Harvesting the Rain

A Construction Manual for Cement Rainwater Jars and Tanks

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Preface

Water is a major and precious natural resource. But around the world, the absence or scarcity of potable water continues to be a growing problem, especially in rural and remote areas of developing countries. Although clean freshwater may still be readily available in many other places, there are serious concerns about the increasing contamination of rivers, streams, lakes and ground water. Furthermore, wells that are being drilled deeper and deeper to extract groundwater are resulting in groundwater depreciation in many continents. Improvements are urgently needed in the conservation, collection, storage, treatment and reuse of water to meet the demands of an ever-increasing population.

Collecting rainwater as it falls from the sky seems immensely sensible in areas struggling to cope with potable water needs as well as contamination issues. Rainwater is one of the purest sources of water available as it contains very low impurities.

Roof catchments with container storage is a practical way to collect rainwater, largely because it is easy, low maintenance and inexpensive, but household cleanliness is necessary. In regions where there is a lack of water, roof catchment works both as a stand-alone supply and as a supplement to a limited ground or surface water supply. Harvesting the rain is an old and traditional practice. Millions of rainwater catchment systems are relied upon in such countries as Australia, China, New Zealand and Thailand as well as throughout Africa, South Asia and Southeast Asia. Such a system is independent of any centralized or localized water system and helps to foster an appreciation for water as an essential and precious resource. And a roof collection system can address both water quality and water quantity issues.

The advantages of utilizing rainwater to supply household needs and ensure household water security are many: Women and children benefit first; people living in situations of armed conflict and in other unstable situations could also benefit from it; quality can easily be maintained; the system is simple to construct; there is no negative environmental impacts; it helps reduce problems such as soil erosion and flood hazards; and the reduced reliance on groundwater allows replenishment of groundwater tables.

This manual for the construction of rainwater jars and tank is intended to be a practical guide to help alleviate water scarcity and to help households in remote and rural areas of developing countries to avoid water shortages. The use of these jars and tanks should also contribute to the reduction in the high incidence of water-borne diseases caused by contaminated water supply in many parts of the world.

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Contents

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I am grateful to the support from successive Directors of the Accelerated Rural Development Department (ARD), Ministry of Interior, Thailand; and to Mr. Chernchai Sukagaranon, technical officer from ARD for his effort in reviewing the manual. The technical inputs to this manual provided by Mr. Pisan Kayansumruas, a former colleague from ARD and now in the Engineering Bureau, Department of Town and Country Planning, Ministry of Interior are much appreciated. Last but not the least, thanks are extended to Mr. Than Soe, my former colleague in the Water Supply and Environmental Sanitation (WES) Section, UNICEF Tanzania and now a WES programme officer, UNDP, East Timor, for his contribution in the compilation of the manual at the early stage.

T.V. Luong

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Using This Manual

This manual is prepared as a tool for use in training courses to make cement rainwater jars and tanks. The manual is intended also to be a practical reference guide for technical personnel, skilled masons and social workers who are involved in promoting the collection of rainwater for domestic purposes, in particular for households, small village health and child centres and village schools. The techniques presented in this manual are also applicable in emergency situations, in particular in situations in transition. UNICEF's Core Corporate Commitments in Emergencies state that UNICEF will ensure the availability of a minimum safe water supply, through provision of technical and materials support to external implementing partners. This manual can be used as well by entrepreneurs in the private sector interested in manufacturing the rainwater jar and tank to sell to the public.

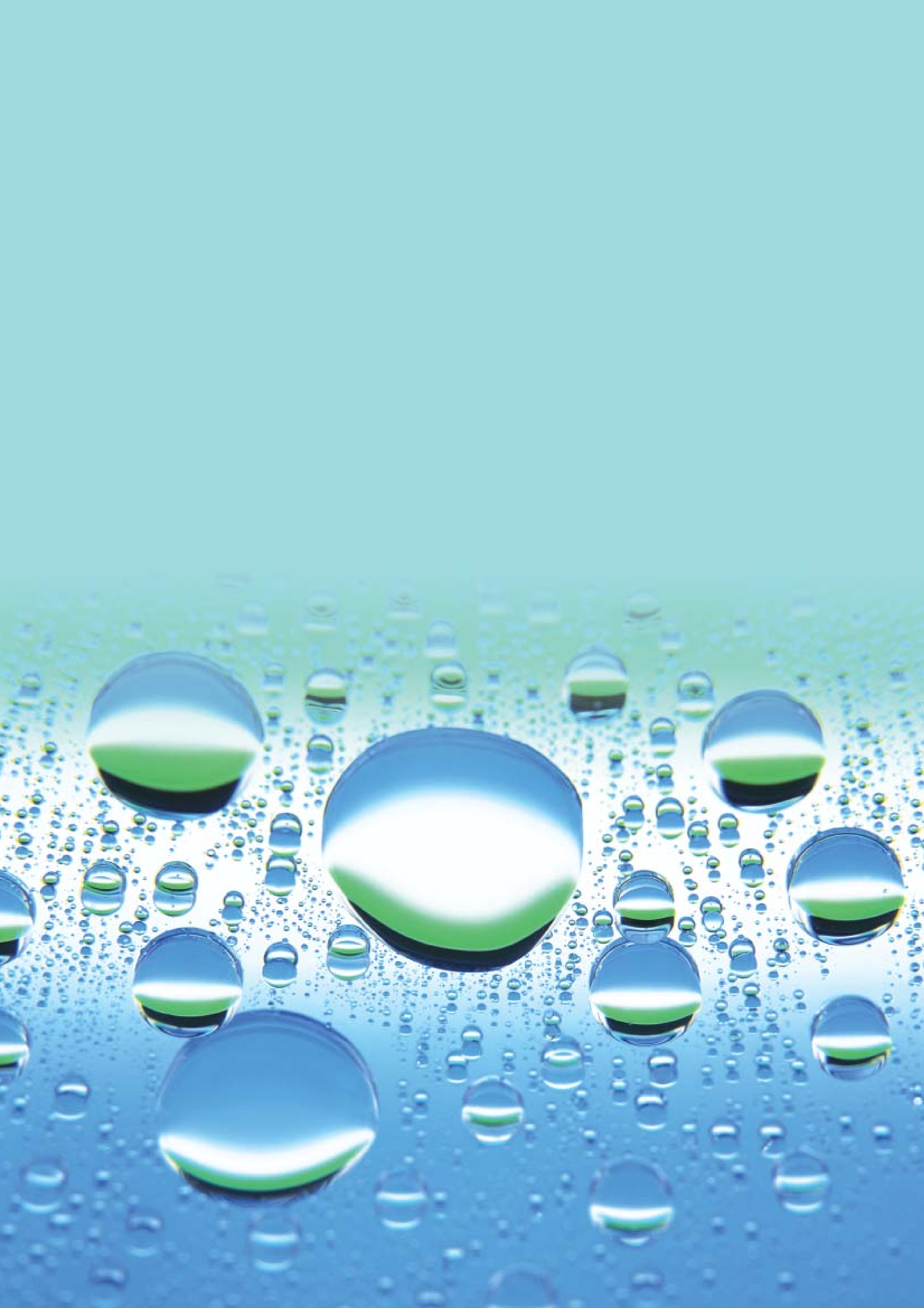
Specifically, the manual aims to reach:

- UNICEF programme and project officers responsible for water, environment and sanitation (WES) activities including rainwater harvesting at family and community levels;
- UNICEF programme and project officers responsible for emergency programmes in the provision of basic needs for safe water supply, sanitation and hygiene;
- Implementers of government agencies and NGOs responsible for rainwater harvesting and water supply and sanitation programmes;
- Supervisors and officials in agencies and organizations employing the above categories of staff; and
- Private sector entrepreneurs and skilled masons.

UNICEF country offices and government agencies are encouraged to translate this manual into vernacular languages for broader promotion of rainwater collection for domestic purposes.

Cross broader technology transfer of constructing Thai rain jar and tank

In country traning of technicians and skilled masons by Thai resource persons can be arranged through Technical Cooperation among Developing Countries (TCDT) Thailand upon request of respective UNICEF country offices to UNICEF East Asia and Pacific Regional office (EAPRO) and UNICEF Thailand.



1. INTRODUCTION

Water, water, every where
And all the boards did shrink;
Water, water, every where
Nor any drop to drink.

Samuel Taylor Coleridge
(1772 - 1834)

1.1 Background

The survival and development of human beings depend on water–its quality and quantity. For ages, many people have been under an illusion that water is abundant, taking for granted that it is a gift from nature and is an inexhaustible resource that is there for the taking. Certainly, the earth appears to encompass an amazing wealth of water. And yet, there are about 26 countries, home to 232 million people, that are experiencing some degree of water scarcity; and 1.1 billion people–nearly one out of every three people in the developing world–are without access to a safe water supply for their basic daily needs. Lack of investment, growing water demand, over-exploitation of existing sources, pollution and maintenance problems have contributed to make the supply of potable water in developing countries extremely difficult. The goal of "Safe Water and Sanitation for All" set by the International Water Supply and Sanitation Decade (IWSSCD) in the 1980s and now extended to the year 2025 may only be a distant dream at best if no collective endeavours on both the national and international scopes are made to revitalize the Water Supply and Sanitation Sector.

There is no shortage of water on earth. But very little of it is actually usable. The total volume of water, some 1.36 billion cubic kilometres, would cover the globe to a height of 2.7 kilometres if spread evenly over its surface. More than 97 percent of the earth's water is seawater, 2 percent is locked in icecaps and glaciers, and a large proportion of the remaining 1 percent lies too far underground to be exploited. The proportion of usable water to the earth's entire supply is equivalent to half a teaspoon out of 100 litres.

Agriculture swallows up the largest share of all the water taken from rivers, lakes and aquifers, accounting for an estimated 65 percent of the global water use. Industries take the second biggest gulp from the global water bodies, accounting for a fourth of total water use. Households, schools, businesses and other municipal activities account for less than a tenth of the earth's water consumption.

People living in rural communities suffer the greatest strains caused by the uneven supply of safe water. Usually they live in areas that rely on natural water sources, such as rivers, streams, shallow wells or stagnant ponds, which are often contaminated with human and animal wastes. As a result, water- and filth-borne diseases account for an estimated 80 percent of all illnesses in developing countries. In addition, millions of women and children walk several kilometres each day just to collect a minimum quantity of water for their families' drinking, cooking and cleaning needs–a drudgery that wastes time and deprives them of the energy for more productive activities and is also a major obstacle to poverty alleviation.

Fortunately, energy from the sun transfers roughly 40,000 cubic kilometres of water from the sea to the land each year. This constitutes the world's renewable freshwater supply. But this water is distributed very unevenly and not all of it can be used by human beings. Two thirds of the water runs off in floods or falls in places too remote to be captured or is needed to support the myriad other species and ecosystems with which we share the planet and on which we depend.

With farmers suffering crop failures in one out of every three years in many parts of the developing countries, new approaches to improving the water supply are desperately needed. Among other things, a wide variety of small-scale "rainwater harvesting" methods are being applied in some countries for irrigation of crops and the sustenance of life generally. Many of these efforts are more cost-effective and less disruptive to local communities than the large schemes that dominated development efforts during the past decades. And, because of their small size and use of local resources, they tend to be less damaging to the environment as well.

Similarly, for people living in situations of armed conflict, natural disasters and in other unstable situations, water, food and shelter are the priority of basic daily needs. Collection of rainwater with adequate storage capacity could also benefit to them.

In the past 20 years, the renaissance of the ancient practice of rainwater collection for domestic use has been adopted in many countries in Southeast Asia and in Africa. Among various rainwater collection methods, rooftop catchment is widely adopted in rural areas of Thailand and other Southeast Asian countries because of its simplicity and the readily available roofing in all households. However, the rain pattern in these tropical countries is usually a heavy downpour within short duration. There is, therefore, an immense need to have adequate storage capacity at each household to collect the rainwater during rainy season. This has led in Thailand, for example, to the popularity of large volume cement jars and tanks of one-, two- and three-cubic metre capacities.

1.2 The Thai Rainwater Jar and Tank Programme

The Government of Thailand initiated a Rainwater Jar Programme in the 1980s with the aim to provide an alternative and supplementary water supply in rural areas with emphasis on self-sufficiency and conservation. The programme proved to be extremely successful. Some 300 million wire-reinforced cement rainwater storage jars and tanks were constructed between 1980 and 1991. The programme was an unusual initiative involving a broad range of stakeholders, including households, communities, NGOs, universities and the private sector with support from the Government at local, provincial and national levels. The result of this "bottom-up" meeting "top-down" approach was a programme that was unprecedented in the way it facilitated the access of rural people to potable water supplies, especially in northeast Thailand. The programme operated with revolving funds provided by the Government to generate resources from the households and communities.

As the project gained momentum with widespread support and readily available community-based revolving funds, the programme shifted from the government initiative to commercial jar-manufacturing enterprises. During 1986 alone, approximately 1.7 million one- and two-cubic metre jars were built in northeast Thailand. During this frenzied construction phase, revolving funds were seen by many as a hindrance to rapid implementation of the programme. Increasingly, the private sector took on responsibility for production, as it was able to turn out good-quality jars at ever-lower prices due to the economies of scale. Many villagers, trained through the government-funded programme, landed jobs with small contractors or set up their own building enterprises. And they did well with two-cubic metre jars selling at around US$20, thereby enabling many householders to purchase them, particularly during the economic boom in Thailand at that time.

Several factors greatly favoured the rapid progress and development of the rainwater jar programme in Thailand. These included:

- A genuine need for water and a preference for the taste of rainwater by most people;
- Strong political will and commitment for rural development at all levels of government and the contribution and hard work displayed by successive technical personnel and administrators at different levels;
- A period of national economic growth and increasing private affluence; and
- The availability of low-cost local cement and skilled artisans with experience in making a similar Thai traditional jar.

