



UNHCR

United Nations High Commissioner for Refugees
Haut Commissariat des Nations Unies pour les réfugiés

Large Ferro-Cement Water Tank

Design Parameters and Construction Details



Technical Support Section
Division of Operational Support
July 2006

Table of Contents

I	Introduction	4
II	Basis for Design and Underlying Concepts.....	6
III	Prototype Construction and Test	7
IV	Construction Steps	9

List of Annexes

VI	Material Specifications	16
VII	Bill of Quantities – Summary Sheet.....	17
VIII	Detail Calculation Sheet	Error! Bookmark not defined.
	Detail Drawings for Three Set of Tanks (45, 75 and 90 cu.m.)	

List of Figures

Figure 1. Wall Cross-section on a Horizontal Plan in Skeletal/Armature	
Method of Construction	8
Figure 2. Tank after One Week of Filling.....	9
Figure 3. Tank after Two Weeks of Filling	9
Figure 4. Preparation of Foundation	10
Figure 5. Preparation of Lean Concrete Base	10
Figure 6. Placement of Rebar for Base Slab.....	11
Figure 7. Casting of Concrete Base Slab.....	11
Figure 8. Vertical Reinforcement and Wall Stiffeners.....	11

Figure 9. Temporary Access	11
Figure 10. Inlet/Outlet Opening.....	11
Figure 11. Overflow Opening	12
Figure 12. Fixed Wire Mesh.....	12
Figure 13. Fixing of Central Column	12
Figure 14. Plastering of Wall.....	13
Figure 15. Fixing of Roof Trusses (Stiffeners)	14
Figure 16. Placement of Roof Reinforcements.....	14
Figure 17. Roof Opening	14
Figure 18. Temporary Formwork for Roof	15
Figure 19. Plastering of Roof	15
Figure 20. Temporary Opening.....	15
Figure 21. Finished Ferro Cement Tank.....	15

I Introduction

UNHCR, the United Nations refugee organization, is mandated by the United Nations to lead and coordinate international action for the world-wide protection of refugees and the resolution of refugee problems. UNHCR's primary purpose is to safeguard the rights and well-being of refugees.

Protection and material relief are interrelated. UNHCR can only offer effective legal protection if a person's basic needs – shelter, food, water, sanitation and medical care – are also met. The agency therefore coordinates the provision and delivery of such items and has designed specific projects for vulnerable women, children and the elderly who comprise 80 percent of a 'normal' refugee population.

Provision of clean water for domestic purposes is among the core services of UNHCR's relief programmes designed for its beneficiaries, often delivered through the implementing partners. A water supply system constitutes a set of components, which are meant for specific functions – abstraction/collection, treatment (if required), conveyance/transmission, storage for balancing and/or service, distribution, disposal (of waste water) and storage at household. Several factors govern effectiveness of a water supply system. One of them is the choice of technologies and skills that are sensitive and appropriate to local know-how and expertise.

Storage of water between the source and the distribution points, whether for a balancing or service purpose, is one of the essential functions in a water supply system, and is the only means of ensuring a constant availability of water to the beneficiaries in a given camp/settlement site. In a refugee operation, its role becomes more important as the amount of water available from the sources is often limited and less reliable, and hence a substantial storage facility would be needed to meet various needs – be it during an emergency, a stabilized or a returnee situation.

Water storage facilities or tanks commonly used by UNHCR and other humanitarian agencies include ground tanks (ponds, basins or reservoirs), masonry or reinforced concrete tanks, collapsible fabric tanks (onion, bladder or pillow type), steel or plastic tanks (pre-fabricated and modular type), standard water storage packs (Oxfam type) and ferro-cement tanks. All these tanks have their relative advantages and disadvantages, and therefore, their choice and application in a specific operation would vary according to the analysis of a situation at the time of water system development planning.

Collapsible fabric tanks and standard water storage packs by virtue of their ease of handling and rapid installation are found to be most useful in the initial stages of an emergency operation. Apart from emergencies, UNHCR and other humanitarian organizations however are often involved in many other operations which are characteristically long-term in nature - for example, stabilized, protracted or reintegration/local settlement programmes. In these situations, the choice of a technology invariably would be governed by parameters which are different from the ones used for short-term needs. Such criteria/parameters would include capital as well as operation costs, ease of operation, durability/service-life, conducive to local know-how/skills for repair/maintenance, availability of material locally, and environmentally sound technologies and construction. All of these are basically linked to cost-effectiveness, operational reliability and long-term sustainability.

Use of ferro-cement tanks, though it fulfills most of the criteria above, is still limited in refugee operations. The reasons for this include inadequate knowledge about and/or exposure to the technology (which is relatively new); lack of access to relevant user-friendly literature and difficulty in constructing large water tanks (> 40,000 litres).

What is Ferro-Cement technology?

Ferro-cement is essentially an extension of conventional reinforced cement concrete (RCC) technology. As such, all the benefits attributed to use of RCC in construction normally apply to ferro-cement as well. There are, however, other advantages that make ferro-cement a preferred choice in many construction projects.

It is a thin-walled construction consisting of rich cement mortar with uniformly distributed and closely spaced layers of continuous and relatively small diameter mesh (metallic or other suitable material). Compared to other cement concrete structures, those made of ferro-cement are light weight (use less material, and therefore, also environmentally benign), tough, durable, crack resistance and can be made into virtually any shape. It is a low technology construction in that it does not necessarily require highly skilled labour and complex construction methods, sophisticated or heavy equipment or manufacturing in a plant, and yet a good performance in construction can be achieved. Finally, it is more economical than other concrete or masonry constructions and can easily be repaired, if necessary.

In an attempt to promote the use of ferro-cement water tanks in UNHCR operations, a research study was conceived on the basis of efforts initiated by the Office in Bhutanese Refugee Programme in Nepal. UNHCR has engaged the services of the *Asian Center for Engineering Computations and Software (ACECOMS)* and the *International Ferro-cement Information Center (IFIC)* at the *Asian Institute of Technology (AIT)*, Bangkok to carry out this research study.

The main purpose of the study was in two folds:

- Review the existing techniques used in ferro-cement construction and develop/design large water tanks with capacities in the range of 40,000 to 100,000 litres, and that can easily be adopted in UNHCR operations.
- Conduct a prototype test to ensure structural integrity, assess operational performance, and prepare and document detailed drawings, bill of quantities, and constructions steps.

This booklet summarizes the underlying design concept of improved large ferro-cement water tanks, and presents easy-to-follow construction details with relevant drawings, bill of quantities and necessary guidance. The goal is for the practitioner engineers in the frontline could use it without much difficulty and that the knowledge is widely shared and applied in the field, both in the realm of humanitarian as well as development programmes.

II Basis for Design and Underlying Concepts

As a prelude to the research study, besides literature surveys and field visits to refugee camps in Jhapa/Nepal, the research team undertook an evaluation of various water tank systems. Main features for comparison included:

- Cost
- Constructability
- Skill and technology requirements
- Availability of materials
- Short and long term performance and
- Adaptability.

After evaluating several water tank systems ferro-cement was found to best serve most of UNHCR's requirements, except in an emergency operation. Initially, two options were considered for further design and prototype testing.

Option 1: Cast-in-place Ferro-cement Tanks

Option 2: Pre-cast Ferro-cement Tanks

For the sake of brevity, the following paragraphs outline only the basis of design and the key features considered in the process without dwelling much on the analytical and other details involved.

To start, a comprehensive modelling procedure and analysis of a typical tank was carried out with an objective to understand the structural behaviour of the tank, to replicate and predict its response to various loads (e.g. hydrostatic), and to evaluate the serviceability state. A full three-dimensional finite element model (FEM) of the tank, including the associated components, was constructed and analyzed using SAP2000 software. Both the wall and the roof were modelled using shell elements.

Results of analysis primarily contain the deformation and the stresses caused by the applied loads. These results were used for checking the safety and serviceability requirements of the tank. Upon evaluating the results, it was found that the maximum stresses under full water load condition are within the acceptable (safe) limits. In other words, the proposed system is safe for full water loading and reasonable live load on the roof.

A number of books, research documents, technical publications, existing design codes, guidelines and recommendations dealing with ferro-cement and laminated cementitious composites were extensively consulted. The final design was based primarily on *Ferro-cement Model Code* (Building Code Recommendations for Ferro-cement (IFS-10-01), January 2001). In addition, the performance of more than 20 ferro-cement water tanks built under the technical supervision of IFIC over a period of 10-15 years was evaluated

to identify the system offering the most cost-effective and desirable short and long-term performance.

The basic design followed the concepts and general principles in current use in structural engineering, particularly for reinforced and pre-stressed concrete structures. The structure was designed to satisfy a number of limit states, where a limit state is defined as the boundary between acceptable and unacceptable performance.

Practical design guidelines to ensure good serviceability of ferro-cement structures were based on allowable stresses under maximum service load, maximum crack width, fatigue life, durability and corrosion, and deflection limitations. Accordingly design parameters were defined for:

- The cover to the first layer of reinforcement;
- Thickness of wall and roof members;
- Size of mesh opening;
- Skeletal reinforcement depth, volume fraction of the reinforcement and specific surface of reinforcement;
- Number of mesh layers, mesh opening area and wire diameter; and
- Fineness of matrix (mortar).

Though the final design was based primarily on the relevant *Ferro-cement Model Code*, the skeletal reinforcement and wire mesh requirements computed based on the code were modified and verified experimentally. The code based calculation showed that more than 4 layer of wire mesh need to be provided but this was reduced to 2 by taking into account the contribution of skeletal steel and providing additional stiffeners (steel channels and the roof trusses). ***This new concept introduced in the present design distinguishes the proposed large ferro-cement water tank from the other.*** The proposed design significantly reduces the cost of the tank without affecting its structural integrity, safety and performance. The finite element analysis was also used to verify the adequacy of the design.

III Prototype Construction and Test

There are several methods for the analysis, design and construction of ferro-cement structures. The main difference among these methods is related to the strength contribution of the skeletal steel. Most ignore the strength contribution of skeletal steel. But based on several tests carried out both IFIC and AIT, it has been found that this results into a very uneconomic design. Rational analytical methods for computing the strength of the ferro-cement structures for tension, bending, shear and their combined effects that take into account the contribution of all the skeletal, mesh, and mortar are not available. Hence, the only way to determine strengths related to these forces is through experimental or prototype tests.

The three main objectives of the prototype testing of the tank are to:

- Study its constructability aspects;
- Verify the strength requirements; and
- Study its water permeability (tightness) and initial stage performance.

