggregates available are beach sand and crushed coral. In the beginning beach sand was used but the strength of the panels produced was only slightly better than sugar cookies. On analysis it is obvious that all of the particles are the same size after being classified by wave action on the beach. The next step was the mixing of beach sand with the material passing the last screen on the coral crusher. This helped but was an additional operation that required attention and control. This made the elimination of the step highly desireable. Therefore the obvious thing to do was to use the material passing the last screen on the crusher as delivered, a practice which is quite satisfactory and continues today. The material is as variable as the pit being excavated or the difference in the pits being excavated. No control is attempted over the amount of fines or particle size. Every delivery is different. The aggregate pile is exposed to the weather. Each new rain brings differences in water required during mixing. The water added to the mix is controlled by experience any differences in water content of the aggregate is compensated for by the men when mixing the concrete. There seem to be no adverse affects from lack of control of the variables mentioned and the process is greatly simplified. When precasts are being made that require extremely high quality, as in rain water storage tanks, the crushed aggregate as received is put through a 1/4 inch (6mm) screen to remove any large pieces that sometimes can interfere with the troweling process.

MATERIALS COSTS:

In December 1985 the following are the costs of materials used, either delivered to Tonga or at the plant in Nuku'alofa.
Cement, rapid hardening: $T 144.50 (100.34 US)
Fibre steel: $970.00 Aus. per metric tonne.
High tensile steel: $ 1060.00 Aus. per metric tonne.
Aggregate: $ 7.00 per cubic meter.

MIX FORMULAS:

The basic formula used for all panel precasting has been adopted from the previous fibrous ferrocement work on rain water tanks. It may be slightly changed to make the process easier, for example, we use all volume measurements except for the steel fibre which is by weight. Volume measurements do not necessitate adjustments for varying moisture content in the aggregrate. Further volume measurements may be simply marked in plastic or any cheap buckets to achieve accurate formula mixes

The author feels that work needs to be done to optimize the mixes on an economic basis and that most probaby a less costly equivalent product could be made. This effort however is not within our field capabilities and expertise and we who manufacture can do no better than we do.

Each pour has specially measured quantities. A formula is calculated for each piece generally equal to half the total requirement of the piece in order that the high tensile wires can be placed exactly in the center of the slab.

The procedure is:

1. Calculate the total volume of the piece.
2. Set the sand volume equal to the total volume.
3. Set the cement volume equal to half the sand volume.
4. Calculate the weight of the cement. (1 cubic meter equals 1508 kg).
5. Calculate the weight of the fibres in killograms by multiplying the weight of the cement by 0.17.
6. Add water by experience so that that the dryest mix that can be easily worked is obtained.

As previously stated the mix is usually cut in half so that the wires can be placed in the center of the panel. Actually the wires are slightly tamped with the flat of the trowel so that the bottom wire is buried, this places the wire perfectly. From our experience no amount of vibration will move the fibre or the wire.

The only time we change this formula is when precasting fence posts when we eliminate the fibre and use only one cement to four aggregrate. Posts can be made more cheaply by increasing the diameter and cutting out the fibre.

REFERENCES:

1. Alexander, Douglas; "The Widening Applications of Ferrocement"; Alexander and Foore, Consulting Engineers, Auckland, New Zealand.

2. Belz, L. H.; "Nuku'alofa Sanitation and Drainage"; Ministry of Health and World Health Organization, Nuku'alofa, Tonga, 1984.