A major study by Wirojanagud et al. of rainwater quality was conducted in northeast Thailand in 1989 where several million people use household rainwater jars. The study examined the route and cause of bacteriological, pathogenic and heavy metal contamination. Samples from roofs and gutters showed faecal coliform to faecal streptococci ratios of less than l (FC:FS<1) suggesting that the contamination is of non-human origin (animal and birds). In the same study, bacteriological analysis of water from 189 rainwater jars and tanks revealed that around 40 percent met World Health Organization (WHO) drinking water standards (0 E. coli count per 100 millilitre). Water samples from 100 in-house storage containers of the same households revealed that almost 90 percent failed to meet the WHO standards. And almost half of the samples had FC:FS ratio of more than 4, implying a secondary faecal contamination of both animal and human origin. Widespread observations were made of poor hygiene and sanitation in households, the contributory factors for contamination of rainwater stored at homes. However, no harmful pathogens were detected in the rainwater stored in the jars, except in only two samples (0.6 percent) from the rainwater tanks. The study concluded that, potentially, rainwater is the safest and most economical source of drinking water in the region with no major health implications to users, as compared to the highly contaminated conventional water sources. The study recommended improved hygienic handling and storage of the rainwater at home, good sanitary practices and the possible use of chlorine or boiling for disinfecting the water.

1.3 Rainwater Harvesting for Domestic Use

Rainwater harvesting by rooftop catchment (using large volume cement jars and tanks) has proven to be sufficient for household use in most rural families in Thailand and for promoting family self-management of household water security. Rainwater harvesting is perceived as being effective in narrowing the gap in drinking water availability between the “haves” and the “have-nots”. Rainwater collection could also play an important role in managing the severe public health problems, such as arsenic and fluoride contamination in wells or groundwater in Bangladesh, Cambodia, China, India, Viet Nam and other countries.

The main requirement for rainwater collection is to have adequate storage at each house. The Thai jar or tank, with a capacity of one-, two- or three-cubic metres, works very well, especially if several jars or tanks are used. It is also possible for families to purchase the jars and tanks, when they could afford it. The construction of a Thai jar or tank is not expensive and not the least bit sophisticated technically. It requires only some common construction materials, such as cement, sand and iron wire etc., and some masonry skills.

The positive aspects of the Thai rain jar and tank make them an ideal solution that could benefit millions of rural people in developing countries, especially in water-problem areas. Because rainwater can be collected even on temporary shelter roofing, this method is particularly useful to increase access to water in emergency situations, situation of displacement, and in situations where displaced people are returning and rebuilding their communities. this has been done in East Timor in the year 2000, when local inhabitants were returning from West Timor.

Cross-broader transfer of this simple but logical technology would spread the benefits. The first stage of such technology transfer is a simple manual that illustrates each step of the jar- and tank-making procedure for easy understanding by the least-technically inclined people.

There are several similar procedures for making the Thai rainwater jar and tank. This manual is based on the technique developed by the Accelerated Rural Development Department (ARD), Ministry of Interior, Thailand. ARD is one of several agencies in Thailand implementing the Government's rural water-supply programme and has played an important role in promoting the use of rainwater jars and tanks in rural areas. UNICEF offices in Tanzania and Bangladesh have collaborated with ARD in conducting training courses in the construction of jars and tanks for local technical personnel and skilled masons. Through such training, the Thai rain jar and tank were introduced for the first time to Africa and South Asia and were well accepted and appreciated by the respective government counterparts, local masons and local community members.

This manual presents a step-by-step guide for the construction of the Thai jar and tank. Although it is intended as a training reference, it can be used by a local skilled mason or even a member of a household if he or she is a do-it-yourself type of person. The purpose is to spread the construction knowledge and the use of rainwater jars and tanks throughout the developing countries as much as possible, which will require that it be translated in the various local languages.

The construction procedures in this manual have been presented as clearly and easily as possible so that any one with a basic knowledge and skill of masonry and carpentry can follow them and master the technique. Section 1 gives the background and the Thai rain jar programme. Section 2 illustrates the different steps in making the cement rainwater jar. The detailed techniques and procedures for construction of the rainwater tank are presented in Section 3. Section 4 provides suggestions and techniques on the installation of rainwater gutters. Section 5 presents some examples of the rainwater jars and tanks in use in rural Thailand. The Thai rainwater jars in use in East Timor are illustrated in Section 6.

2. CONSTRUCTING CEMENT RAINWATER JARS

2.1 Material Requirements for Making the Rainwater Jars

Table 2-1: Material requirements for making rainwater jars

MATERIAL REQUIREMENTS	1,000-LITRE JAR	2,000-LITRE JAR
Cement	3 bags	4 bags
Sand	2 cubic metres	3 cubic metres
Aggregate	0.3 cubic metre	0.3 cubic metre
Wire, 0.04 inch (or 0.1centimetre) diameter	3 kilograms	4 kilograms
GS pipe, 3/4 inch (or 1.9 centimetres) inner diameter	0.8 metre	0.8 metre
GS socket, 3/4 inch (or 1.9 centimetres) inner diameter	2 pieces	2 pieces
Tap, 3/4 inch (or 1.9 centimetres) inner diameter	1 piece	1 piece
GS plug, 3/4 inch (or 1.9 centimetres) inner diameter	1 piece	1 piece
Aluminium or iron wire, 0.12 inch (or 0.3 centimetre) diameter	2 kilograms	2 kilograms
Nylon net	1 square metre	1 square metre
Jute cloth (like that used for rice sacks)	4 square metres	6 square metres
Big iron sewing needle	1 piece	1 piece
Wooden or aluminium cover	1 piece	1 piece
Skilled mason	2 days	2 days
Unskilled labourer	2 days	2 days

Note: Cost of the jar can be calculated using local prices.

2.2 Techniques for Constructing the Cement Rainwater Jar

Step-by-step procedures for making cement rainwater jar

a. *Iron moulds for rainwater jar construction*

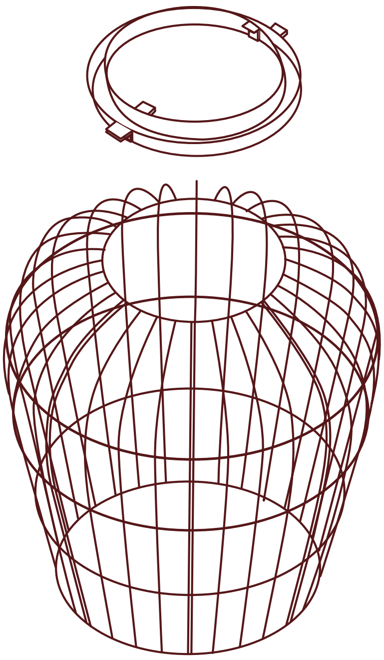


Figure 2-1: Iron moulds for the body of the jar and the iron rim moulds for the jar mouth. The iron bar for the body mould should be a 1.2 centimetres diameter. To make the rim moulds, iron strips that are of 0.4 centimetre thick and 5 centimetres and 7 centimetres wide, respectively, are used to make the rim moulds for jar mouth, as per the measurements given in **Table 2-2**. Iron moulds are made by the local black smith.

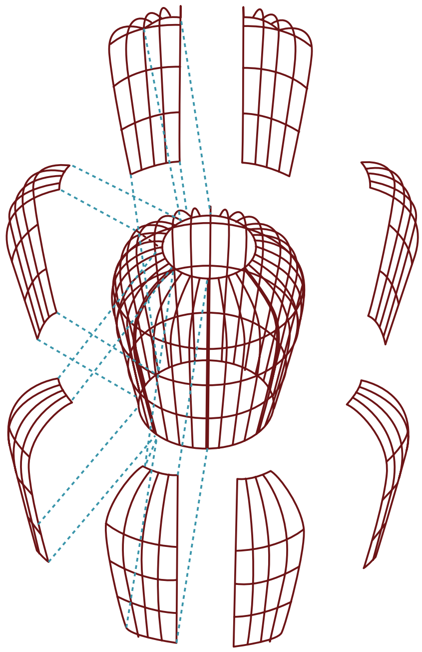


Figure 2-2: Cut the iron mould of the jar body into 8 uniform segments as shown.

Table 2-2: Detailed measurements of vertical and horizontal iron bars for making iron moulds for the jar body and measurements of the iron strips for the making rim moulds for the jar mouth.

IRON MOULDS FOR JAR BODIES															RIM MOULDS FOR JAR MOUTH			
CAPACITY	DIAMETER, cm (CIRCUMFERENCE), cm					LENGTH, cm							No. OF VERTICAL BER PER SEGMENT	No. OF SEGMENT	DIAMETER, cm		WIDTH, cm	
LITRE	A	B	C	D	E	F	G	H	I	J	K	L			M	N	R	T
1,000	55 (173)	115 (361)	125 (393)	110 (346)	96 (302)	10.5	132	107	32	35	33.5	21	4	8	61	56	5	5
2,000	65 (204)	145 (455)	155 (487)	138 (434)	120 (377)	13.5	166	135	40	44.5	42.5	27	5	8	73	66	7	7

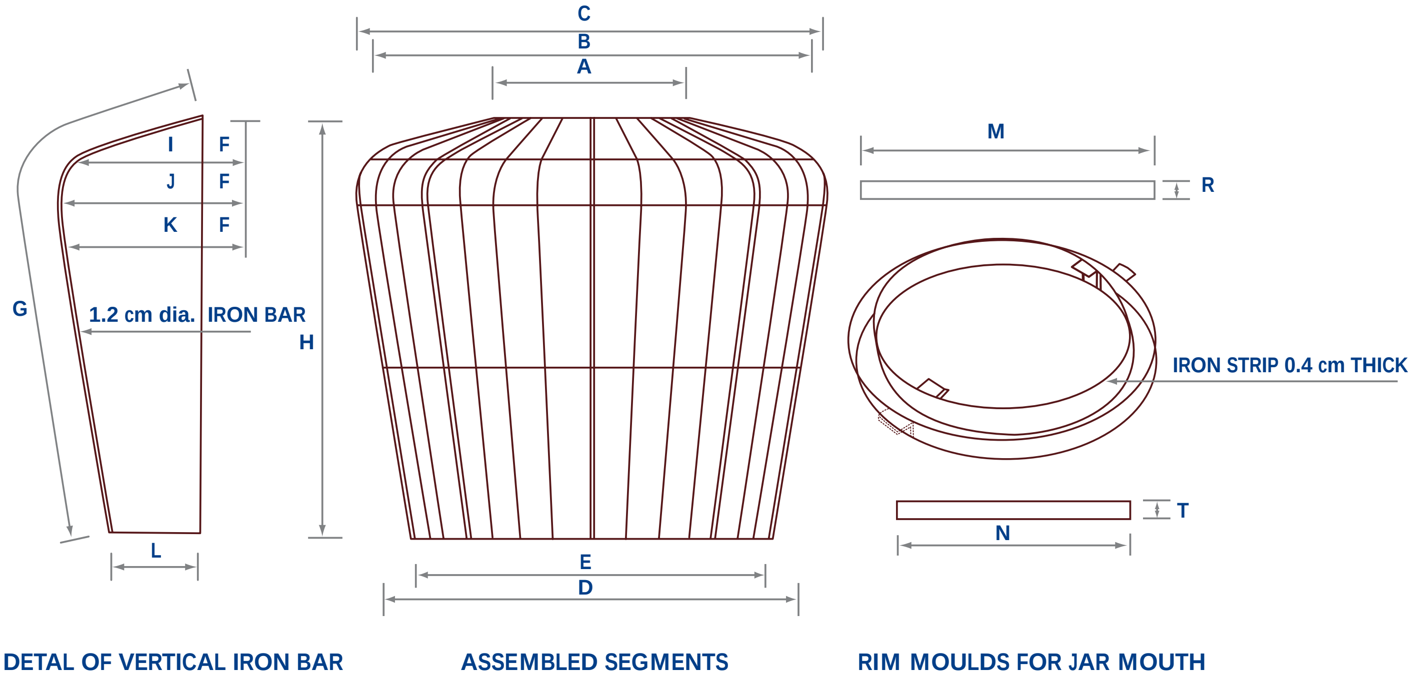


Figure 2-3: Drawing shows the dimensions of iron moulds for the jar body and rim moulds for the jar mouth. Detailed measurements for both moulds are given in **Table 2-2**.