Among several methods available for construction, the Skeletal/Armature method (shown in the sketch below) was chosen for its obvious advantages – no framework required, good mortar penetration can be achieved, easy to patch-up all areas from both sides. The armature method is a framework of tied reinforcing bars (skeletal steel), wires or strands, to which layers of reinforcing mesh are attached on each side. Mortar is then applied, preferably from one side, and forced through the mesh layers until a slight excess appears on the other side. This excess is then pressed back through the armature and struck off as finishing.

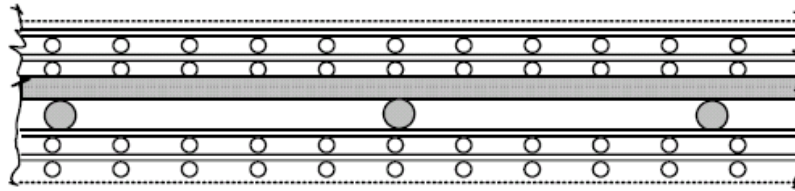


Figure 1. Wall Cross-section on a Horizontal Plan in Skeletal/Armature Method of Construction

The strength requirements were verified as follows:

Strength of walls: The strength of the walls was verified by filling the tanks progressively with water over a span of 5 days (20% at a time) and observing the performance at each stage. No unusual behaviour was observed for the first month after filling the tanks to their full capacity.

Strength of Roof: The roof was loaded with over two tons of cement bags for a period of half an hour after a month following completion of the tank. The capacity was also verified by applying live load, over 14 persons (AIT students) standing on the roof during a site visit.

The most effective and natural way to study the water tightness of a tank is to fill it with water and observe whether or not there is any leakage. With this objective, the tank was filled with water progressively over a span of 5 days until sufficient overflow water obtained from the overflow pipe near the top. Some seepage was observed during the first week of filling but dried up within few days. Seepage in the first week of filling is expected, as it is the inherent property of ferro-cement structures. The chemical reaction of the remaining cement mortar ingredients with water (hydration) causes the expansion of such particles, thereby reducing the permeability of the wall. We can also observe white patches (effervescent) of the products of the chemical reaction on the exterior surface of the tank. However, they vanished within couple of weeks as the cement attains proper setting with the progress of time.



Figure 2. Tank after One Week of Filling



Figure 3. Tank after Two Weeks of Filling

IV Construction Steps

The following paragraphs outline the easy-to-follow details on the how to proceed with the construction of the cast-in-place ferro-cement tank. They are separated into three sections: foundation, wall and roof. These should be read in conjunction with the Sections on Material Specifications and Drawings, as that is where dimensions and quantities are provided.

Foundation

Step 1: Selection of Site: The site should be located in an area higher than its surroundings. The other considerations include the sources of water supply, areas in which the water is to be distributed, possibility of flooding, and practical aspects of construction. The final decision should be taken by a qualified engineer.

Step 2: Site Clearance: The site must be cleared, with loose surfaces compacted and levelled properly. The area should be protected or fenced, if necessary.

Step 3: Preparation of Foundation: The type of foundation required may differ depending upon geographical locations, soil condition, and size of the water tank. **The design should be carried out by a civil or geotechnical engineer.** For the prototype, the foundation consists of compacted soil and sand up to 0.5 m above the existing ground level. To facilitate the retention and compaction and provide additional strength, concrete hollow blocks with vertical bars along the circumference at about 20-30 cm centre to centre can be used. However, other methods that would serve the same purpose can also be employed depending on the requirements of the site and the availability of type of local construction material.

Steps to prepare the foundation

- 1) Mark the location of the foundation perimeter (circular ring).
- 2) Lay the blocks.
- 3) Insert the vertical bars (dia. 6 or 9mm, 20-30 cm c/c); fill the holes with cement mortar.

- 4) Fill the space with soil/sand. At least top 10 cm should be filled with sand.
- 5) Compact the soil using a compacting hammer or other devices.
- 6) Wet the sand with water and compact.



Figure 4. Preparation of Foundation



Figure 5. Preparation of Lean Concrete Base

Step 4: Preparation of Lean Concrete Base: Lean concrete provides a level base and water-tightening layer for the concrete slab to be cast upon. This layer should be laid over the foundation. Generally, 5-6 cm thick lean concrete (typically a mix of 1: 3: 5 by weight) is used.

Step 5: Preparation of Base Slab Reinforcement: There are two ways to prepare the slab reinforcement: either at its final location or at a nearby location and then move to the final place. In this prototype, two layers were prepared outside the tank area and transferred by lifting. Generally 4 to 6 persons are required for moving and placing the reinforcement.

Step 6: Laying Base Slab Reinforcement: The two layers of slab reinforcement were placed in their final position. The distance between the layers can be controlled using small separators made up of crushed concrete pebbles or pre-cast pieces.

Step 7: Erecting L-bars Along the Wall-Base Junction: L-shaped bars are used both for strength and to improve constructability. It is difficult to fix the long vertical bars (1 to 2.5 m) to the base slab reinforcement at this stage. L-shaped bars being shorter/lighter, it is easier to tie into base slab reinforcement. One or two tie wire pieces are required for each L-shaped bar. If long vertical bars are fixed at this stage it is not convenient to pour the concrete and go inside for levelling. It is always convenient to place at least two (the top and bottom) circular rings and then fix the L-shaped bars as anchor bars.

Step 8: Placing Vertical Dowel/Fixing Plate/Bars for Central Column: Similar to the L-shaped bars placed along the perimeter, 4-8 bars can be placed at the location where the central column is to be erected. Alternatively a base plate with holes/bolts can be fixed at this stage.



Figure 6. Placement of Rebar for Base Slab



Figure 7. Casting of Concrete Base Slab

Step 9: Casting the Base Slab: After fixing the rebar for slab, the central column and the peripheral L-shaped bars, the slab can be concreted. The surface should be levelled properly with trowel or smooth planks. The concrete (1:2:4 by weight) can be mixed at the site or can be ordered from the ready-mix supplier.

Wall

Step 10: Erecting Vertical Reinforcement and Stiffeners for the Wall: As the water pressure decreases with height, the amount of reinforcement required also varies with height. Bars can be spaced tightly at the lower part and the spacing can be increased with height. Therefore, there are vertical bars of two different lengths (but same diameter) – the first type extending only up to 1 meter from the base and the other type extending up to the top of the wall with some additional length to bend into the roof ($2.2 + 0.3 = 2.5\text{m}$). These bars are fixed with tie wire to the L-shaped base bars. It is convenient to erect a few bars at first just enough to hold the topmost circular ring and then only to erect the remaining vertical bars. The top and bottom rings now provide the anchorage for the vertical bars.

Eight steel channels are used to provide additional stiffness to the wall at every 45 degree angle. These channels are placed with the hollow part facing inward (ease for plastering). The height of these channels will be equal to the height of the wall. The eight shallow roof trusses will be welded with these channels at the top.



Figure 8. Vertical Reinforcement and Wall Stiffeners

Step 11: Keeping Openings for Construction and Pipe Works: A temporary access opening should be provided for the movement of the workers in and out of the tank during construction. The size of the opening should be large enough for one person to enter the tank. This opening will be plastered at the end.

Similarly, openings for inlet, outlet, overflow and ventilation pipes are required at this stage. It is not recommended to make holes when plastering has been completed. If any other fixings are required they should be added at this stage.



Figure 9. Temporary Access **Figure 10. Inlet/Outlet Opening** **Figure 11. Overflow Opening**
Opening

Step 12: Fixing the Wire (Chicken) Mesh (WM1 and WM2): Chicken mesh comes in rolls. Normally two layers of chicken mesh are used. The mesh is wrapped around the wall reinforcement and fixed with tie wire at a few locations. It is convenient to start from the bottom and move upward. About 10 cm of overlapping is recommended at discontinuous ends. Both inner and outer layers should be placed before starting the plastering.



Figure 12. Fixed Wire Mesh

Figure 13. Fixing of Central Column

Step 13: Preparation and Fixing of the Central Column: There are several options for the selection, preparation, and fixing of central columns. The central column can be made up of concrete alone, galvanized iron (GI) pipe filled with concrete, a GI pipe alone, properly painted steel pipe/tube, or ceramic pipe filled with mortar. The main considerations for selection are strength, corrosion protection and workability. The mortar filling of the pipe or tube may or may not contain the reinforcement.

There are two methods for preparation: either the column can be prepared completely outside and fixed at its final position or alternatively, all the work, including placement of rebar and fixing of the top plate, can be performed when it is erected.

NOTE: Considering several factors, it is strongly recommended to finish the column to the ready-to-fill stage before erecting. The dowel bars coming out of the base slab at the slab centre should be encased by the bottom end of the pipe. If required, some temporary support may be provided. The plate at the top of the column may be fixed before or after erection. It is generally welded with the column rebar at top.

Step 14: Plastering the Wall: Once wall reinforcement and central column erection have been completed, the wall is ready for plastering. The first step for plastering is the preparation of the mortar (sand and cement only, ratio 1:2) with a workable consistency (limiting water cement ratio in the range of 0.35 to 0.45 by weight gives the optimum results, and helps to attain low porosity of the mixture).

It is easier to work the inside face first and then the outer face. The plaster is applied by the mason from the inside, pushing the mortar into the layers of mesh, with a helper holding a sheet of plywood/wooden plank on the corresponding area outside. Therefore the plastering of the first face requires at least two persons, one to hold the plywood/wooden plank at outer face, and a mason to plaster from inside. However, once one face has been completed, the already completed side acts as a wooden plank for the other face, thus eliminating the need for temporary support on the opposite face. Special care should be taken while plastering around the edges, rings and

openings so as to avoid leaks in the future.



Figure 14. Plastering of Wall

Roof

Step 15: Preparation of Roof Shallow Truss: Eight roof trusses of about 10 cm depth made up of 9mm (top and bottom) and 6 mm (vertical and diagonal) welded bars are used to stiffen the roof. Typically the fabrication of a truss involves cutting, bending and welding the top and bottom chords vertically and diagonally.

16: Fixing Roof Trusses (Roof Stiffeners): The roof-stiffening trusses are welded with the top of C-channels in the wall at the lower end and with the column top base plate at the other end. While cutting bars for the trusses, additional lengths are required to facilitate welding with the C-channels. These trusses are braced laterally by similar trusses at their mid-length, forming an octagon. If the welding facility is difficult to mobilize to the site, a simpler method like nuts and bolts or other hooking mechanisms can substitute the welding needs.



Figure 15. Fixing of Roof Trusses (Stiffeners)

Step 17: Placement of Roof Reinforcements: Once the main and bracing roof trusses have been placed, the circumferential and radial bars for the roof must be placed. Some of the radial bars can be curtailed at mid-length along the roof surface. The portions of the vertical bars extending above the height of the wall are bent into the roof.