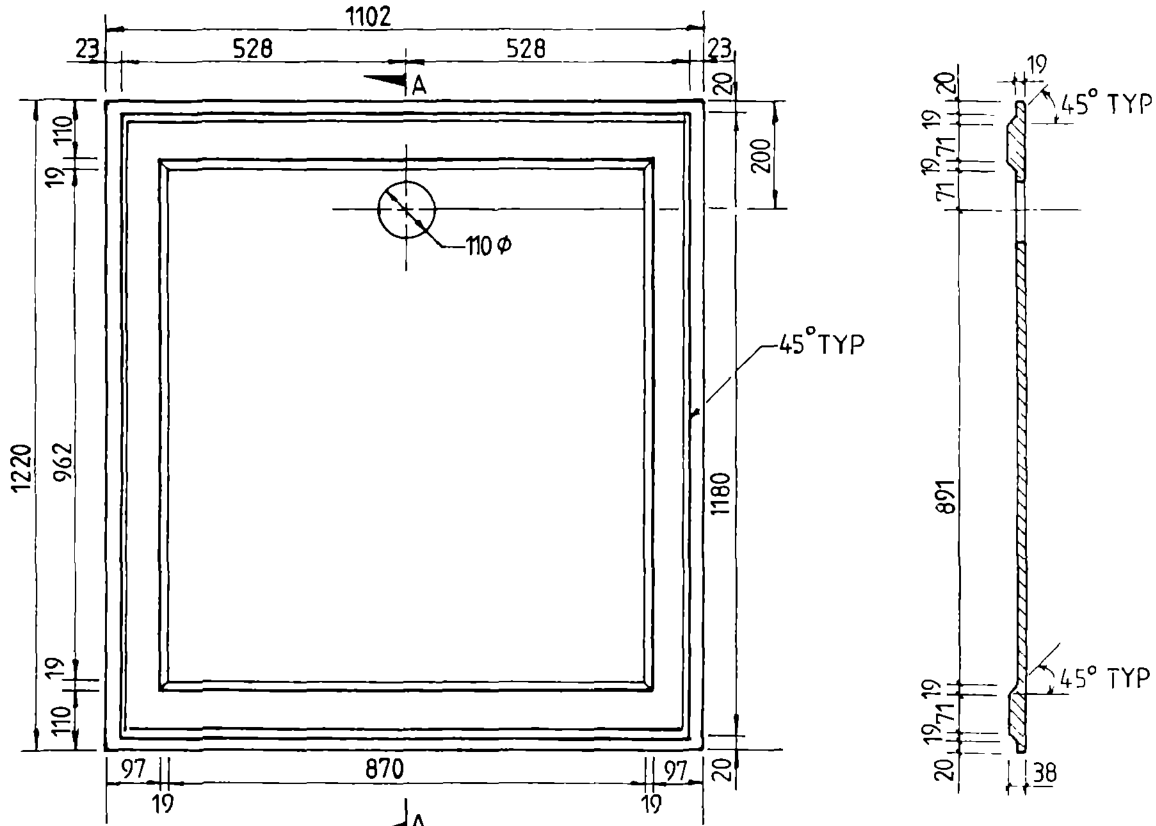
3. Videnov, T., Dekel, E.; "Manual on the Construction of the Cook Island Type Modular Water Tank", World Health Organization WHO/ICP/BSM/001 May 1982, Suva, Fiji.

EPILOGUE:

Education, maintenance, operation, housekeeping, use and objectives:

Nothing will function indefinitely without maintenance. Stationary parts cast from fibrous ferrocement require little or no maintenance over their expected life. Moving parts and parts subject to corrosion, such as doors, valves, flyscreens require constant care. The very people these units are designed to help are the least appreciative of the need for maintenance. The units will fail to perform their function properly if dicipline is not furnished in this area by periodic inspections by public health inspectors. If the health inspectors do not understand the function of the components of the unit or the objectives of the effort or the need for maintenance then building the units is the wrong place to expend resources.

Housekeeping. Keeping an excreta disposal facility clean requires daily care and sweeping or mopping. Mud and dirt are constantly being tracked inside. Misuse of the facility will be common. It is up to the head of the household or the keeper of the household to see that this care is given. It is up to the educators probably through womens groups to make the facts known. If the facility is not kept clean and in the new concept acceptable it will not be used. The finest facility in the world is a waste if it is not used. The methods and adequacy of handling of human bodily wastes in any given location is an excellent indicator of the state of civilization in that location.