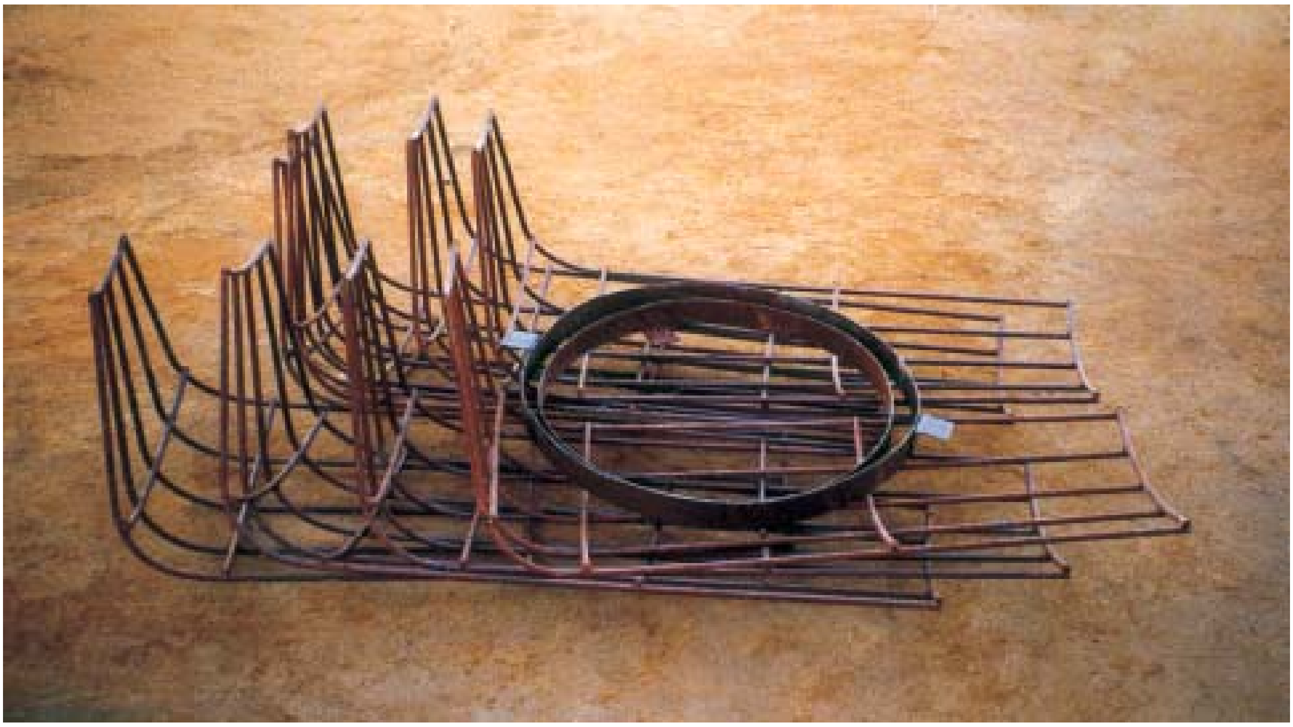


Figure 2-4: Iron mould segments ready for jar construction.

b. Construction of the jar foundation

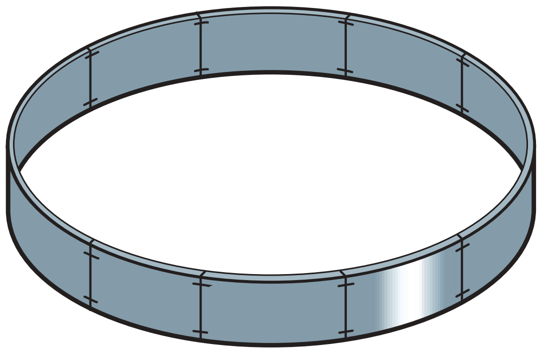


Figure 2-5: Clean and level a ground surface. Prepare a circular shape frame with pre-cast cement segments to form the foundation. 8 pre-cast cement segments are needed to form a circle of about 130 centimetres diameter for a 1,000-litre jar foundation. And 10 pre-cast cement segments are used to form a circle of near 160 centimetres diameter for the 2,000-litre jar foundation. (Steps for making the pre-cast cement segments are illustrated in **Section 3**, **Figures 3-6** to **3-13**.)

Figure 2-6: Join the pre-cast cement segments with 0.1 centimetre diameter binding wire.

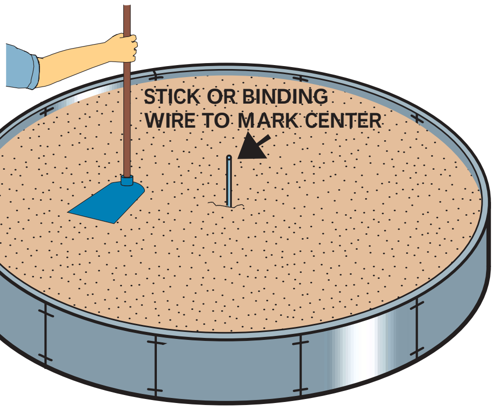


Figure 2-7: Mark the centre point of the cement segment circle using a piece of binding wire. Then fill the foundation with sand, up to 6 centimetres deep, and pack it down very tight.

Figure 2-8: Pour in the aggregate, about 5 centimetres deep, on top of the sand. Pack it down tight. Reinforce the segment circle with 0.1 centimetre diameter binding wire as shown.

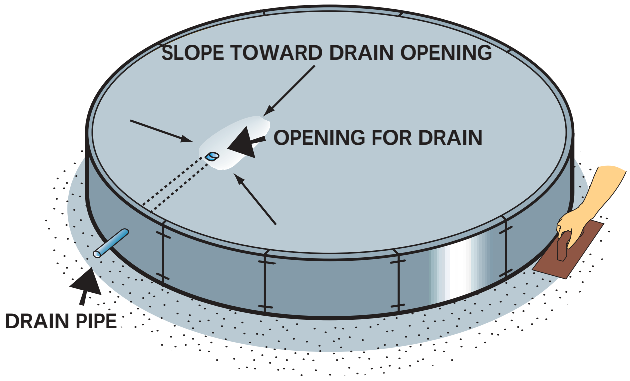


Figure 2-9: Make a wire reinforcement using aluminium or iron wire of 0.3 centimetre dia. as shown. Place the wire reinforcement on top of the aggregate.

Figure 2-10: Cover the aggregate and reinforcement wire with 1:3 cement mortar about 4 centimetres thick. Place a drainpipe inside the cement mortar and then plaster the top with additional cement mortar, but of a 1:2 ratio. Make sure the surface of the foundation has a proper slope toward the drainpipe opening to enable the water to flow out.

Figure 2-11: Smooth the foundation surface with cement mortar and make an opening for the drain as shown.

c. *Preparation of moulds for jar construction*

Figure 2-12: Cover each iron segment mould with jute cloth and sew it tightly onto the mould with a big iron needle.

Figure 2-13: Sew jute cloth onto the segment moulds.

Figure 2-14: Join the jute cloth-covered segment moulds together with binding wire.

d. Construction of jar

Figure 2-15: Place the joined jute cloth-covered jar mould onto the foundation.

Figure 2-16: Smear the jute cloth with a thin layer of mud slurry. (Mud slurry is made by mixing mud and water.)

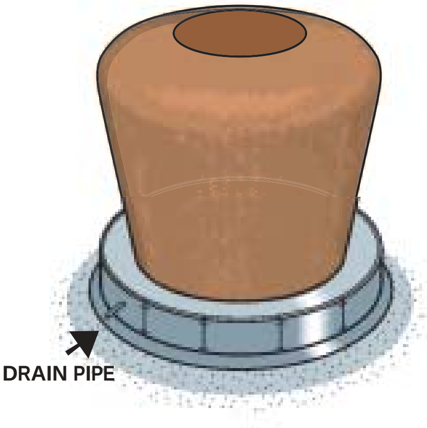


Figure 2-17: A mud-coated jute clothe jar mould. Wait about 30 minutes for it to become slightly dry before plastering its outside with cement mortar of 1:2 ratio.

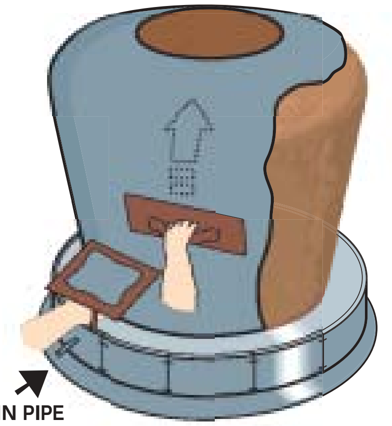


Figure 2-18: Plaster the first 1:2 cement mortar coating about 1.2 centimetres thick onto the outside of the mud coated jute cloth mould. Wait about 30 minutes and then plaster the second coating of 1:2 cement mortar, also 1.2 centimetres thick. Care must be taken to avoid making the mortar layer too thick as the weight of it may cause it to fall.

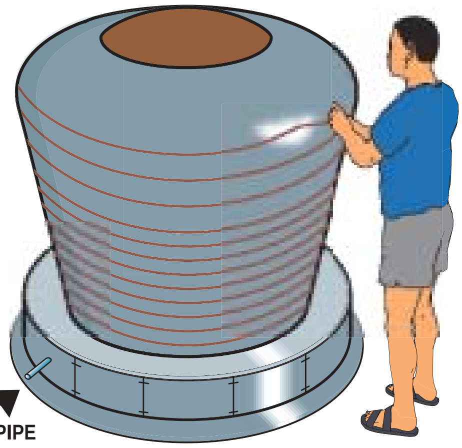


Figure 2-19: Fasten binding wire horizontally around the jar, on top of the cement mortar, as reinforcement. The space between each piece of binding wire should vary from 3 centimetres to 6 centimetres from the jar bottom to the top.

Figure 2-20: A binding wire-reinforced jar body.

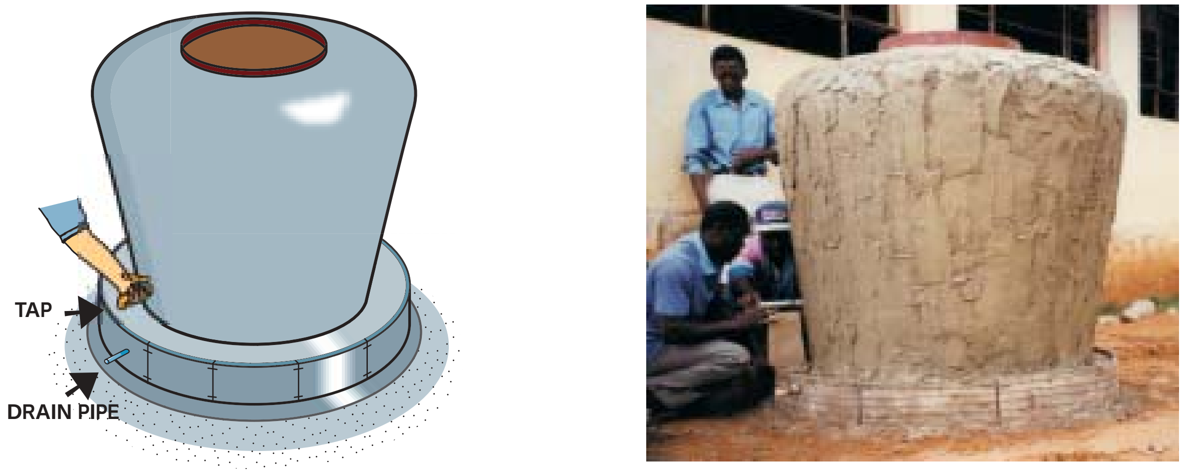


Figure 2-21: Insert a tap into the side of the jar body, about 10 centimetres above the foundation surface.

Figure 2-22: Plaster a third and fourth coating of 1:2 cement mortar, each about 1.5 centimetres thick. Again, wait about 30 minutes between each plaster layer for proper drying.

e. *Casting the jar mouth*

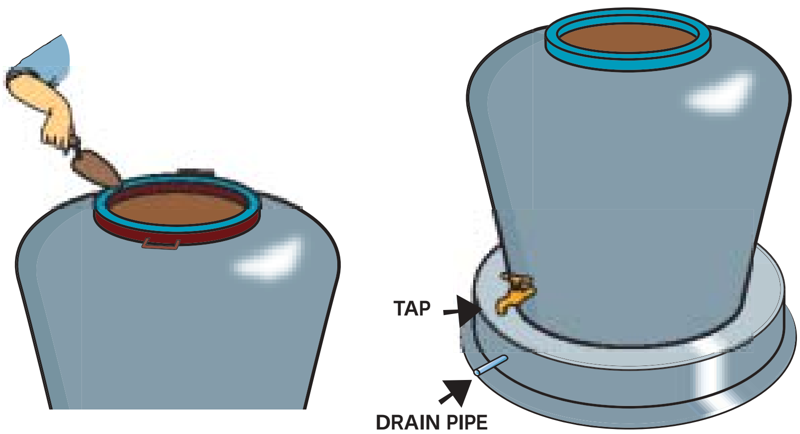


Figure 2-23: Place the two rim moulds on the jar mouth and fill the space between the rim moulds with cement mortar. Remove the moulds before the cement mortar is set.

Figure 2-24: Smooth the jar surface.

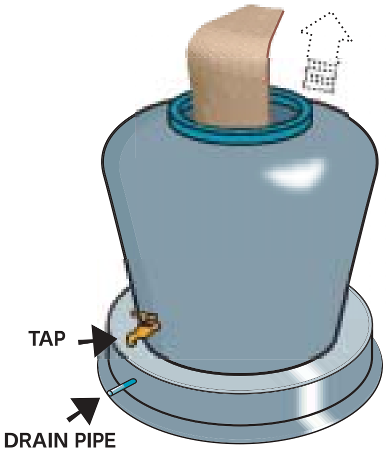


Figure 2-25: Remove the segment moulds from inside the jar the next day or after at least 12 hours. Clean the inside wall of the jar using a brush and then splash it with cement water slurry.

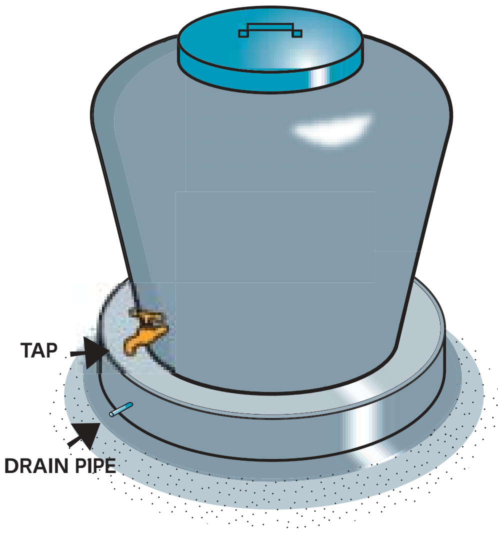


Figure 2-26: A completed cement rainwater jar with cover.

Figure 2-27: A 1,000-litre cement rainwater water jar (rain water gutter and connecting pipe are yet to be fixed).

Figure 2-28: A 2,000-litre cement rainwater jar (rain water gutter and connecting pipe are yet to be fixed).