Figure 16. Placement of Roof Reinforcements



Figure 17. Roof Opening

Step 18: Providing Openings in the Roof: At least one manhole should be constructed as access to the tank's interior for inspection, cleaning and repair purposes. An additional hole may be constructed for fixing inlet or ventilation pipes. An additional bar of 9mm can be placed along the perimeter of the opening.

Step 19: Plastering of Roof Trusses: The roof trusses perform basically two functions: during construction they act as support for the wet roof surface and, throughout the life of the structure, they act as stiffeners. Therefore these trusses (main and bracing) are plastered before plastering the roof surface. The process of plastering these trusses is similar to that for walls.

20: Temporary Formwork for Plastering Roof Surface: Similar to the walls, the plastering of the roof is also carried out from the top against a sheet of plywood/wooden plank placed on the working area underside. This requires a temporary formwork for supporting the wooden plank/plywood. A plank/plywood may be supported by 2-3 props.



Figure 18. Temporary Formwork for Roof



Figure 19. Plastering of Roof

Step 21: Plastering the Roof Surface: As explained previously, plastering the roof is also carried out from the top against a sheet of plywood/wooden plank placed on the working area underside. It is highly recommended to plaster the area near the truss first and progress sideways.

Step 22: Plastering the Temporary Openings: These areas should be the last items to be plastered. Now the roof opening should be used as access. One person should enter into the tank through the permanent opening in roof to assist plastering. The temporarily bent bars at the openings should be straightened before closing with mesh and plastering.

Step 23: Finishing the Surface: The excess mortar and uneven surfaces should be brushed off to finish the surface. Finally, the exterior of the tank should be painted with a cement coat of a preferred shade, and the periphery of the plinth should be back-filled with a layer of grass-turf on the top and drainage developed to avoid accumulation of rainwater.



Figure 20. Temporary Opening



Figure 21. Finished Ferro Cement Tank

VI Material Specifications

MATERIAL	COMMENTS														
Cement	Use ordinary Portland cement Type I or II for tropical countries and Type II for cold climates.														
Sand	<p>Use well graded sand. Sand that is too fine or too coarse is not suitable.</p> <p>Separate sand from stone using 6.4 mm (1/4 inch) mesh screen.</p> <p>No organic or chemical impurities. If quality is in doubt, wash with clean water.</p> <p>Desirable sand grading as follows</p> <table border="1" data-bbox="634 743 1192 1178"> <thead> <tr> <th>Sieve</th> <th>Percent Passing</th> </tr> </thead> <tbody> <tr> <td>3/8 in. (9.5 mm)</td> <td>100</td> </tr> <tr> <td>No. 4 (4.75mm)</td> <td>95 to 100</td> </tr> <tr> <td>No. 8 (2.36mm)</td> <td>80 to 100</td> </tr> <tr> <td>No. 14 (1.18mm)</td> <td>50 to 85</td> </tr> <tr> <td>No. 30 (600µm)</td> <td>25 to 60</td> </tr> <tr> <td>No. 100 (150µm)</td> <td>2 to 10</td> </tr> </tbody> </table>	Sieve	Percent Passing	3/8 in. (9.5 mm)	100	No. 4 (4.75mm)	95 to 100	No. 8 (2.36mm)	80 to 100	No. 14 (1.18mm)	50 to 85	No. 30 (600µm)	25 to 60	No. 100 (150µm)	2 to 10
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No. 100 (150µm)	2 to 10														
Water	Water fit for drinking is suitable. Salty water should never be used.														
Wire Mesh	<p>Must be easy to handle and flexible enough to be bent around corners.</p> <p>Galvanized wire mesh is preferred as it is less likely to rust or corrode.</p> <p>Use 0.5 mm to 1.00 mm diameter with 10 mm to 25 mm mesh opening.</p> <p>Free from grease, oil, rust and anything that might reduce bond.</p>														
Skeletal Steel	<p>Free from grease, oil detergents, organic matter and cracks of blow holes.</p> <p>Bars are acceptable if no cracks appear after the following field test: "Bend bar into a U shape and then straighten it out. Bend it again into a U shape in the opposite direction and straighten it out."</p> <p>Grade SR24: yield strength = 2400-2600 ksc</p>														
Steel Channel	<p>Free from grease, oil detergents, organic matter, cracks of blow holes</p> <p>Size 7.50 mc x 3.75 cm (height x width)</p>														

	Grade $F_y = 2400-2600$ ksc (34-36 ksi) and $F_U = 4000-4500$ ksc (57-64 ksi)
Tie Wire	Use annealed (soft) galvanized wires of 24 or 26 gauge. Cut pieces of wire from meshes could also be used for tying.

Mix Proportions

Lean Concrete = 1:4:8 (Cement: Sand: Aggregate by weight)

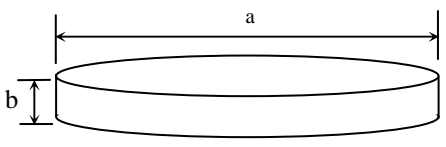
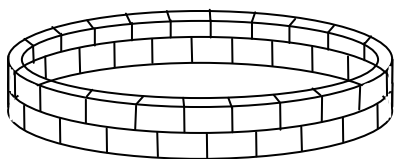
Slab Concrete = 1:2:4 (Cement: Sand: Aggregate by weight)

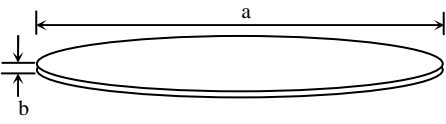
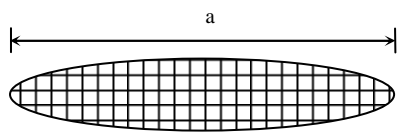
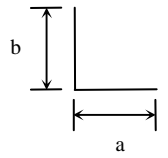
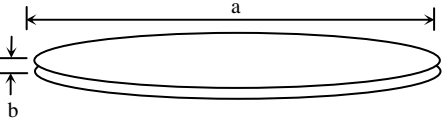
Mortar for wall and roof = 1:2:0.4 (Cement: Sand: Water by weight)

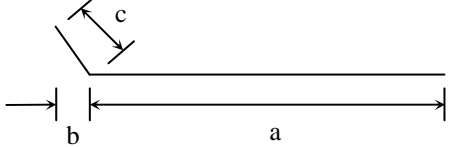
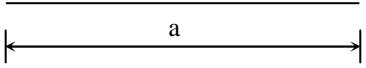
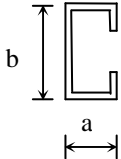

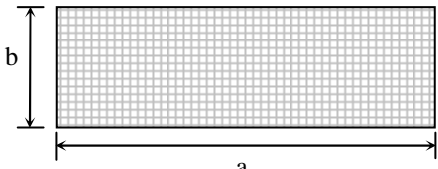
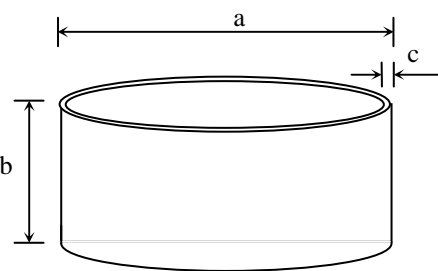
VII Bill of Quantities – Summary Sheet

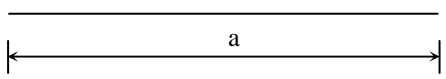
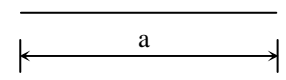
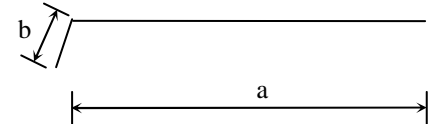
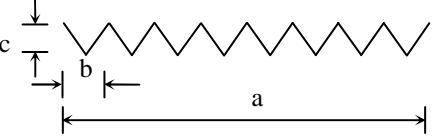
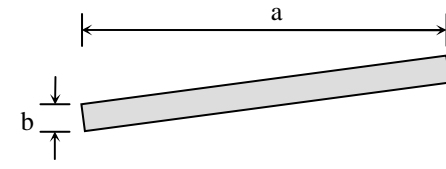
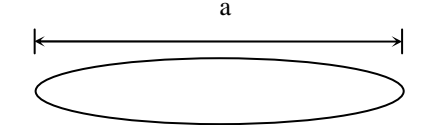
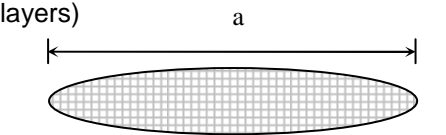
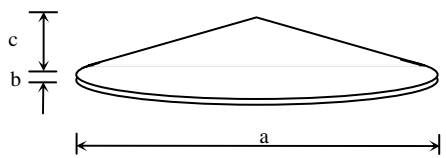
Items	Unit	Quantity		
		45 cu. m.	75 cu. m.	90 cu. m.
Coarse Sand for Basement	m ³	14	21	25
Hollow Blocks	pieces	150	280	195
Cement	kg	3267	4553	5072
Fine Sand	m ³	4.26	6.0	7.0
Coarse Aggregate	m ³	5.0	7.0	8.14
Reinforcement Bar 6 mm	m	164	242	279
Reinforcement Bar 9 mm	m	1452	1976	2375
Steel Channels (7.5 cm x 3.75 cm)	m	18	18	18
Wire Mesh	m ²	123	168	191
GI Pipe	m	2.7	2.7	2.7
Steel Plate	m ²	0.09	0.09	0.09
<p>Note: Plumbing fixtures (inlet, outlet, overflow and flush-out), cement paint on the exterior, backfill, grass turf and drainage around the tanks to be added as appropriate. Construction period is three to four weeks for about 60-75 man-days of skilled labour.</p>				

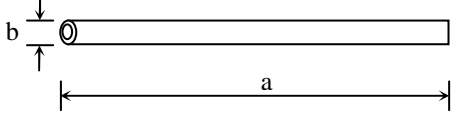
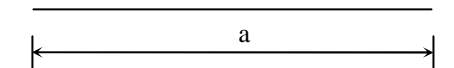
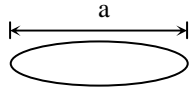
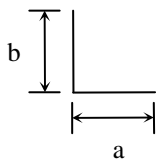
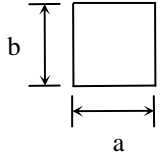
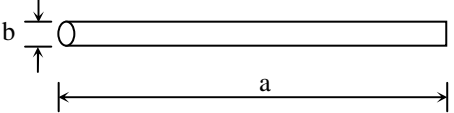
VIII Detail Calculation Sheet