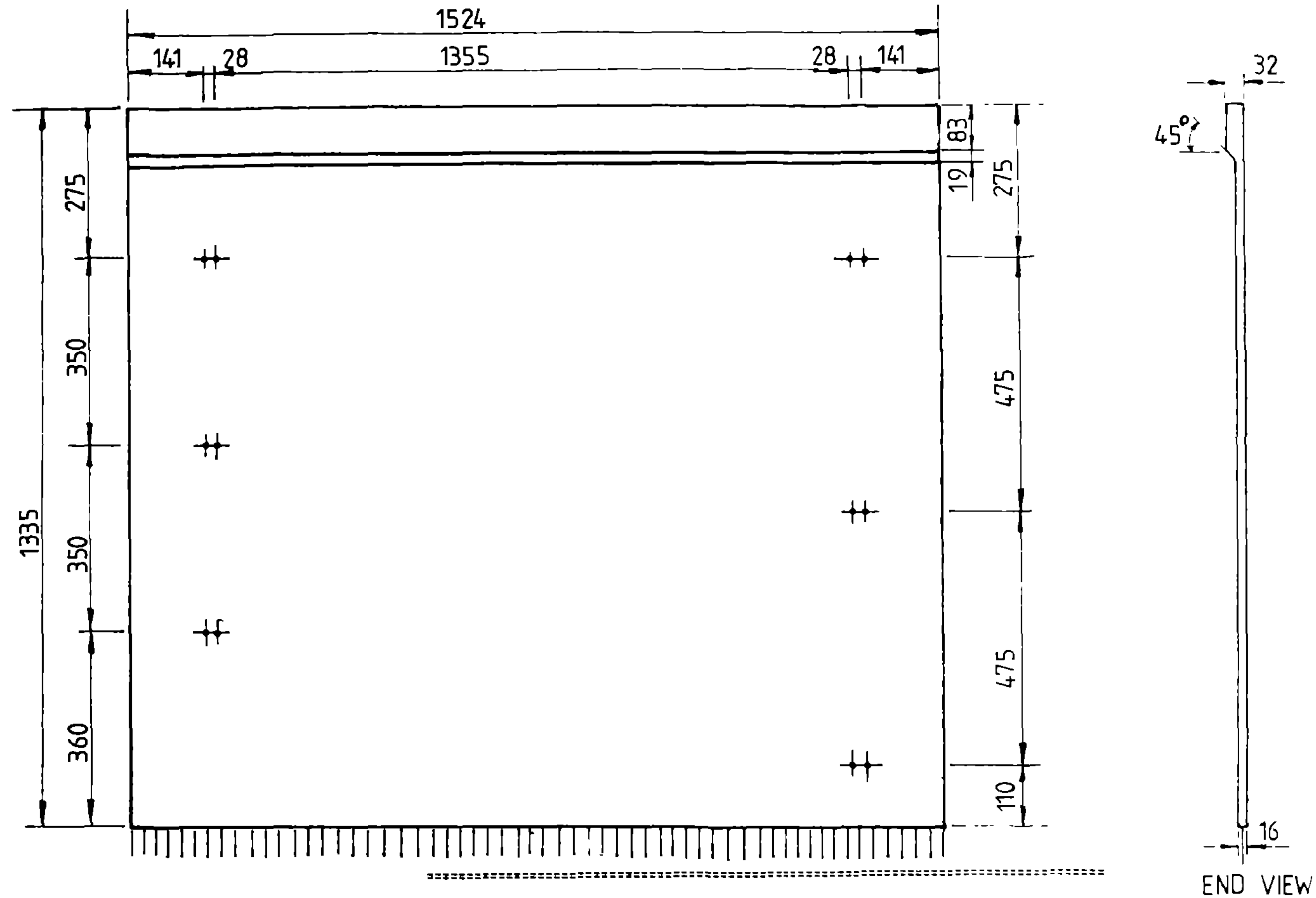
SECTION A-A

BASIC SEPTIC TANK:
END, TWO REQUIRED: VOLUME= .0329 WIDTH= 1220 LENGTH= 1102

ITEM	UNIT COST	AMOUNT	COST
SAND	12.36	.03	.41
CEMENT	.1445	22.36	3.23
FIBER	.97	3.80	3.69
H.T.STEEL	.0266	103.56	2.75
TOTAL COST OF MATERIALS=			10.08
COST PER SQUARE METER=			7.50