3.1 Material Requirements for Construction of a 3,200-litre Rainwater Tank

Table 3-1: Material requirements for making a 3,200-litre rainwater tank

MATERAILS REQUIRED	QUANTITY
Cement	7 bags
Sand	4 cubic metres
Aggregate	0.4 cubic metre
PVC elbow, 3 inch (or 7.6 centimetres) inner diameter	1 piece
PVC pipe, 3 inch (or 7.6 centimetres) inner diameter	0.2 metre
Wire, 0.04 inch (or 0.1 centimetre) diameter	5 kilograms
GS pipe, 3/4 inch (or 1.9 centimetres) inner diameter	0.8 metre
GS socket, 3/4 inch (or 1.9 centimetres) inner diameter	2 pieces
Tap, 3/4 inch (or 1.9 centimetres) inner diameter	1 piece
GS plug, 3/4 inch (or 1.9 centimetres) inner diameter	1 piece
Iron bar, 0.24 inch (or 0.6 centimetre) diameter	0.8 metre
Aluminium or iron wire, 0.12 inch (or 0.3 centimetre) diameter	2 kilograms
Nylon net	0.04 square metre
Skilled mason	3 days
Unskilled labourer	3 days

Note: Cost of the tank can be estimated using local prices of the materials.

3.2 Techniques for Construction of Cement Rainwater Tank

Step-by-step procedures for construction of cement rainwater tank are illustrated in the following figures.

a. Iron moulds for construction of tank

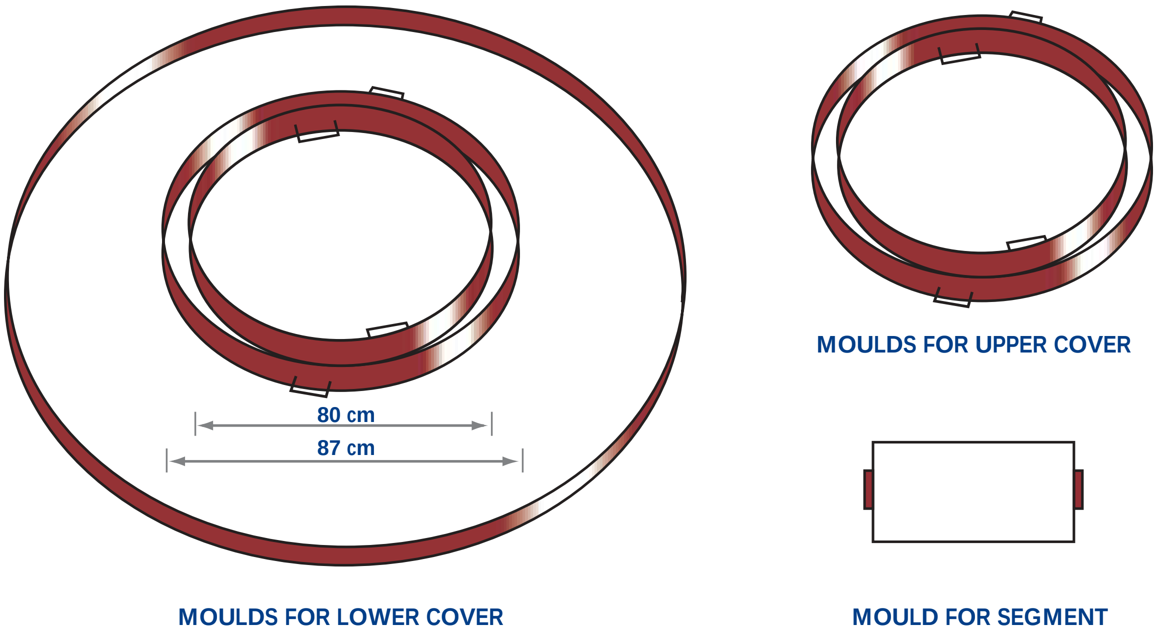


Figure 3-1: Set of iron moulds for construction of tank.

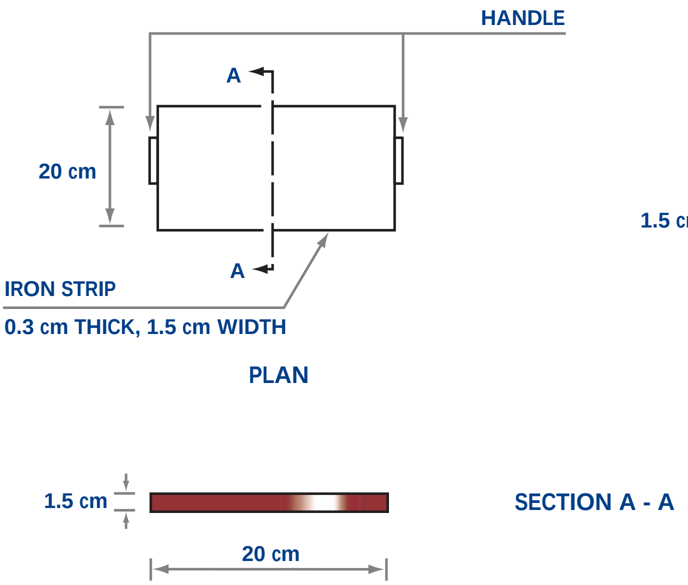


Figure 3-2: Measurements of iron segment mould. Iron strips of 1.5 centimetres wide and 0.4 centimetre thick is used for making the segment mould. The segment mould has a curved shape that is 20 centimetres wide and 50 centimetres long. Details of dimensions are shown in the drawing.

Figure 3-3: Iron segment moulds for casting tank segments.

MOULDS FOR UPPER COVER

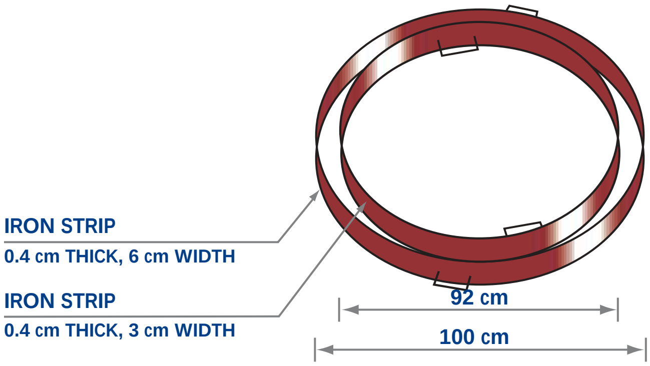
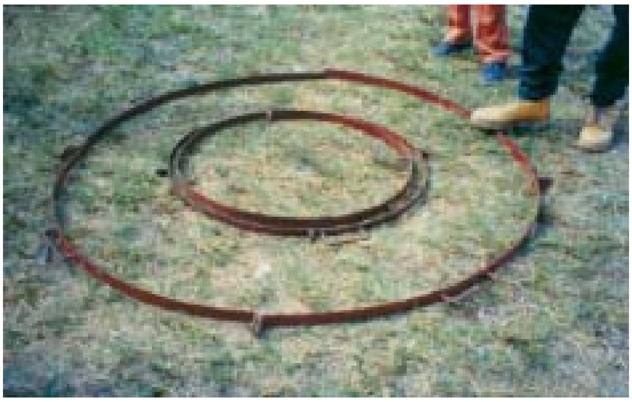


Figure 3-4: Measurements of moulds (set of 2) for the UPPER COVER of the tank. Iron strips 0.4 centimetre thick and width of 6 centimetres and 3 centimetres are used to make the moulds. Diameters of the outer and inner moulds are 100 centimetres and 92 centimetres, respectively. Details of dimensions are shown in the drawing.

MOULDS FOR LOWER COVER



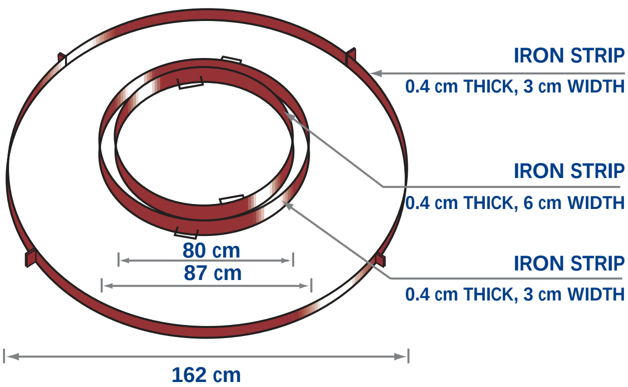


Figure 3-5: Measurements of moulds (set of 3) for the LOWER COVER of tank. Iron strips of 0.4 centimetre thick and width of 6 centimetres and 3 centimetres are used to make the moulds. Diameters of the outer and inner moulds are 162 centimetres, 87 centimetres and 80 centimetres, respectively. Detail dimensions are shown in the drawing.

b. *Casting cement segments for rainwater tank*

Cement segments are required for making the rainwater tank and the foundations for both the jar and tank. It is necessary to cast sufficient cement segments. For making one rainwater tank, 100 segment pieces are needed (80 pieces for the tank body, 12 pieces for the foundation and 8 extra pieces in case of breakage).

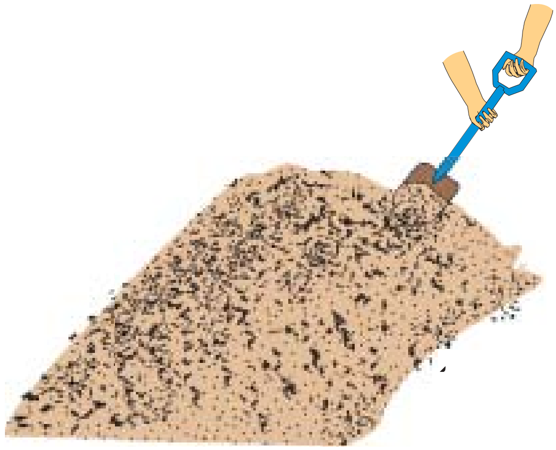


Figure 3-6: Prepare a sand base in a straight line on smooth ground that is approximate 60-70 centimetres wide and 15 centimetres high. The length of the sand base depends on the availability of the space. It should be long enough to cast as many segments as possible.

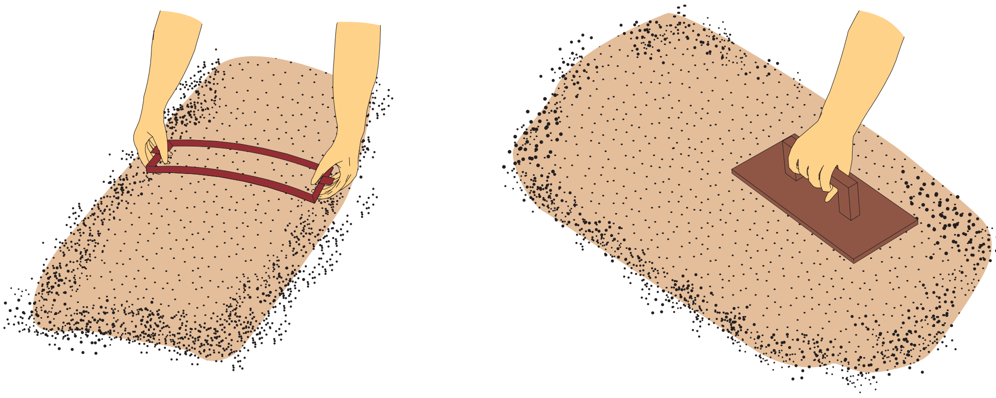


Figure 3-7: Shape the surface of sand base by using the segment mould to get proper curvature and then smooth and slightly pack the curved sand surface with a wooden trowel.

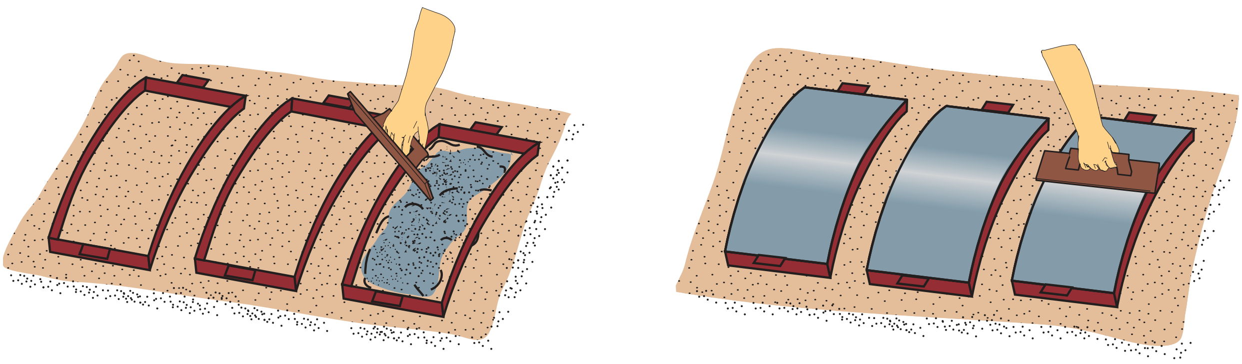


Figure 3-8: Place the segment moulds on top of the sand base. Then fill with cement mortar prepared in a 1:3 proportion. Pack thoroughly and smooth the surface with a wooden trowel.

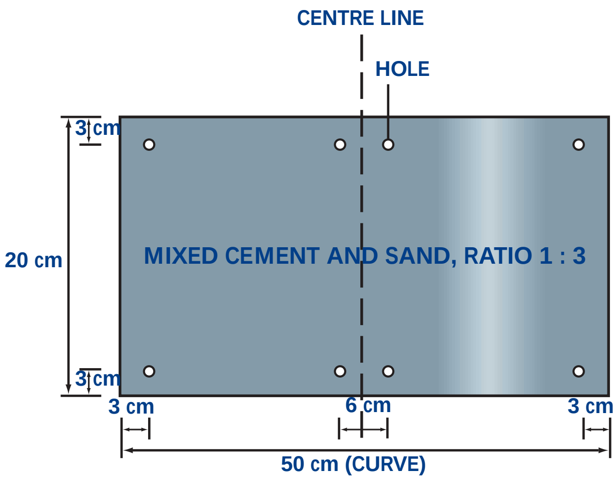


Figure 3-9: Wait about 15 minutes, then make holes in the cement segments with a 7centimetres long nail, as shown in the drawing.