Basement								
Item/Shape	Dimensions (m)			Material	Quantity			Unit
	45 m ³	70 m ³	90 m ³		45 m ³	70 m ³	90 m ³	
Coarse Sand 	a = 6.30 b = 0.45	a = 7.70 b = 0.45	a = 8.30 b = 0.45	Coarse Sand	14.0	21.0	25.0	m ³
Hollow Blocks (0.20 m x 0.40 m) 				Hollow Blocks (3 rows) Cement Sand Water RB 6 mm @ 0.40 m (L = 0.20 m)	150 250 0.25 0.10 10.0	180 300 0.30 0.12 12.0	195 325 0.33 0.13 13.0	pieces kg m ³ m ³ m

Base Slab								
Item/Shape	Dimensions (m)			Material	Quantity			Unit
	45 m ³	70 m ³	90 m ³		45 m ³	70 m ³	90 m ³	
Lean Concrete 	a = 6.30 b = 0.05 (1.6 m ³)	a = 7.70 b = 0.05 (2.4 m ³)	a = 8.30 b = 0.05 (2.7 m ³)	Cement Sand Stone Water	384 0.84 1.40 0.27	576 1.25 2.09 0.41	648 1.41 2.35 0.46	kg m ³ m ³ m ³
ST1 & SB1 (RB 9 mm @ 0.20 m: 2 Layers) 	a = 6.30	a = 7.70	a = 8.30	RB 9 mm (304 m/1 layer)	608	880	1120	m
SL1 (RB 9 mm @ 0.10 m) 	a = 0.40 b = 0.30 (168 pieces)	a = 0.40 b = 0.30 (212 pieces)	a = 0.40 b = 0.30 (232 pieces)	RB 9 mm (0.7 m/1 piece)	118	149	163	m
Concrete 	a = 6.30 b = 0.12 (4.0 m ³)	a = 7.70 b = 0.12 (5.6 m ³)	a = 8.30 b = 0.12 (6.5 m ³)	Cement Sand Stone Water	1280 1.80 3.56 0.75	1792 2.52 5.00 1.05	2080 3.00 5.79 1.22	kg m ³ m ³ m ³

Ferro-cement Wall								
Item/Shape	Dimensions (m)			Material	Quantity			Unit
	45 m ³	70 m ³	90 m ³		45 m ³	70 m ³	90 m ³	
WV1 (RB 9 mm @ 0.20 m) 	a = 2.20 b = 0.04 c = 0.30 (84 pieces)	a = 2.20 b = 0.04 c = 0.30 (106 pieces)	a = 2.20 b = 0.04 c = 0.30 (116 pieces)	RB 9 mm (2.5 m/ 1 piece)	210	265	290	m
WV2 (RB 9mm @ 0.20 m) 	a = 1.00 (84 pieces)	a = 1.00 (106 pieces)	a = 1.00 (116 pieces)	RB 9 mm (1.0 m/ 1 piece)	84.0	106	116	m
Steel channel (8 pieces) 	a = 0.0375 b = 0.075	a = 0.0375 b = 0.075	a = 0.0375 b = 0.075	C 7.0x3.75 cm (2.2 m/ 1 piece)	17.6	17.6	17.6	m
WH1 (RB 9 mm @ 0.20 m: 12 pieces) 	a = 5.30	a = 6.70	a = 7.30	RB 9 mm (16.7 m/ 1 piece)	201	252	276	m
WM1 & WM2 (Chicken Mesh: 2 layers) 	a = 16.70 b = 2.20	a = 21.00 b = 2.20	a = 23.00 b = 2.20	Chicken Mesh (37 m ² / 1 layer)	74.0	92	101	m ²
Ferro-cement 	a = 5.30 b = 2.20 c = 0.03 (1.1 m ³)	a = 6.70 b = 2.20 c = 0.03 (1.4 m ³)	a = 7.30 b = 2.20 c = 0.03 (1.5 m ³)	Cement Sand Water	7110.7 2 0.70 0.29	905.80 0.91 0.37	970.50 0.98 0.39	kg m ³ m ³

Ferro-Cement Roof								
Item/Shape	Dimensions (m)			Material	Quantity			Unit
	45 m ³	70 m ³	90 m ³		45 m ³	70 m ³	90 m ³	
RD1 (RB 9 mm @ 0.40 m) 	a = 2.60 (42 pieces)	a = 3.30 (53 pieces)	a = 3.60 (58 pieces)	RB 9 mm	110	175	209	m
RD2 (RB 9 mm @ 0.40 m) 	a = 1.50 (42 pieces)	a = 1.50 (53 pieces)	a = 1.50 (58 pieces)	RB 9 mm	63.0	80.0	87.0	m
Upper and Lower Code for truss (RB 9 mm: 16 pieces) 	a = 1.50 b = 0.10	a = 3.30 b = 0.10	a = 3.60 b = 0.10	RB 9 mm (2.70m/ 1 piece)	44.0	55.0	60.0	m
Bracing for truss (RB 6 mm: 8 pieces) 	a = 2.60 b = 0.20 c = 0.10	a = 3.30 b = 0.20 c = 0.10	a = 3.60 b = 0.20 c = 0.10	RB 6 mm (3.7m/ 1 piece)	30.0	38.0	40.0	m
Chicken Mesh for truss (8 pieces) 	a = 2.60 b = 0.10	a = 3.30 b = 0.10	a = 3.60 b = 0.10	Chicken Mesh (0.52 m ² / 1 piece)	5.0	6.0	6.0	m ²
RC1 (RB 6 mm @ 0.20 m) 	a = 5.00- 5.30 (13 pieces)	a = 6.30- 6.70 (17 pieces)	a = 7.00- 7.30 (18 pieces)	RB 6 mm (1.6 – 16.7 m)	119	187	221	m
RM1 @ RM2 (Chicken Mesh: 2 layers) 	a = 5.30	a = 6.70	a = 7.30	Chicken Mesh (22 m ² / 1 layer)	44.0	70.0	84.0	m ²
Ferro-cement 	a = 5.30 b = 0.03 c = 0.50 (0.67m ³)	a = 6.70 b = 0.03 c = 0.50 (1.1 m ³)	a = 7.30 b = 0.03 c = 0.50 (1.3 m ³)	Cement Sand Water	433.49 0.44 0.18	711.70 0.72 0.29	841.10 0.85 0.34	kg m ³ m ³

Central Column								
Item/Shape	Dimensions (m)			Material	Quantity			Unit
	45 m ³	70 m ³	90 m ³		45 m ³	70 m ³	90 m ³	
GI pipe (diameter = 0.15 m) 	a = 2.70 b = 0.15	a = 2.70 b = 0.15	a = 2.70 b = 0.15	GI pipe	2.70	2.70	2.70	m
CV1 (RB 9 mm: 4 pieces) 	a = 2.70	a = 2.70	a = 2.70	RB 9 mm	11.0	11.0	11.0	m
CH1 (RB 6 mm @ 0.20 m: 12 pieces) 	a = 0.12	a = 0.12	a = 0.12	RB 6 mm (0.38 m/ 1 piece)	4.60	4.60	4.60	m
SL1 (RB 9 mm: 4 pieces) 	a = 0.40 b = 0.30	a = 0.40 b = 0.30	a = 0.40 b = 0.30	RB 9 mm (0.70 m/ 1 piece)	3	3	3	m
Steel Plate (thickness = 12 mm: 1 piece) 	a = 0.30 b = 0.30	a = 0.30 b = 0.30	a = 0.30 b = 0.30	Steel Plate	0.09	0.09	0.09	m ²
Mortar (0.32 m ²) 	a = 2.70 b = 0.15	a = 2.70 b = 0.15	a = 2.70 b = 0.15	Cement Sand Water	207 0.21 0.08	207 0.21 0.08	207 0.21 0.08	kg m ³ m ³

Ferrocement Cast-in-place Water Tank (45 Cu. M.)

Designed by:



ACECOMS, IFIC
School of Civil Engineering
Asian Institute of Technology (AIT)

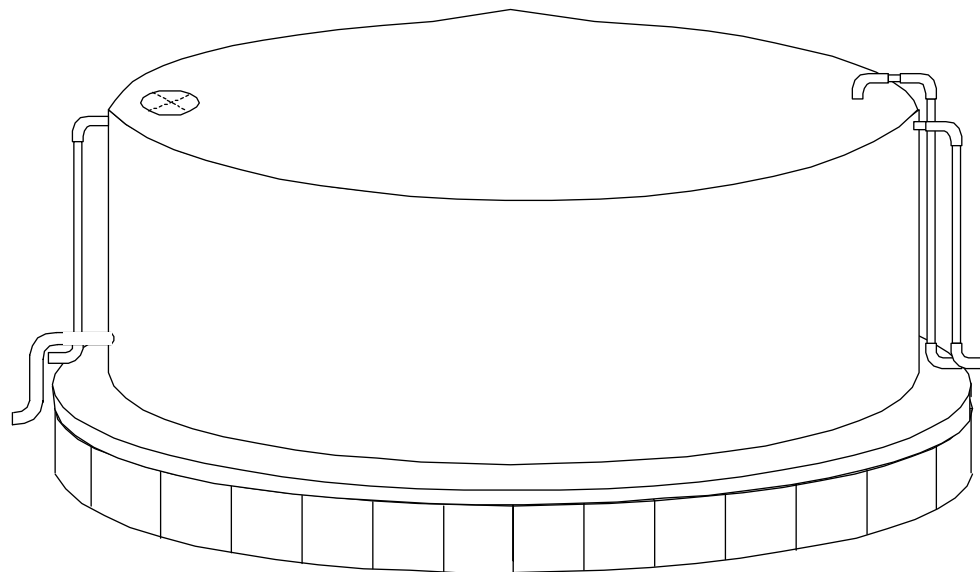


Designed for:



United Nations High Commissioner for Refugees (UNHCR)

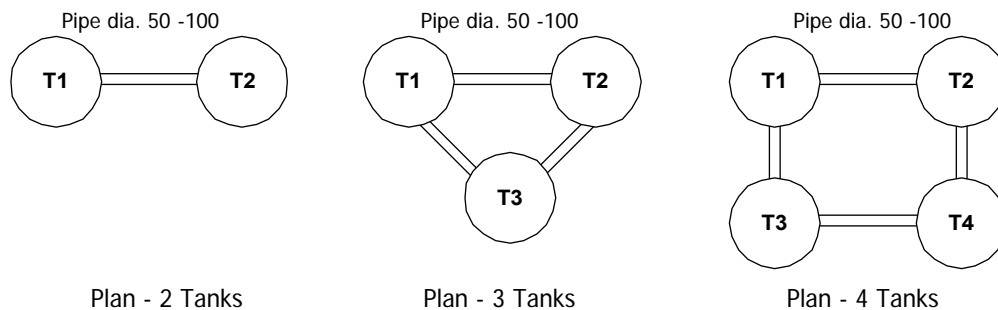
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Drawing Number	Title
CD45-01	Key Features
CD45-02	Plan, Elevation and Section
CD45-03	Foundation Details
CD45-04	Base Slab Details
CD45-05	Wall and Central Column Details
CD45-06	Roof Details
CD45-07	Reinforcing Steel Skeleton
CD45-08	Construction Tools and Steps
CD45-09	Material Specification and BOM