FORMULA FOR HALF BATCH

329.00 MM SAND IN .05 MM SQ BUCKET
164.50 MM CEMENT IN .05 M SQ BUCKET
1.90 KG FIBER



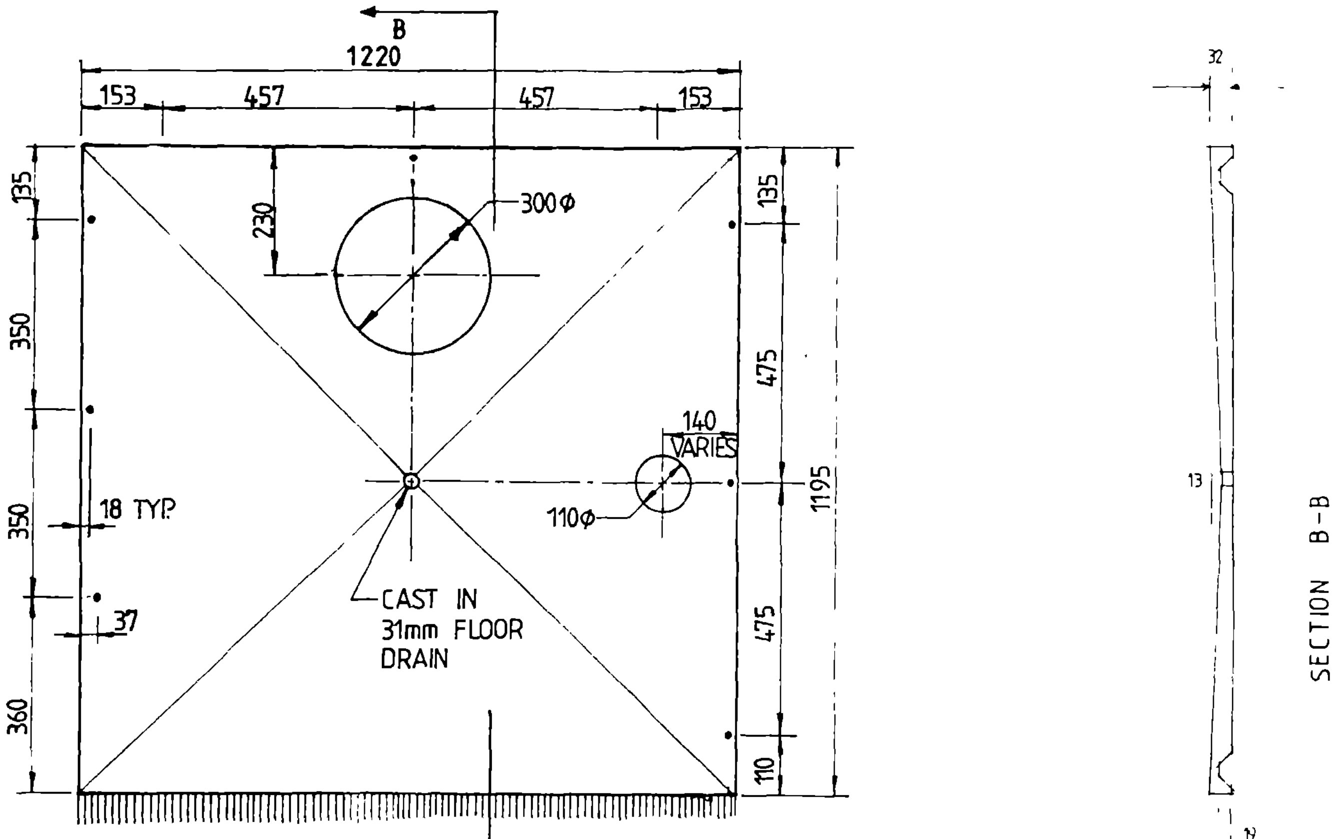
SHOWER HOUSE FOR SEPTIC TANK:
ROOF, TWO REQ'D: VOLUME= .0352 WIDTH= 835 LENGTH= 1981