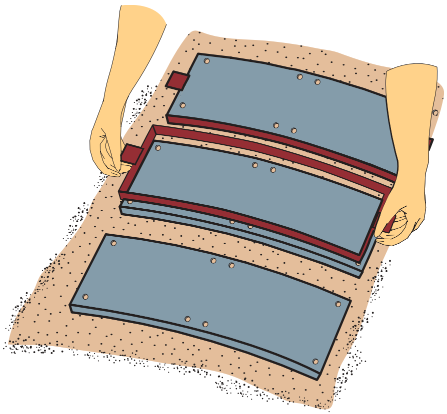


Figure 3-10: Wait about 20 minutes more. Then remove the segment mould one by one carefully. And then wash the moulds to clean them properly for reuse.

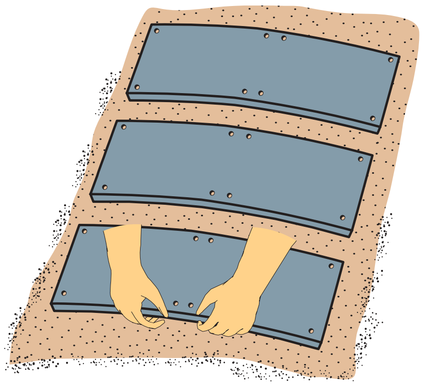


Figure 3-11: Remove the cement segments from the sand base the next day or after at least 12 hours. While removing the cement segments, it is very important to handle them carefully by holding at the middle of the segment, as shown, to avoid breakage.

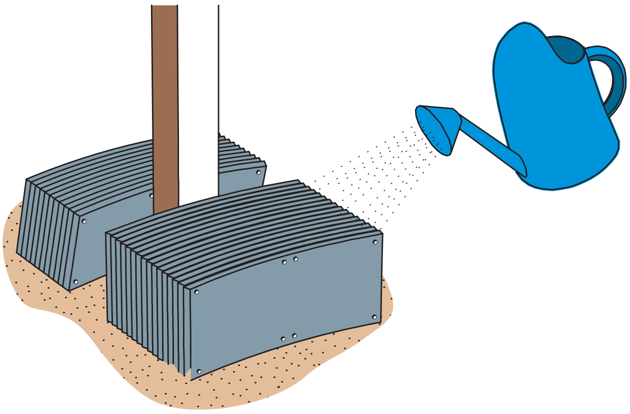


Figure 3-12: Keep the cement segments in shade and cure with water for a minimum of 3 days but, ideally, cure for 7 days if possible.

Figure 3-13: Cast cement segments for tank construction in action.

c. Casting the upper cover of tank

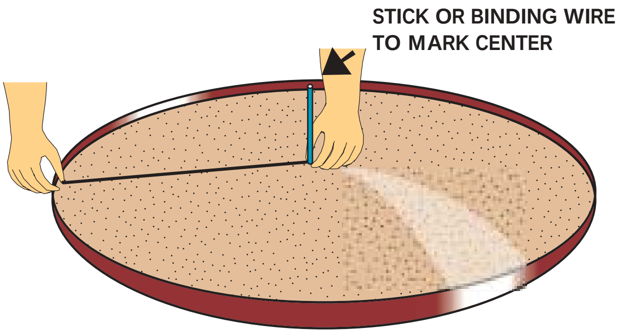


Figure 3-14: Prepare a conical sand base inside the 92 centimetres diameter inner mould with 18 centimetres height at the centre. Insert a piece of wire into the sand to mark the centre.

Figure 3-15: Make the upper cover wire reinforcement and two handles on top of the conical sand base. The 0.3 centimetre diameter binding wire is used to make the reinforcement and 0.9 centimetre diameter iron bar is used for the handles. The arrangement of wire reinforcement and handles is shown in the picture.

Figure 3-16: Set aside the wire reinforcement for use later on. Cover the top of sand base with paper, and place the outer mould on top of the paper ready for casting.

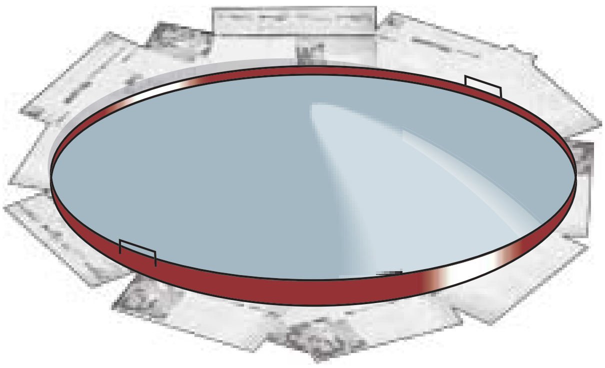


Figure 3-17: Fill with the mixture of cement mortar that has been prepared in a proportion of 1:2 and make it about 2.5 centimetres thick on top of the paper. Smooth the mixture uniformly on top of the paper.

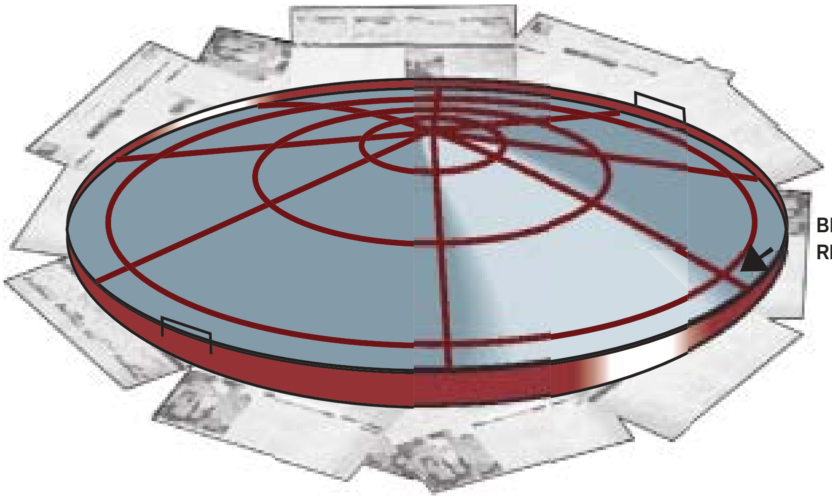


Figure 3-18: Place the wire reinforcement with handles on top of the cement mortar.

Figure 3-19: Add another layer of the 1:2 cement mortar mixture on top of the wire reinforcement; fill up to the top level of mould. Remove the outer mould after one hour, before the concrete mortar is set. Cure the cast upper cover with water for at least 3 days, though, again, curing for 7 days is better.

Figure 3-20: A finished upper cover with handles.

d. Casting the lower cover of tank

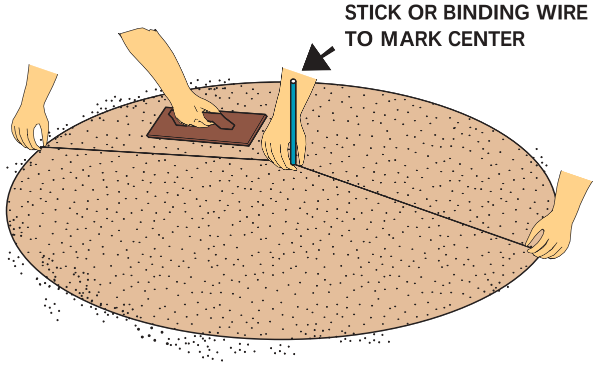


Figure 3-21: Prepare a conical sand base inside the lower cover outer mould (diameter 162 centimetres) with a height of 18 centimetres at the centre. Insert a piece of wire to mark the centre.

Figure 3-22: Make the lower cover wire reinforcement and two handles on top of the conical sand base. Use 0.3 centimetre diameter binding wire for reinforcement and 0.9 centimetre diameter iron bar for handles. The arrangement of handles and binding wire reinforcement is shown in the photo.

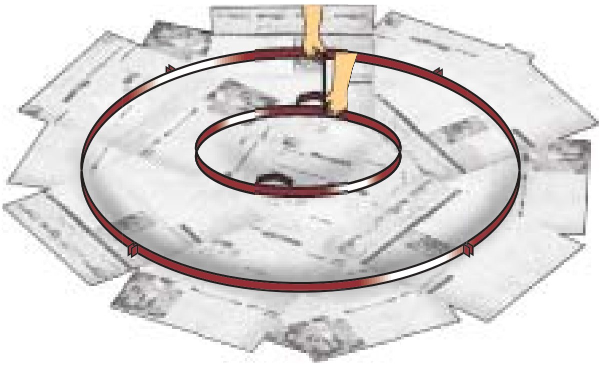


Figure 3-23: Set aside the wire reinforcement for use later on. Cover the top of sand base with paper and place the outer mould (162 centimetres) and inner mould (87 centimetres) on top of the paper.

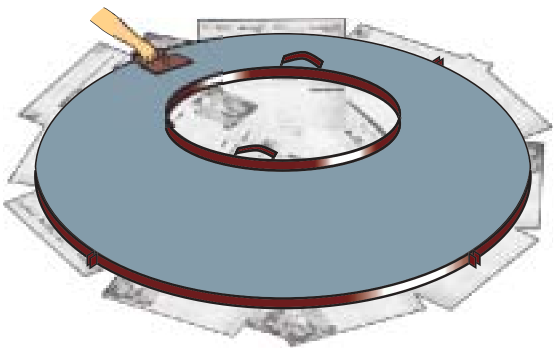
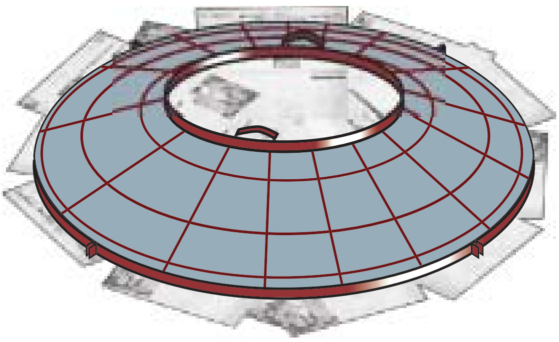


Figure 3-24: Fill the space between the two moulds with a mixture of 1:2 cement mortar and make it 2.5 centimetres thick and spread it uniformly.



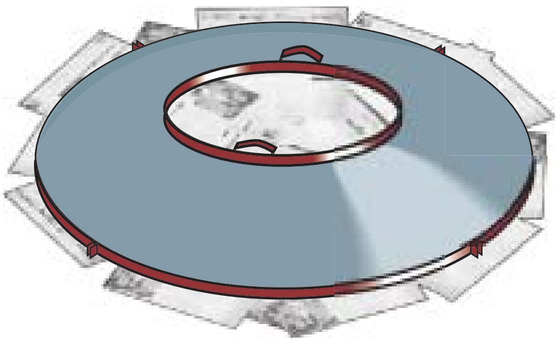


Figure 3-25: Place the wire reinforcement on top of the cement mortar.

Figure 3-26: Fill the space between two moulds with more of the 1:2 cement mortar up to the top level of the moulds and then smooth the surface.

Figure 3-27: Place the 80 centimetres diameter inner mould on top of the paper-covered sand base to cast the tank mouth. Fill the space between the two moulds with the 1:2 cement mortar and fill up to the top level of the moulds.

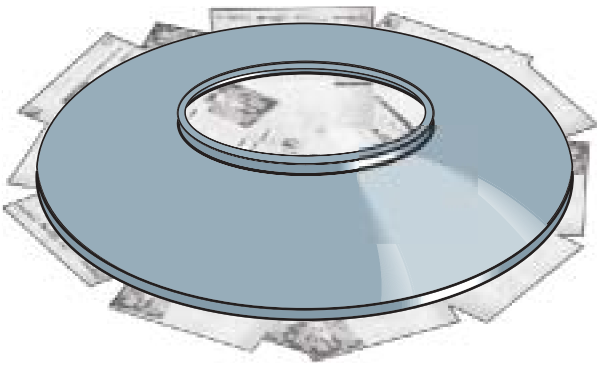


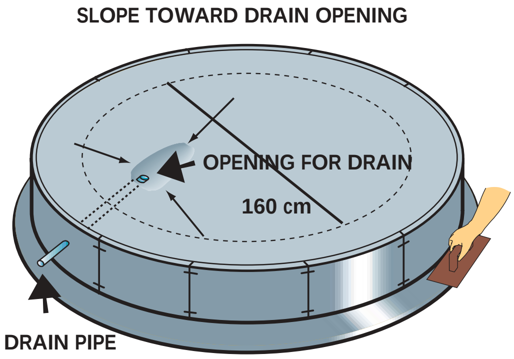
Figure 3-28: Remove the moulds after one hour. Water the cast cover for curing for at least 3 days, though again, curing for 7 days would be better.

Figure 3-29: Finished segments and covers for tank.

e. Construction of foundation for tank

For the tank foundation, 12 pre-cast cement segments are used. The steps of making the tank foundation are the same as for the jar, which is illustrated in **Sector 2**, **Figures 2-5** to **2-11**.

f. Construction of the tank body



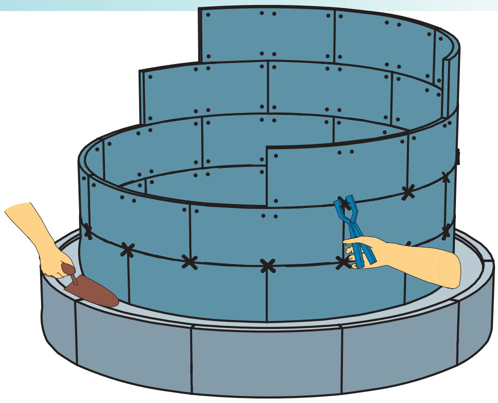
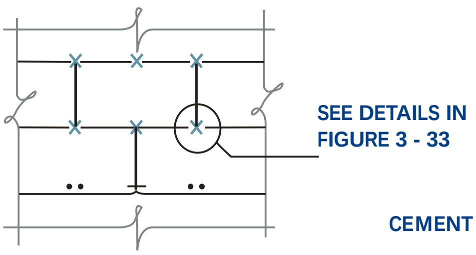


Figure 3-30: A finished tank foundation using 12 pre-cast cement segments.