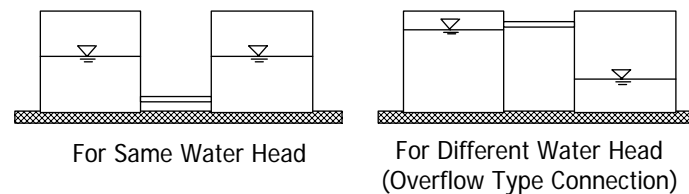
Key Features

Capacity	45 Cu. m
Diameter	5300
Height	2700 (2200+500)
Foundation	Compacted Sand/ Soil (thk. = 500) Retained by Hollow Blocks/ Masonry Bricks
Base Slab	Reinforced Concrete (thk. = 120)
Wall	Ferrocement (thk. = 30) Stiffened by Embedded Steel Channels
Roof	Ferrocement (thk. = 30) Stiffened by Embedded Trusses
Central Column	GI Pipe (Diameter = 150) Filled with Mortar
Access Opening	Diameter = 600 (in Roof)
Pipe Work	Intel, Outlet and Over Flow Pipes
Finishing	<ul style="list-style-type: none"> • Inside Plastering Only • Outside Ordinary Paint • No Special Paint/Additives

Single Tank



Examples for Connecting Multiple Tanks



Note: - RB = Round Bar
 - GI = Galvanized Iron
 - All dimensions are in millimeter
 - Foundation height depends upon water head required



**Ferrocement Cast-in-place Water Tank
(45 Cu.m.)**

Designed by



School of Civil Engineering (AIT)



Drawing Title:

Key Features

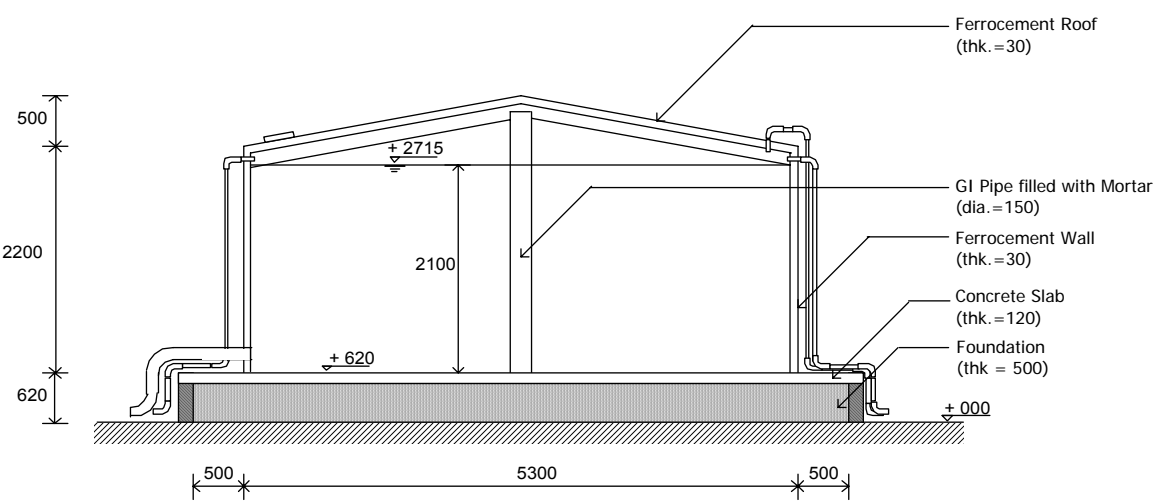
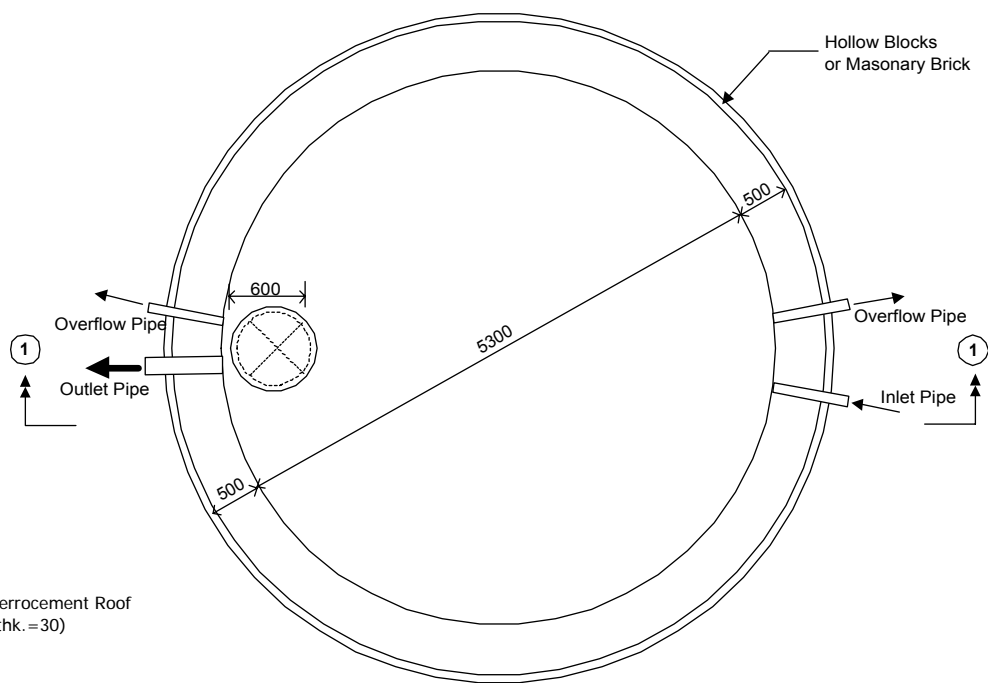
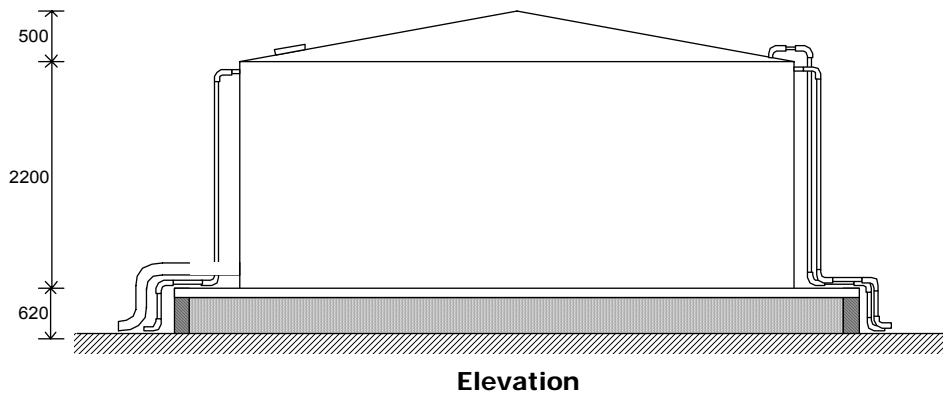
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Client: UNHCR

Drawing No:

CD45-01



Date: March 2002



Note: - RB = Round Bar
 - GI = Galvanized Iron
 - All dimensions are in millimeter
 - Foundation height depends upon water head required



**Ferrocement Cast-in-place Water Tank
 (45 Cu.m.)**

Designed by

 School of Civil Engineering (AIT)


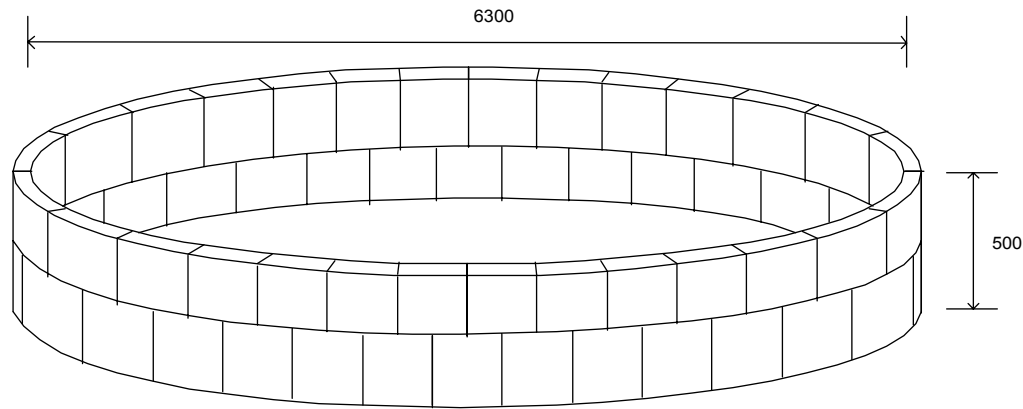
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Plan, Elevation and Section