ITEM	UNIT COST	AMOUNT	COST
SAND	12.36	.04	.44
CEMENT	.1445	23.92	3.46
FIBER	.97	4.07	3.94
H.T.STEEL	.0266	122.16	3.25

TOTAL COST OF MATERIALS= 11.08
COST PER SQUARE METER= 6.70

FORMULA FOR HALF BATCH

352.00 MM SAND IN .05 MM SQ BUCKET
176.00 MM CEMENT IN .05 M SQ BUCKET
2.03 KG FIBER

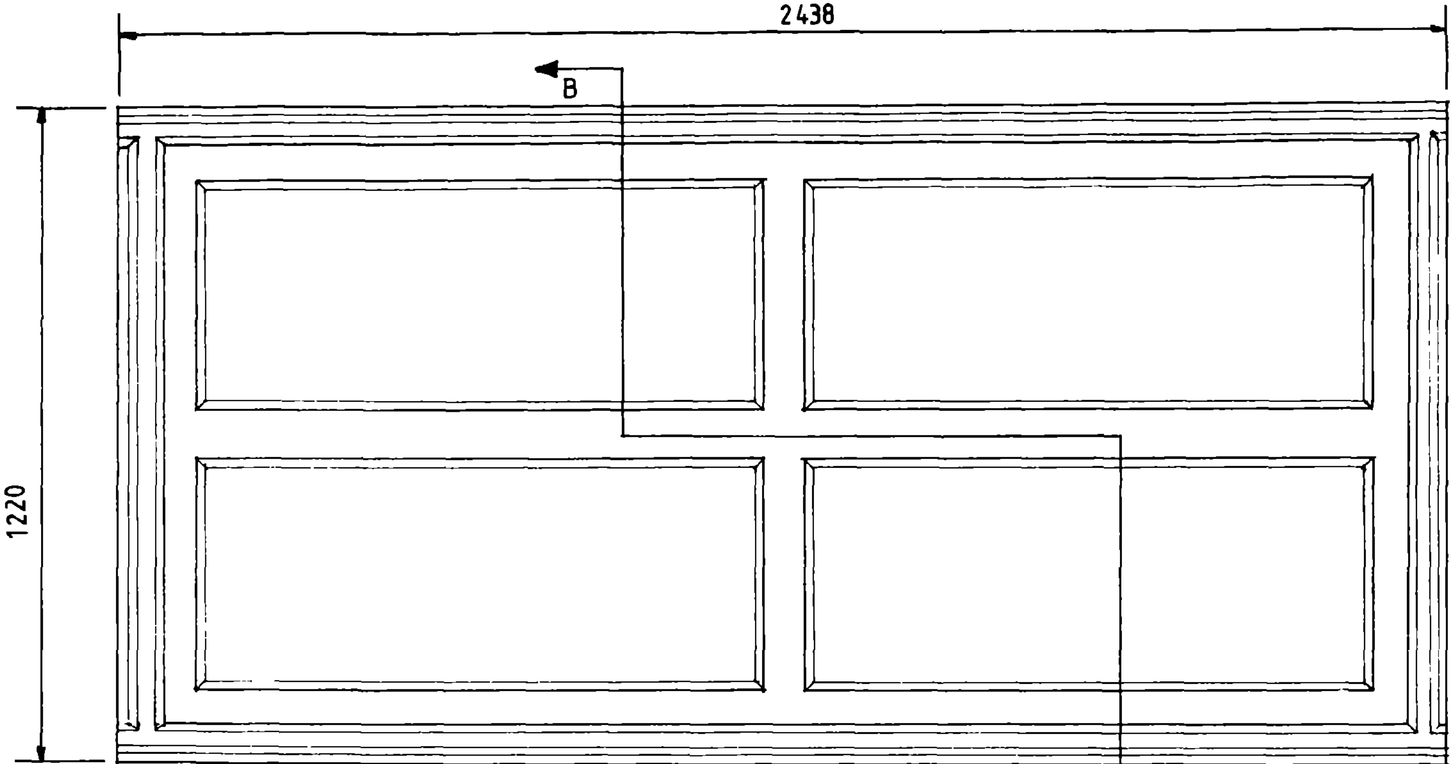


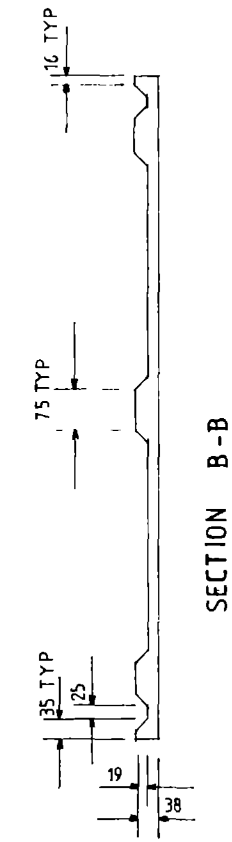
SEPTIC TANK WITH SHOWER PAN FLOORS:
SHOWER FLOORS, TWO REQ'D: VOLUME= .0403 WIDTH= 1220 LENGTH= 1195

ITEM	UNIT COST	AMOUNT	COST
SAND	12.36	.04	.50
CEMENT	.1445	27.38	3.96
FIBER	.97	4.66	4.52
H.T.STEEL	.0266	97.19	2.59
TOTAL COST OF MATERIALS=			11.56
COST PER SQUARE METER=			7.93