Figure 3-31: Join 10 pieces of pre-cast cement segments with binding wire along the inner circle that is 160 centimetres in diameter to form one layer. 8 layers are needed for the tank body. It is important to check and adjust the diameter of each layer as and when it is completed. Details of joining segments with binding wire are shown in **Figures 3-32** and **3-33**.



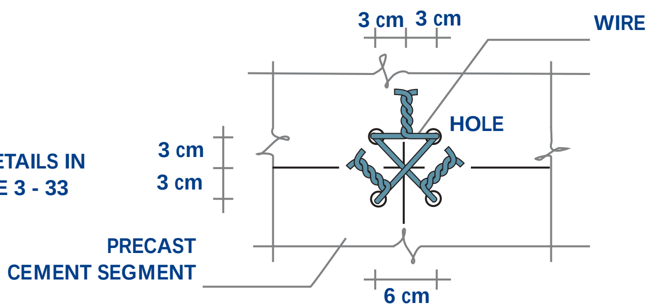


Figure 3-32: Fix pre-cast cement segments with 0.1 centimetre diameter binding wire. (see details in **Figure 3-33**)

Figure 3-33: Proper way of joining the pre-cast segments with binding wire.

Figure 3-34: Assemble the pre-cast segments to form a tank body.

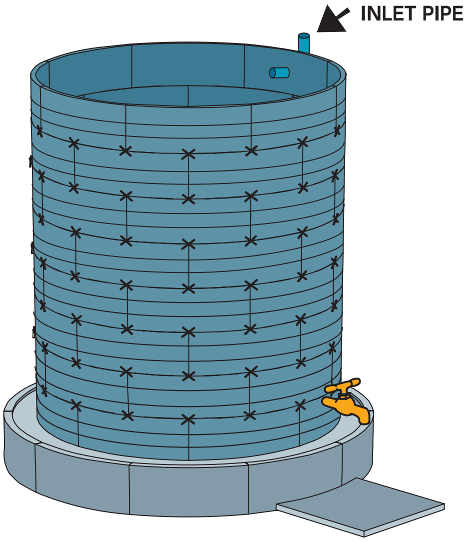


Figure 3-35: Reinforce the 8 layer-segment tank body with 0.1 centimetre diameter binding wire as shown. Insert a tap about 10 centimetres above the foundation floor. An inlet pipe is fixed onto the last layer of segment.

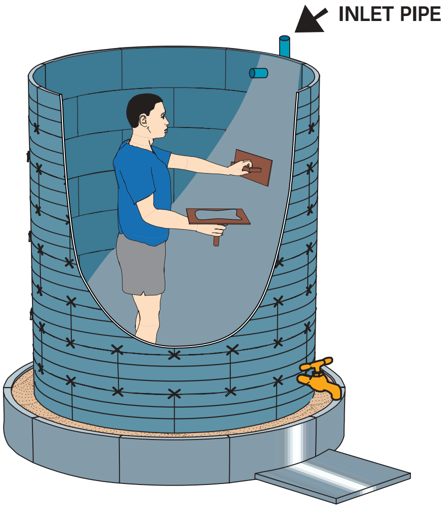


Figure 3-36: Plaster the inside wall of tank with two coatings of 1:2 cement mortar that are each 1.5 centimetres thick. It is necessary to wait a half an hour before plastering the second coating. Care should be taken to avoid making the mortar plastering too thick, as it may fall off of the wall.

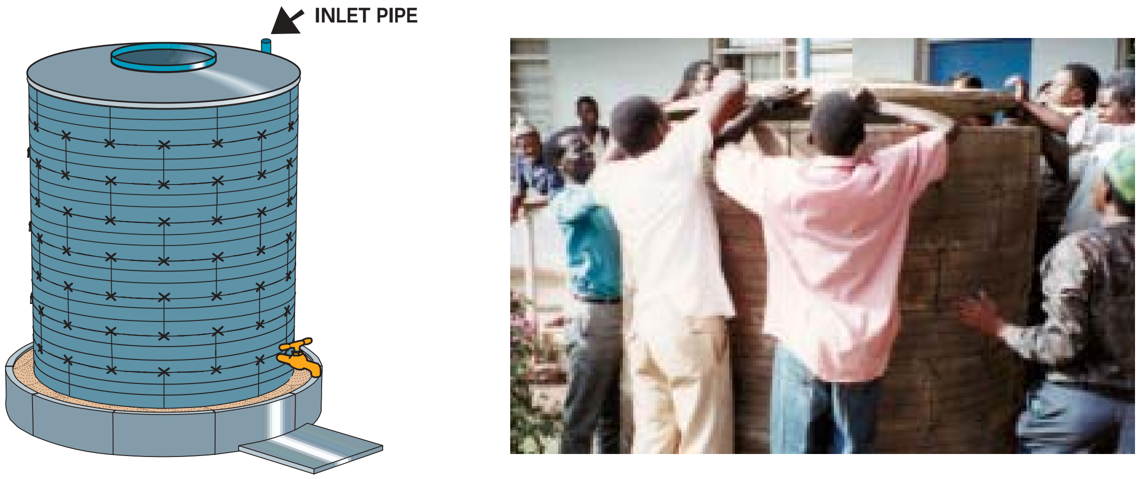


Figure 3-37: Put the cover on top of the tank after plastering the inside tank wall.

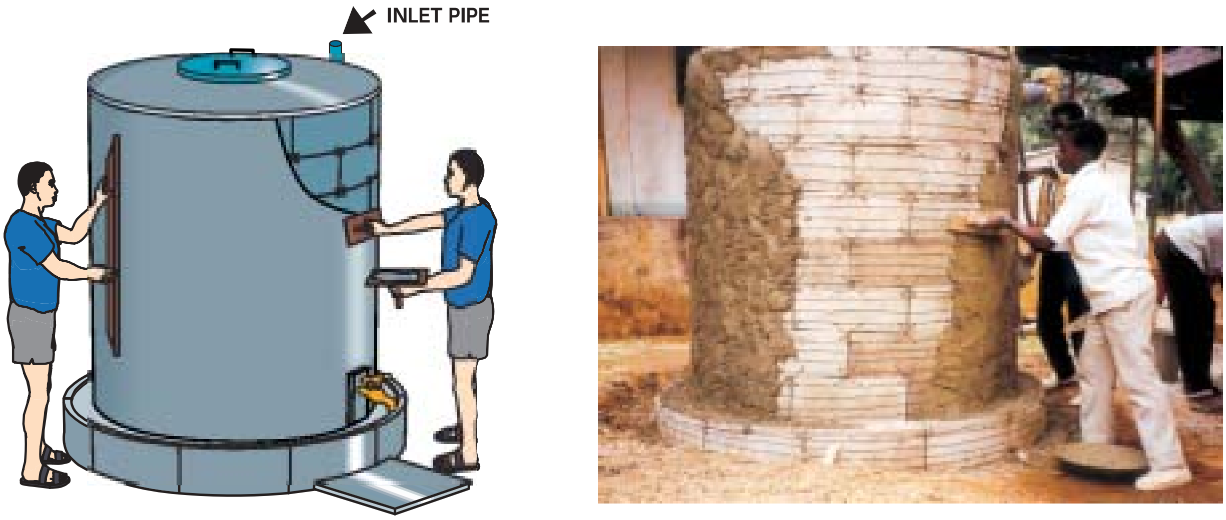


Figure 3-38: Plaster the outside wall of tank with two coatings of 1:2 cement mortar that are each 1.5 centimetres thick. Again, it is necessary to wait for a half an hour before plastering the second coating. And again, care must be taken to avoid making the mortar plastering too thick.

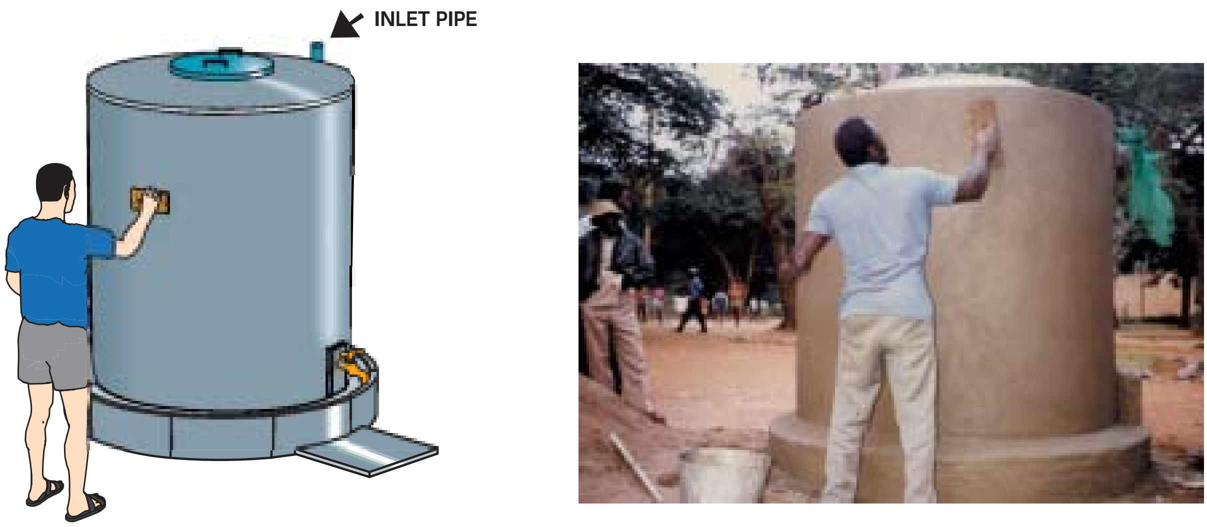


Figure 3-39: Use a sponge to smooth the tank surface.

Figure 3-40: Fix the rain gutter and connecting pipe to the tank.

Figure 3-41: A completed 3,200-litre tank.

4.1 Rainwater Gutters

A rain gutter is used for collecting rainwater from the roof. The collected rainwater flows through an outlet drain that is connected by a pipe to the rainwater container (jar/tank). The rain gutter can be made from various materials depending on local availability, such as:

- Galvanized iron sheet
- Bamboo
- Wood (join 2-3 pieces of wood together and fill the joints with tar or cover the joints with plastic sheet)

a. Galvanized iron gutter

Commercially available galvanized iron gutter is made in different shapes such as semi-circular, trapezoid, etc.

b. Bamboo gutter

Bamboo gutter is commonly used where bamboo is available. It is easy to make and install.

c. Wooden gutter

A wooden gutter is made by joining pieces of wood (2.5 centimetres thick by 6 centimetres wide, or 1.2 centimetres thick by 15 centimetres wide) into a “V” shape. Fill the joints with a mixture of tar and lime or with resin. Sometimes, plastic sheet is used to cover the joints. There is no need to fill them.

4.2 The Gutter Holder

The function of a gutter holder is to secure the gutter to the roof structure at certain intervals. A gutter holder can be made using iron sheet, wood and tree twigs.

4.3 Sizes of Rain Gutter and Outlet Drain

The roof area and slope determine the size of rain gutter. The diameter of the outlet drain is proportional to the roof area and the width of the gutter. An appropriate gutter width and outlet drain diameter corresponding to the roof areas are shown in **Table 4-1**.

Table 4-1: Appropriate Width of Gutter and Diameter of Outlet Drain and Various Roof Areas

ROOF AREA, sq. m	GUTTER WIDTH, cm	OUTLET DRAIN dia., cm
50	12	6.5
60	13	6.5
70	14	6.5
80	15	7.5
90	16	7.5
100	17	7.5

a. Depth of gutter

The depth of the gutter is one-half of the gutter width. For example, if the gutter is 14 centimetres wide, then the depth is 7 centimetres.

b. Diameter of outlet drain

The diameter of the outlet drain is proportional to the volume of rainwater collected in the gutter. The rainwater would overflow if the outlet drain were too small. Recommended diameter of the outlet drain is shown in **Table 4-1**.

4.4 Fixing the Rain Gutter to the Roof Structure

Different ways of fixing various types of rain gutter to the roof structure are illustrated in the following figures.

a. Fixing the galvanized iron gutter

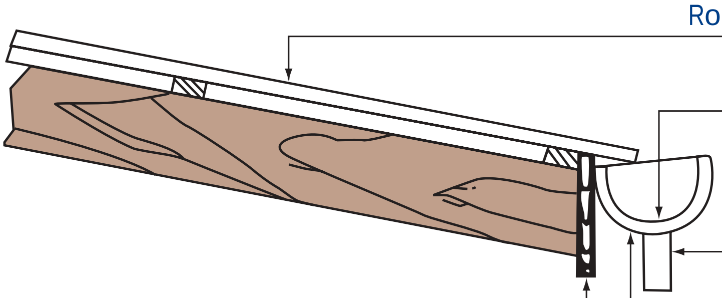


Figure 4.1: Fix the semi-circular shape galvanized iron gutter to wooden roof structure using iron gutter holders.

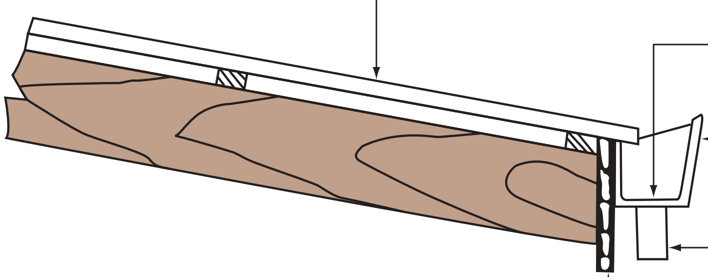


Figure 4-2: Fix the "U" shape galvanized iron sheet gutter to wooden roof structure using the iron gutter holders.