Drawing No:
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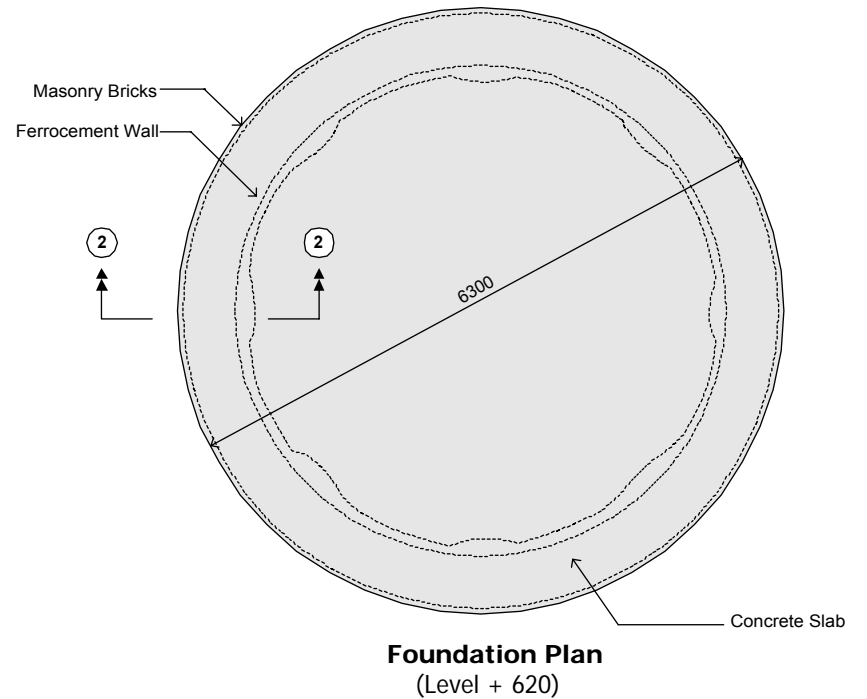
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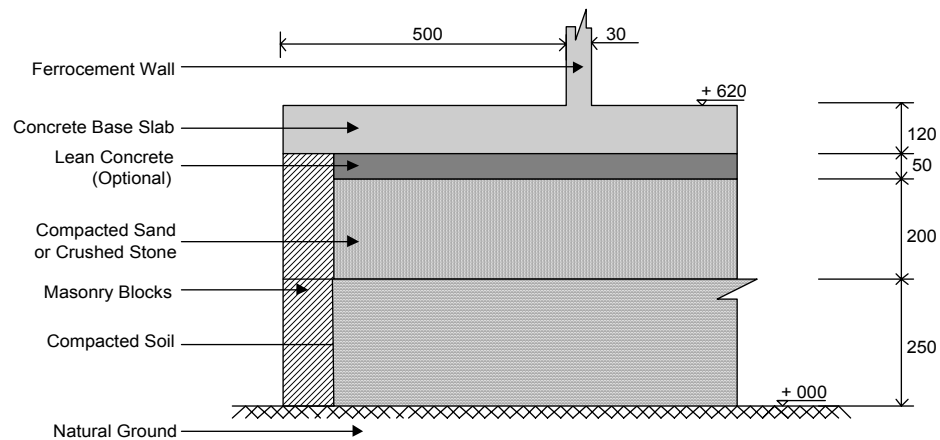
Date: March 2002



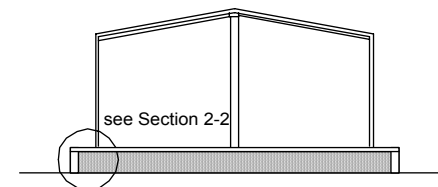
Masonry Brick Layout



**Foundation Plan
(Level + 620)**



Section 2-2: Foundation Detail



Note: - RB = Round Bar
 - GI = Galvanized Iron
 - All dimensions are in millimeter



**Ferrocement Cast-in-place Water Tank
(45 Cu.m.)**

Designed by



School of Civil Engineering (AIT)

Drawing Title:

Foundation Details

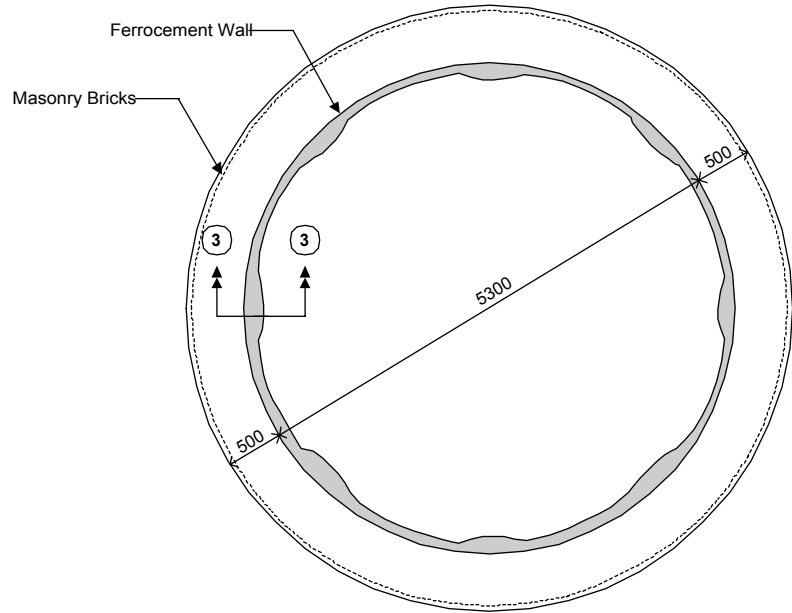
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CD45-03

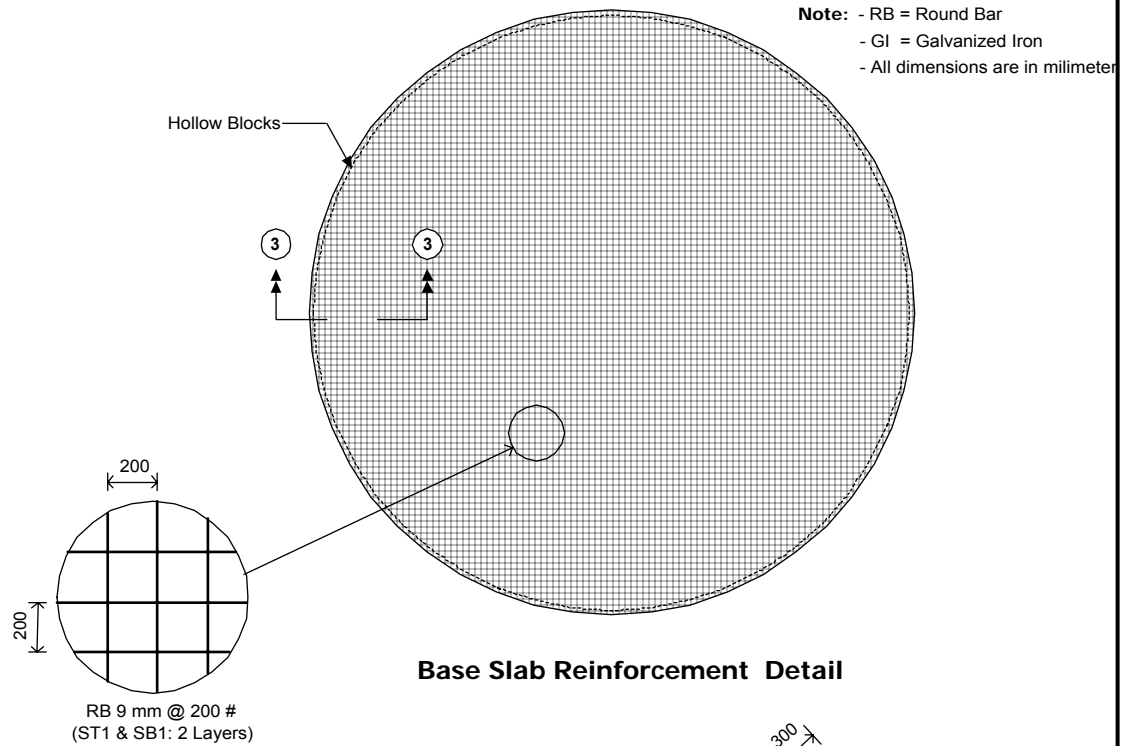
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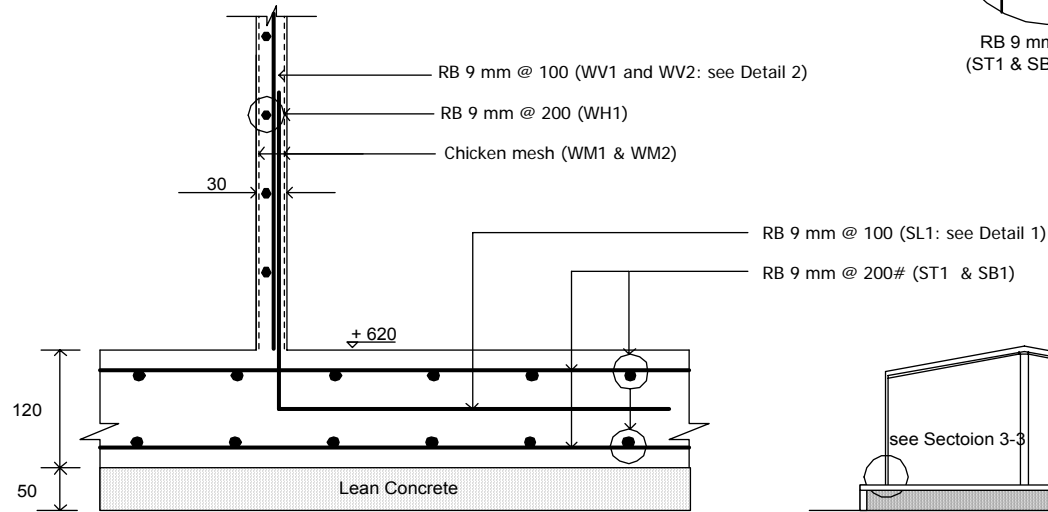
Date: March 2002



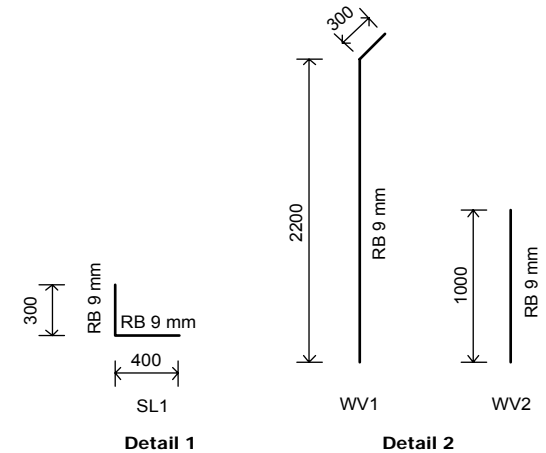
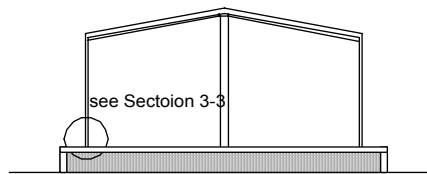
Water Tank Plan



Base Slab Reinforcement Detail



Section 3-3: Slab Detail



**Ferrocement Cast-in-place Water Tank
(45 Cu.m.)**

Designed by



School of Civil Engineering (AIT)

Drawing Title:

Base Slab Details

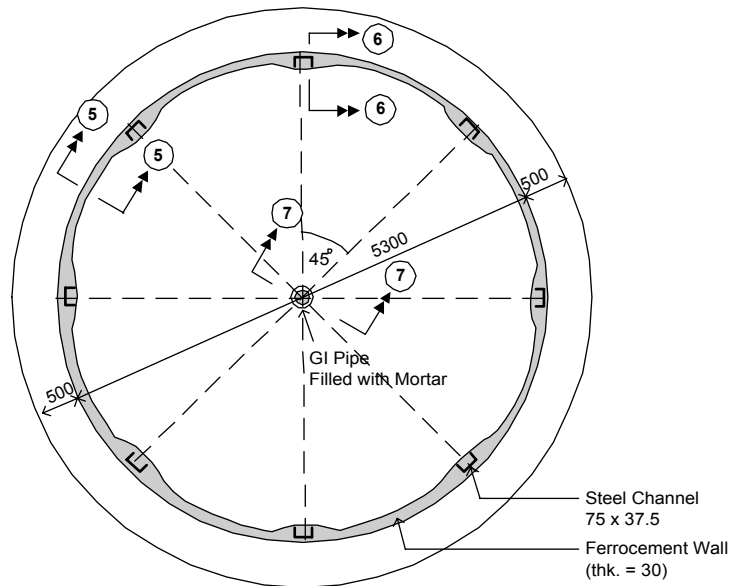
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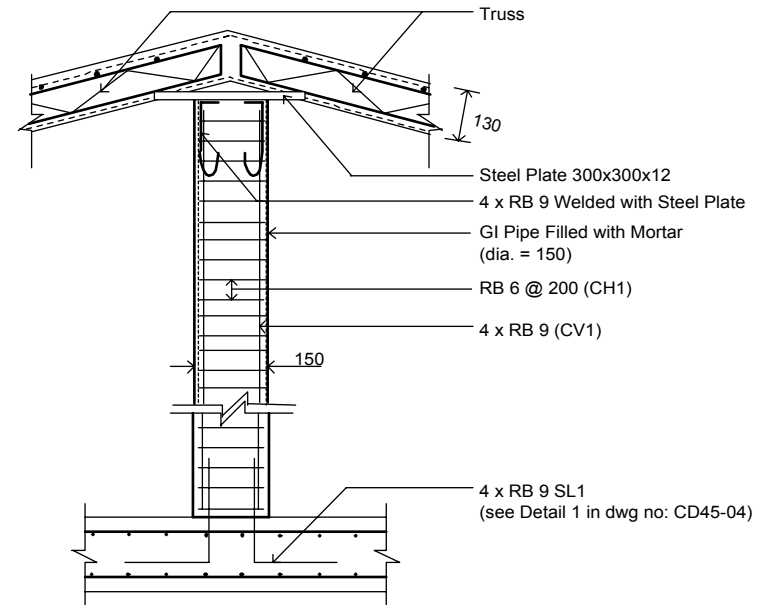
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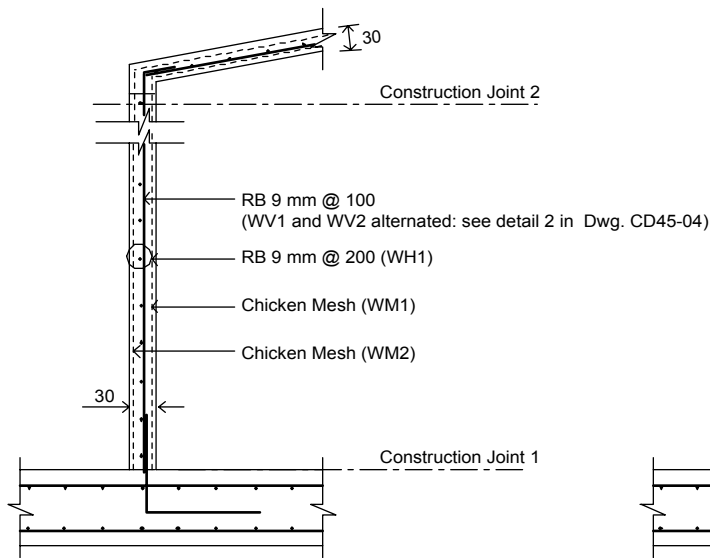
Date: March 2002



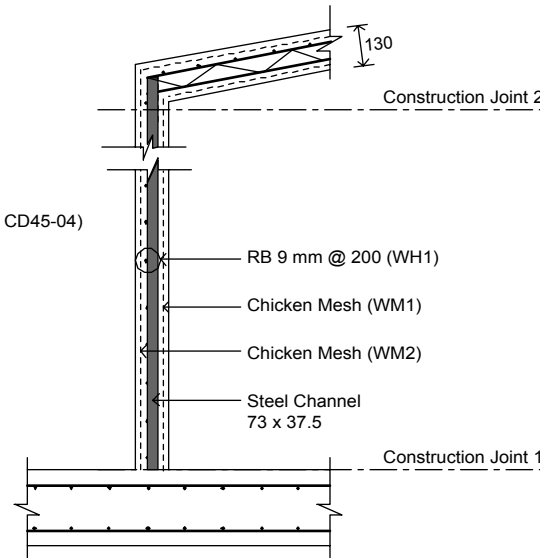
Section 4-4: Water Tank Wall Section



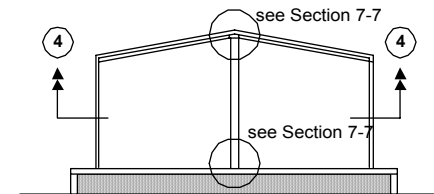
Section 7-7: Central Column Detail



Section 5-5



Section 6-6



Note: - RB = Round Bar
- GI = Galvanized Iron
- All dimensions are in millimeter



**Ferrocement Cast-in-place Water Tank
(45 Cu.m)**

Designed by

ACECOMS



School of Civil Engineering (AIT)

Drawing Title:

Wall and Central Column Details

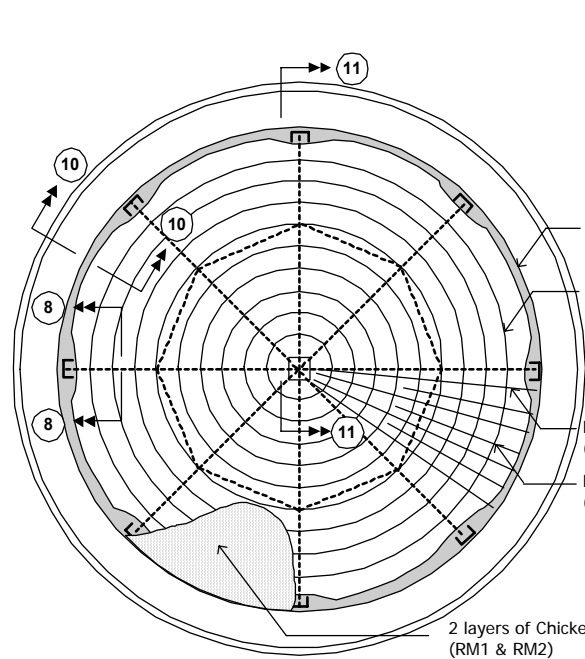
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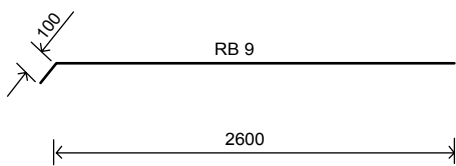
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Date: March 2002

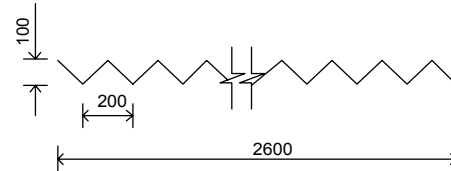


Section 9-9: Roof Framing Plan

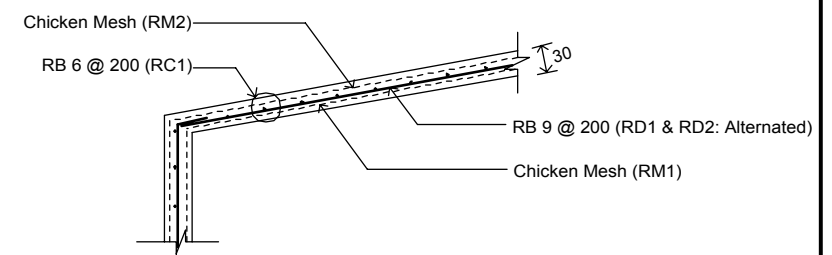
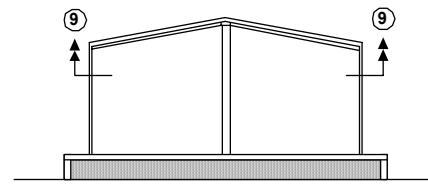
- Steel Channel 75 x 37.5
- Truss (see Section 11-11)



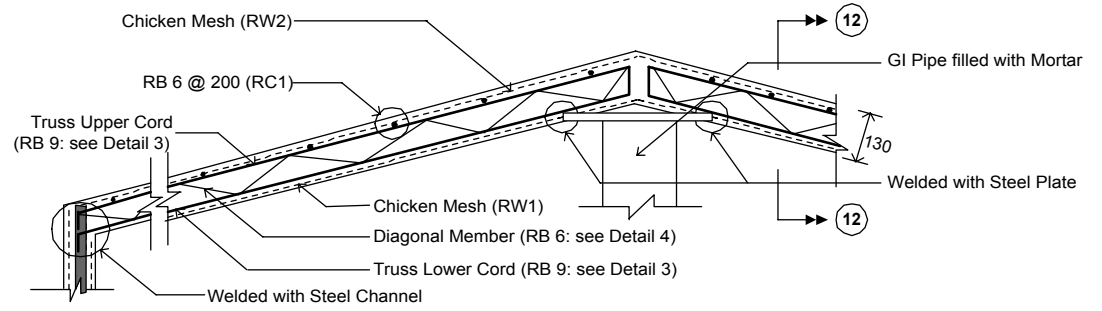
Detail 3: Truss Upper and Lower Cord Detail



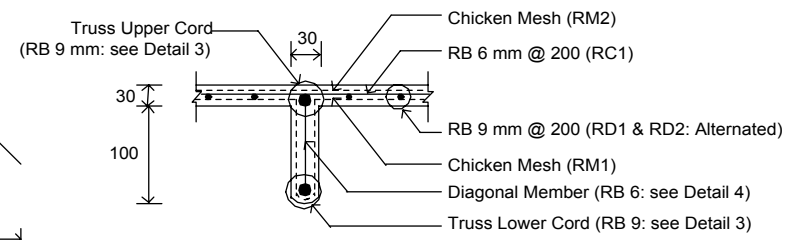
Detail 4: Diagonal Member Detail Welded to Upper and Lower Chord



Section 10-10: Roof Slab Detail



Section 11-11: Truss Detail



Section 8-8: Truss Section

Note: - RB = Round Bar
 - GI = Galvanized Iron
 - All dimensions are in millimeter