FORMULA FOR HALF BATCH

403.00 MM SAND IN .05 MM SQ BUCKET
201.50 MM CEMENT IN .05 M SQ BUCKET
2.33 KG FIBER





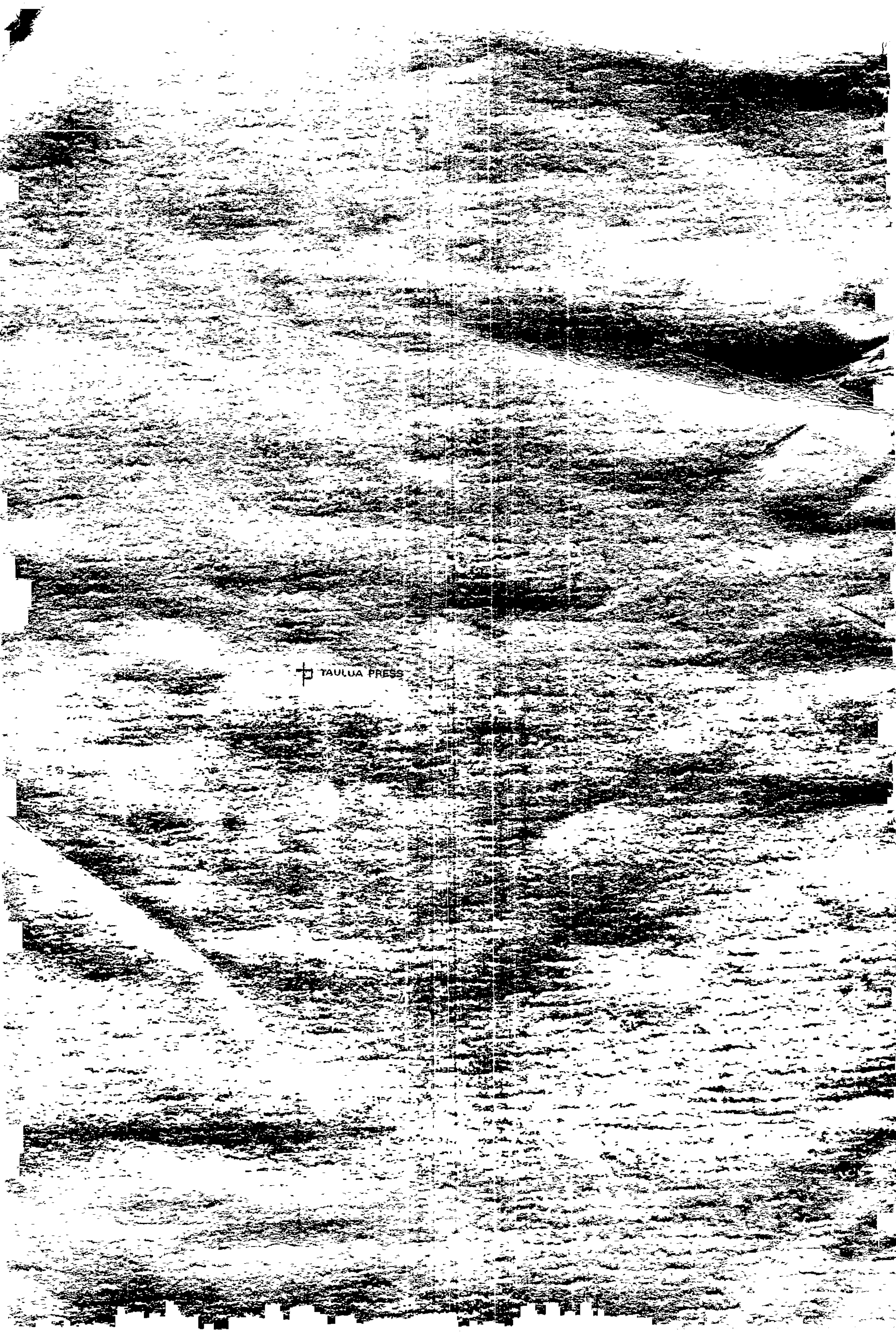
BASIC SEPTIC TANK:
PLAIN TOP OR BOTTOM SLAB: VOLUME= .0784 WIDTH= 1220 LENGTH= 2438

ITEM	UNIT COST	AMOUNT	COST
SAND	12.36	.08	.97
CEMENT	.1445	53.27	7.70
FIBER	97	9.06	8.78
H.T.STEEL	.0266	238.53	6.34

TOTAL COST OF MATERIALS= 23.80
COST PER SQUARE METER= 8.00

FORMULA FOR HALF BATCH

784.00 MM SAND IN .05 MM SQ BUCKET
392.00 MM CEMENT IN .05 M SQ BUCKET
4.53 KG FIBER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