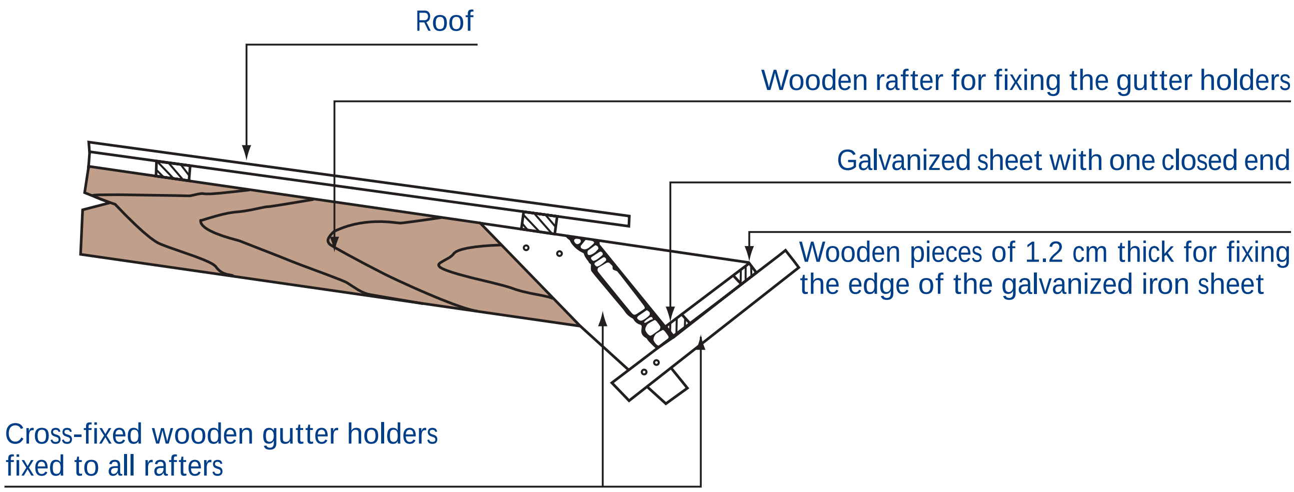


Figure 4-3: Fix the "V" shape galvanized iron sheet gutter to wooden structure using the wooden gutter holders.

b. Fixing the bamboo gutter

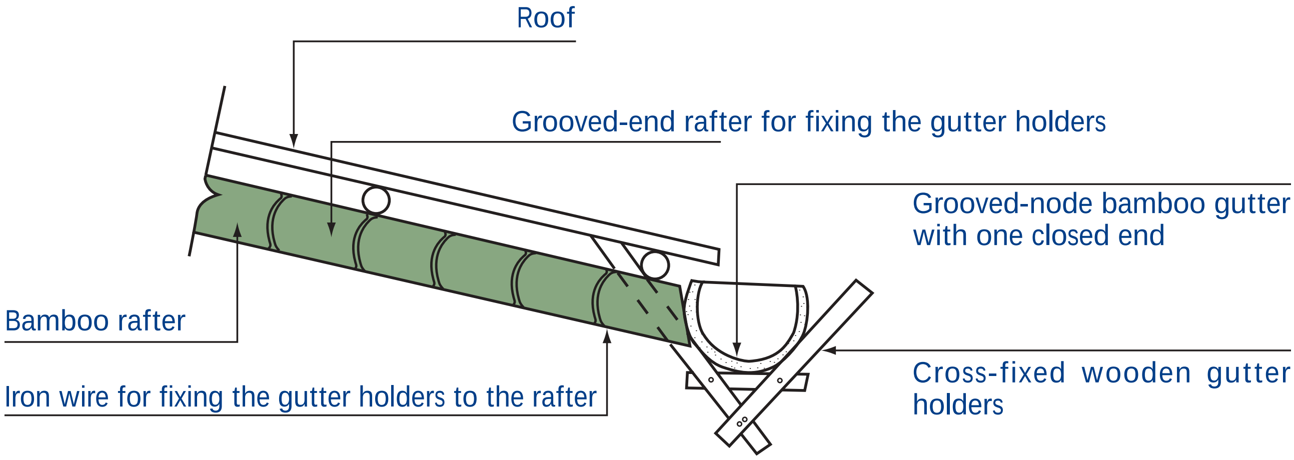


Figure 4-4: Fix the bamboo gutter to the bamboo roof structure using cross-fixed wooden gutter holders.

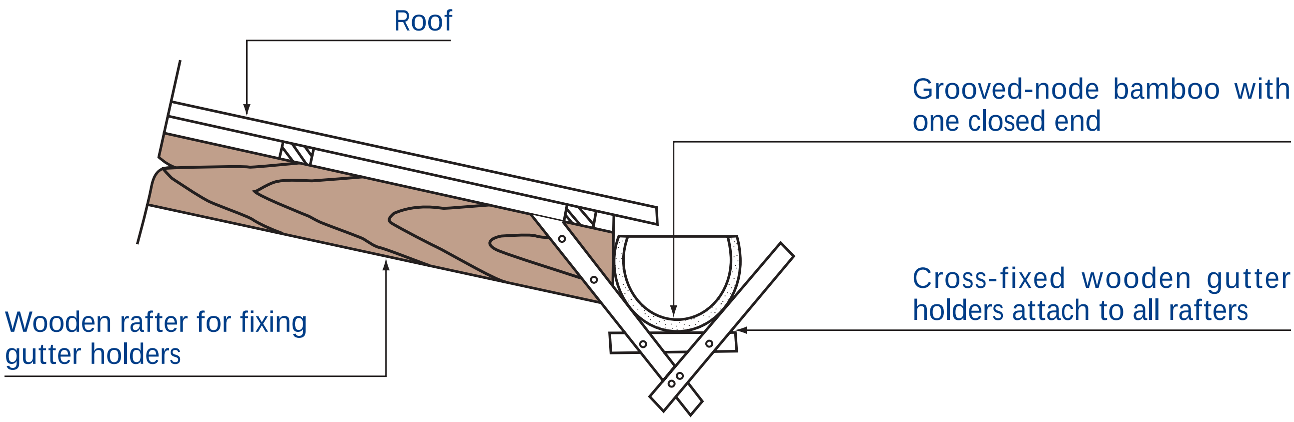


Figure 4-5: Fix the bamboo gutter to wooden roof structure using cross-fixed wooden gutter Holders.

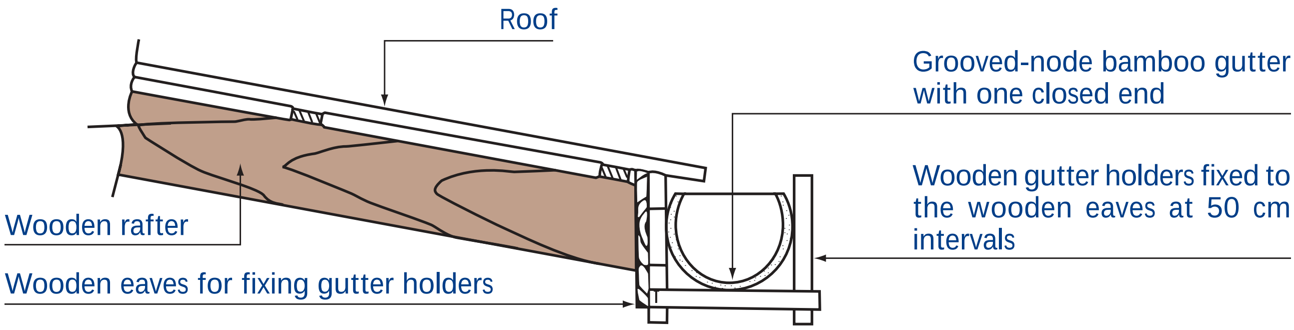


Figure 4-6: Fix the bamboo gutter to wooden roof structure using wooden eaves.

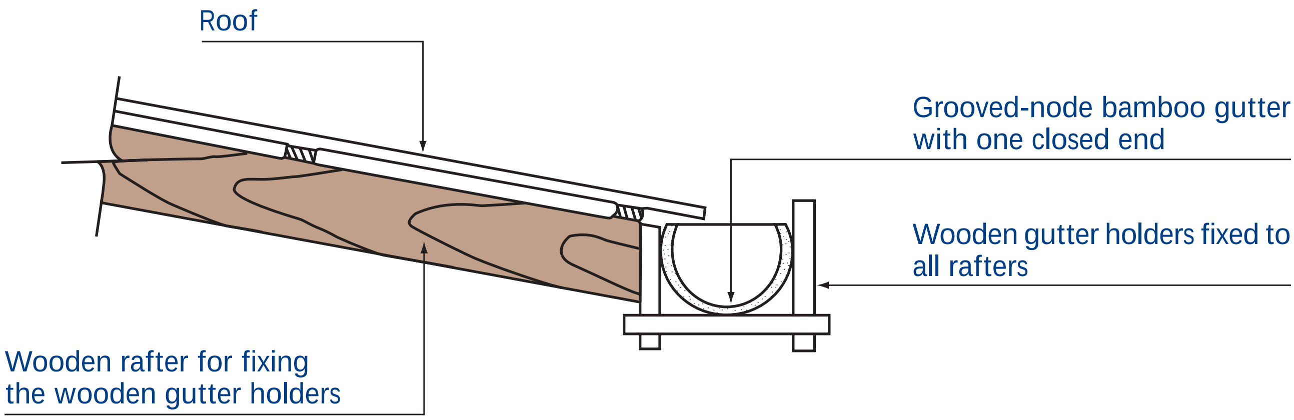


Figure 4-7: Fix the bamboo gutter with wooden gutter holders to wooden roof structure without eaves.

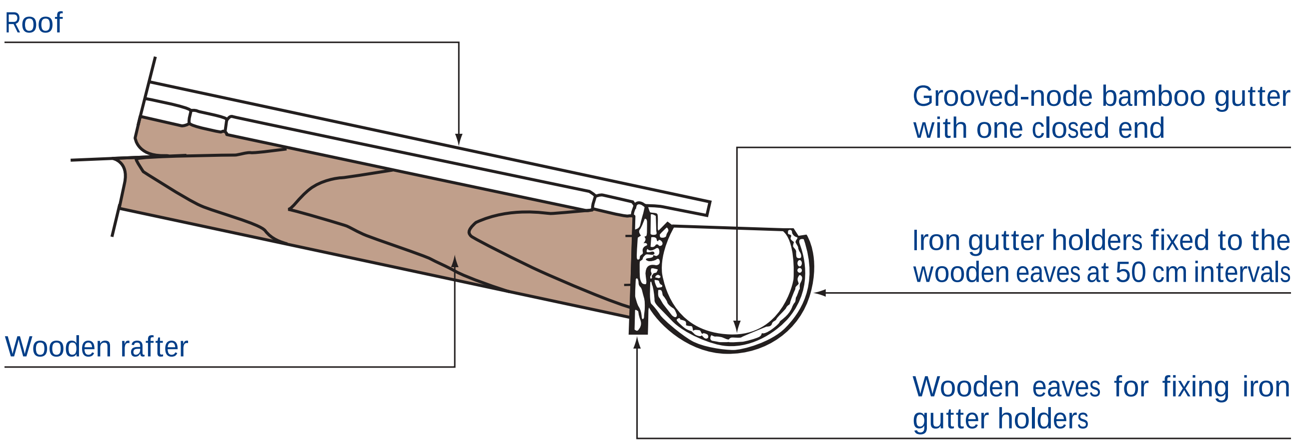


Figure 4-8: Fix the bamboo gutter with iron gutter holders to wooden roof structure using wooden eaves.

c. *Fixing the wooden gutter with plastic sheet to cover joints*

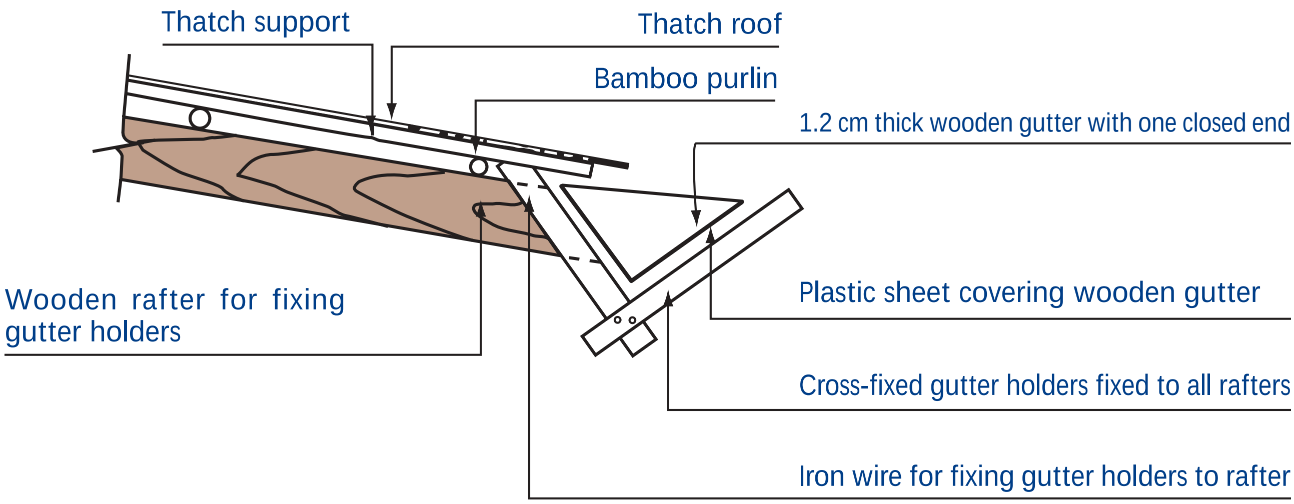


Figure 4-9: Fix the "V" shape wooden gutter to bamboo roof structure.

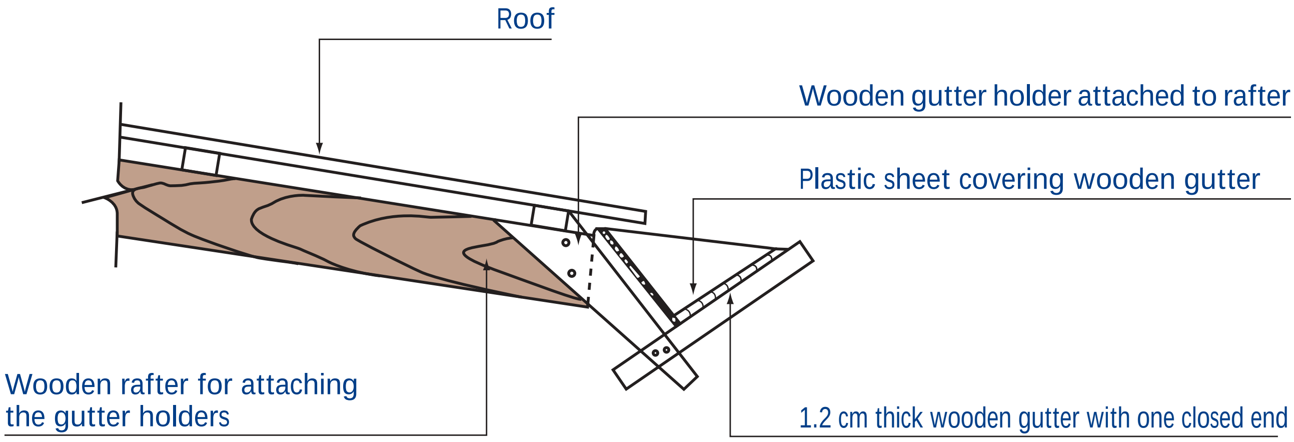


Figure 4-10: Fix the "V" shape wooden gutter to wooden roof structure.

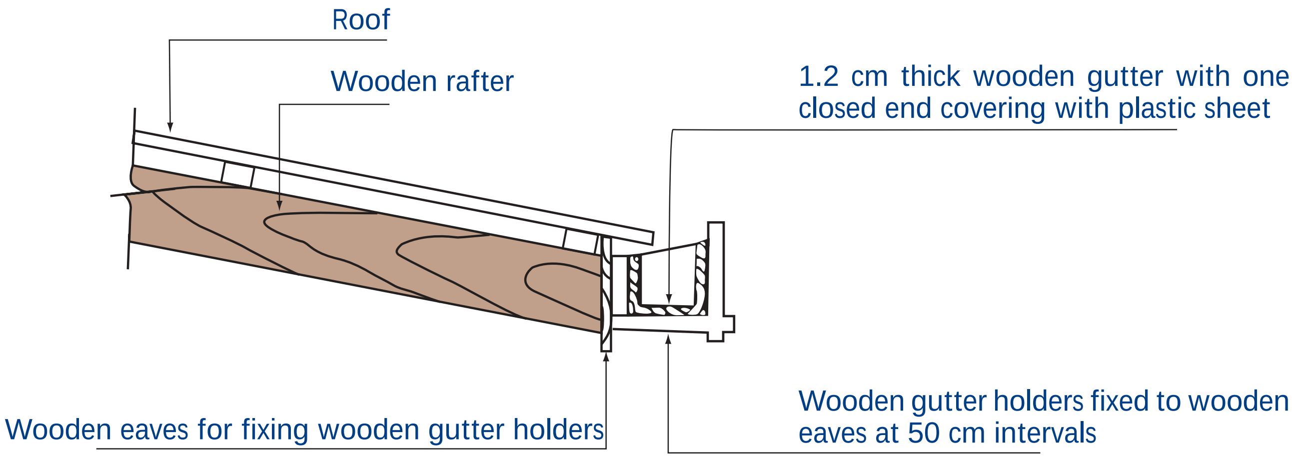


Figure 4-11: Fix the "U" shape wooden gutter to wooden roof structure.

4.5 Making Tree Twig Gutter Holder

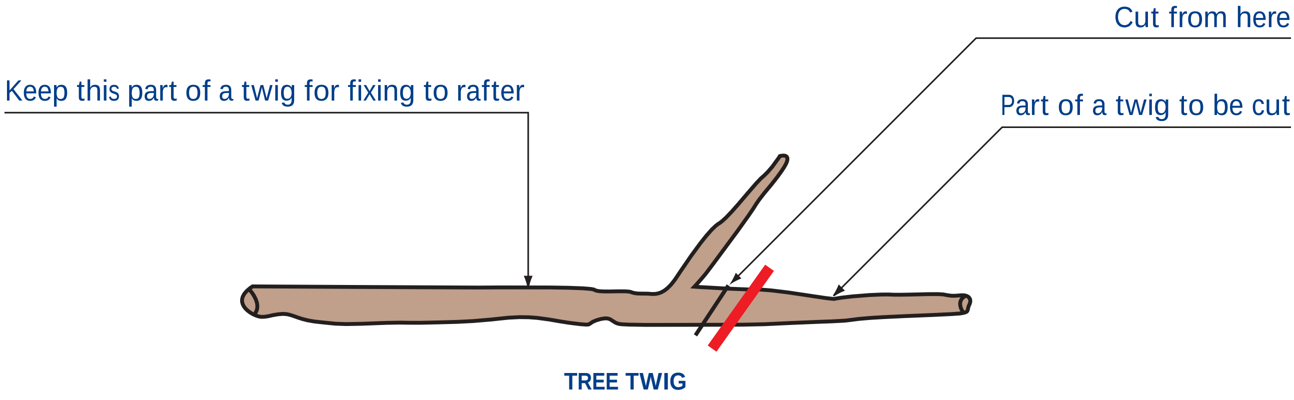


Figure 4-12: Details of making tree twig gutter holder.

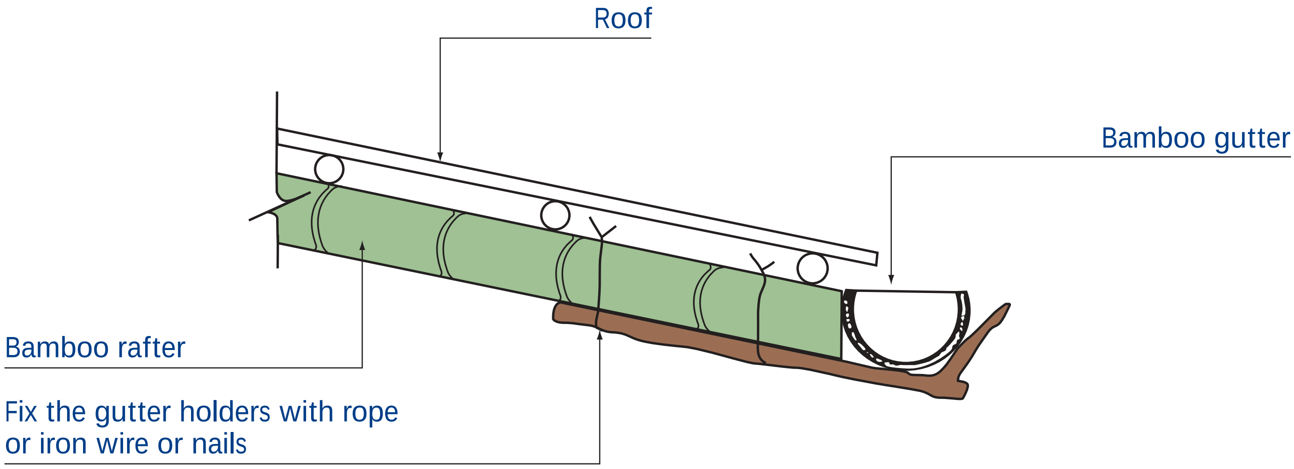


Figure 4-13: Fix the tree twig gutter holders to the roof structure.

Millions of households in rural Thailand have been collecting rainwater for drinking and domestic purposes. The rainwater jars and tanks are produced by the private sector and are readily available in the local market. Many families buy the rain jar and tank as and when needed over a period of time until they have got adequate storage capacity to collect the rainwater for household use. A rain jar of 2000 litres and a tank of 3200 litres currently cost about Thai Bahts 900-1000 (US$ 20-25) and Thai Bahts 1100-1200 (US$ 25-30) respectively, including the delivery charge through waterways in many rural areas.

To collect rainwater for domestic use, families are advised to strictly follow the code of practices mentioned below so as to ensure that the rainwater collected is safe for human consumption and no mosquitoes breed in the tanks and jars.

- Drain away the first and the second rain falling on the rooftop collected in the gutter at the beginning of the rainy season each year, as the first and the second rain in the gutter invariably contain the dirt and the bird droppings deposited on the rooftop during the dry season.
- Keep the connecting pipe between the gutter outlet and the tank inlet, or the jar mouth, movable for easy draining away the first and the second rain when the rainy season starts.
- Clean the tank and jar annually, prior to the start of the rainy season, for ready storage of the fresh rain.
- Cover the tank inlet with a piece of nylon net to prevent mosquitoes from entering into the tank.
- Keep the mouth of tank and jar covered to avoid mosquitoes and dirt from getting into the rain tank and jar.
- DO NOT empty the tank and jar completely at any time. Maintain a level of water inside the tank and jar at the bottom up to the tap level during dry season to prevent cracking of the tank and jar.

This Section illustrates rainwater collection in rural Thailand, in particular, the various indigenous ways of fixing the connecting pipe between the gutter outlet and the tank or jar using local materials.

Figure 5-1: Production of rainwater tanks and jars in the yard of a local private entrepreneur in a village.

Figure 5-2: Household collects rainwater in a series of four tanks.

Figure 5-3: Bamboo is used as connecting pipe between the gutter outlet and the inlet of the tank.

Figure 5-4: A piece of gravalised sheet bent into a “U” shape is used as connecting pipe for rainwater to flow from gutter outlet to the tank.

Figure 5-5: A piece of gravalised sheet bent into a “U” shape is used as connecting pipe for rainwater to flow from gutter outlet to the jar.

Figure 5-6: A piece of plastic tube attached to a funnel hanging under the gutter outlet is used as a connecting pipe. The plastic tube can be moved away from the mouth of the jar or the tank inlet to drain away the first and the second rain of the season.

Figure 5-7: A plastic bottle is used instead of a funnel and fixed onto the connecting pipe inserted into the inlet of the tank.

Figure 5-8: A plastic bottle is used in replace of the funnel and fixed onto the connecting pipe inserted into the mouth of the jar.

Figure 5-9: Even a thatch roof can be used as the catchment for rainwater collection. A half-cut PVC pipe or bamboo is fixed on the thatch roof as a gutter to collect rainwater into a tank.

Figure 5-10: Gravalised sheet bent into "U" shape and fixed under the roof serves dual functions as rain gutter and connecting pipe to the tank.

Figure 5-11: This household shows an innovative way of making three rainwater tanks with very large diameter cement rings to store rainwater collected from the rooftop.

Figure 5-12: A newly constructed modern rural household is also collecting rainwater for drinking and domestic purposes.

Figure 5-13: Household collects rainwater from rooftop, which is stored in a square tank built on the ground. The connecting pipe between the gutter outlet and the ground tank is a plastic tube.

Figure 5-14: Closed up view of a connecting pipe made of half-cut PVC pipe collecting water from the gutter outlet to the tank inlet. The tank inlet is covered with a piece of nylon net to keep away the mosquitoes.

Figure 5-15: A gravalised pipe is fixed as the connecting pipe between the gutter outlet and the tank inlet.

Figure 5-16: The rooftop of a village meeting place is an idea rain catchment. Series of tanks are installed on the ground to collect rainwater from the rooftop for community consumption.

1994, Jock Montgomery

Figure 5-17: Rain jars are delivered or put on sale in a barge cruising along a river or klong (canal in Thai) in many rural areas.

6. THAI RAINWATER JARS IN USE IN EAST TIMOR

UNICEF has been supporting the government of East Timor in providing safe water supply and improved sanitation at the household level in 66 villages of 33 sub-districts in all 13 districts in the country. The assistance began during the emergency period from 1999-2000 and continues now in the transition time when people are returning to rebuild their communities. The UNICEF assisted Water Supply and Sanitation programme adopts several appropriate methods, including hand-dug wells, the rehabilitation of hand pumps and building cement jars for collecting rainwater, to ensure household water security, particularly in the rainy season.

Harvesting the rain and storing it in cement jars of 1,300-litre capacity is becoming popular in East Timor. The rainwater jars, known as *kusi* in the local language, are especially useful for displaced people returning to their villages and to homes that need rebuilding. Some families are using the *kusi* for storing water taken from dug wells or handpumps. Since mid 2001, some 1,040 rain jars have been built by families in East Timor.

Rainwater jars are very practical in coastal areas where the salinity level in dug-wells is high. In the mountain areas, the jars hold a quantity of water that is sufficient to reduce or eliminate the constant need to travel long distances to collect water for a family's basic needs - a chore typically relegated to women and girls. The rainwater jars save people time and energy. And they can be used year-round by storing water taken from other sources.

This section provides examples of rainwater jars in use among families in East Timor. The rainwater jar being promoted in East Timor is made of cement and sand with iron wire for reinforcement. The technique comes from Thailand via Vietnam. It was taught to East Timorese Water Supply and Sanitation team members by a Vietnamese technical team that had been trained by Thai resource persons through the Technical Cooperation among Developing Countries (TCDC) scheme. This has demonstrated the wide spread of the Thai rain jar technology in Southeast Asia and beyond.

Figure 6-1: Having adequate safe water at home is a source of pride; this rainwater jar was built by the family in their yard.

Figure 6-2: Safe rainwater stored in a jar helps improve hygiene. This two-year-old girl washes her hands and face with soap and water from the rain jar.

Figure 6-3: A placard, which describes the operation and maintenance procedure for a family to follow, is attached to each rainwater jar.