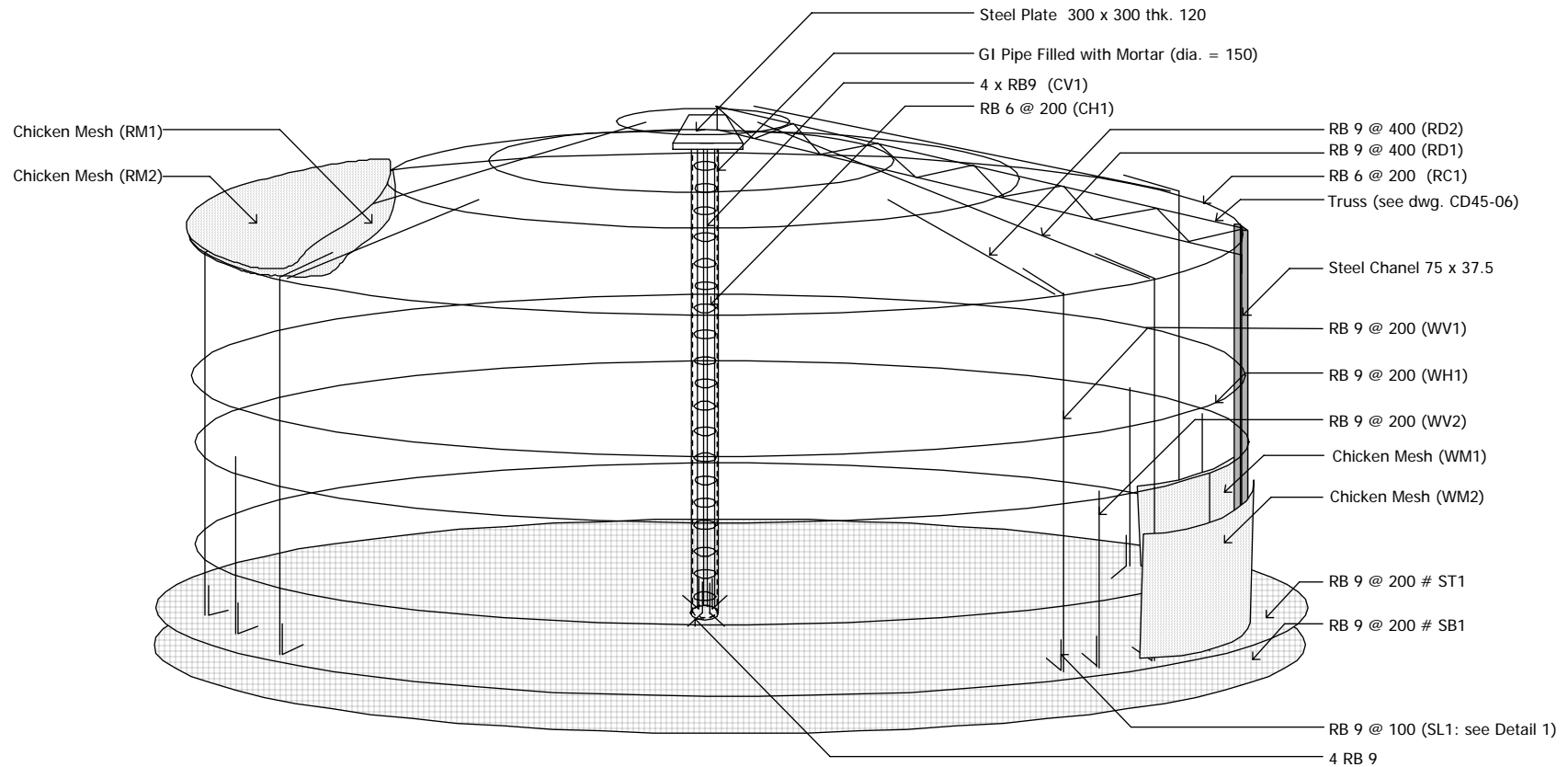
Ferrocement Cast-in-place Water Tank (45 Cu.m.)

Designed by

 School of Civil Engineering (AIT)

Drawing Title:
Roof Details
 Scale: Not to Scale

Drawing No:
CD45-06
 Client: UNHCR
 Date: March 2002



Note: Only Selected Typical Elements Shown

Note: - RB = Round Bar
 - GI = Galvanized Iron
 - All dimensions are in millimeter



**Ferrocement Cast-in-place Water Tank
 (45 Cu.m.)**

Designed by



School of Civil Engineering (AIT)

Drawing Title:

Reinforcing Steel Skeleton

Scale: Not to Scale

Client: UNHCR

Drawing No:

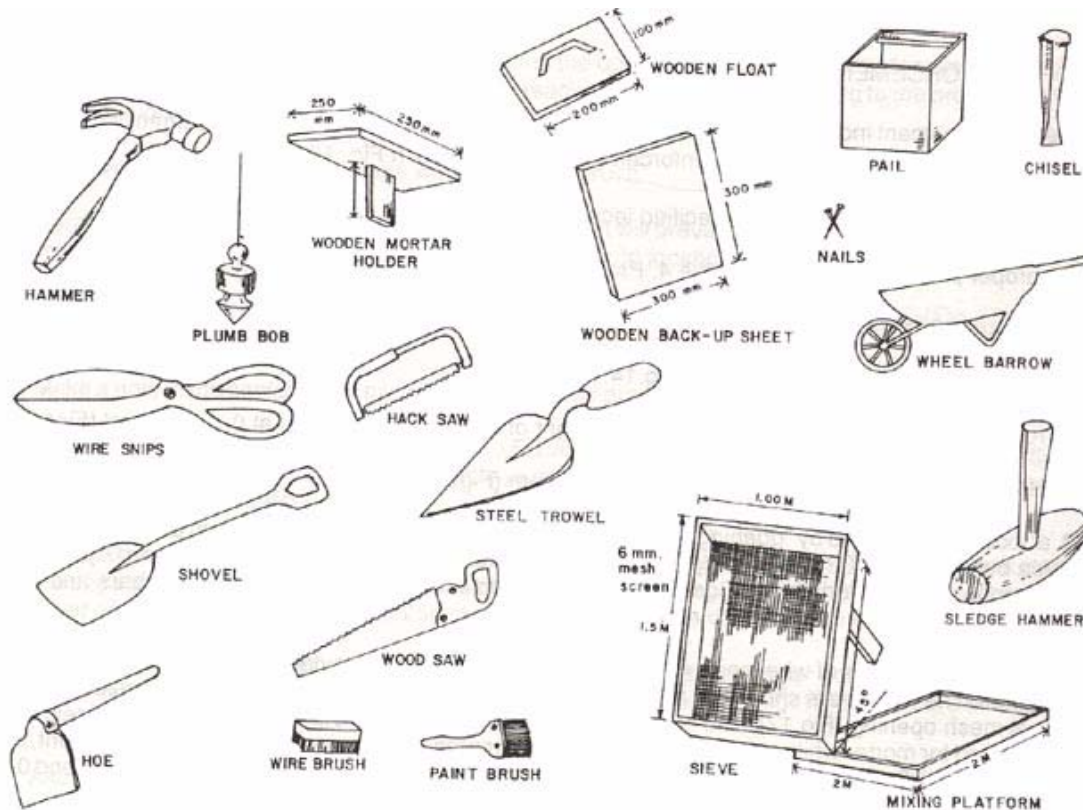
CD45-07

Date: March 2002

Construction Main Steps

- Step 1: Selection of Site
- Step 2: Site Clearance
- Step 3: Preparation of Foundation
- Step 4: Preparation of Lean Concrete Base
- Step 5: Preparation of Base Slab Reinforcement
- Step 6: Laying Base Slab Reinforcement
- Step 7: Erecting L-bars Along the Wall-Base Junction
- Step 8: Placing Vertical Dowel/ Plate/Bars for Central Column
- Step 9: Casting the Base Slab
- Step 10: Erection of Vertical Reinforcement and Stiffeners for Wall
- Step 11: Keeping Openings for Construction and Pipe Works
- Step 12: Fixing Wire (Chicken) Mesh (WM1 and WM2)
- Step 13: Preparation and Fixing the Central Column
- Step 14: Plastering the Wall
- Step 15: Preparation of Roof Shallow Truss
- Step 16: Fixing Roof Trusses (Roof Stiffeners)
- Step 17: Placing Roof Reinforcements
- Step 18: Fixing the Roof Mesh
- Step 19: Providing Openings in the Roof
- Step 20: Plastering Roof Trusses
- Step 21: Temporary Formwork for Plastering of Roof Surface
- Step 22: Plastering Roof Surface
- Step 23: Plastering Temporary Openings
- Step 24: Finishing the Surface

[For Construction Procedure Details Refer to "How to Manual"]



Ferrocement Construction Tools



**Ferrocement Cast-in-place Water Tank
(45 Cu.m.)**

Designed by

ACECOMS



School of Civil Engineering (AIT)

Drawing Title:

Construction Tools and Steps

Drawing No:

CD45-08

Scale: Not to Scale

Client: UNHCR

Date: March 2002

Material Specification

Cement: Use ordinary Portland cement Type I or II for tropical countries and Type II for cold climates

Sand:

1. Use well graded sand. Sand that is too fine or too coarse is not suitable
2. Separate sand from stone using 6.4 mm (1/4 inch) mesh screen.
3. No organic or chemical impurities. If quality is in doubt, wash with clean water.
4. Desirable sand grading is as follow:

Sieve	Percent passing
3/8 in (9.5mm)	100
No. 4 (4.75mm)	95 to 100
No. 8 (2.36 mm)	80 to 100
No. 14 (1.18mm)	50 to 85
No. 30 (600um)	25 to 60
No. 100 (150um)	2 to 10

Water:

1. Water fit for drinking is suitable.
2. Salty water should never be used.

Wire Mesh:

1. Must be easy to handle and flexible enough to be bent around corners.
2. Galvanized wire mesh is preferred as it is less likely to rust or corrode.
3. Use 0.5 mm to 1.00 mm diameter with 10 mm to 25 mm mesh opening.
4. Free from grease, oil, rust and anything that might reduce bond.

Skeletal Steel :

1. Free from grease, oil detergents, organic matter, cracks of blow holes.
2. Bars are acceptable if no cracks appear after the following field test:
"Bend bar into U shape and then straighten it out. Bend it again in U shape in the opposite direction and straighten it out."
3. Grade SR24: Yield strength = 2400-2600 ksc

Steel Channel:

1. Free from grease, oil detergents, organic matter, cracks of blow holes
2. Size 7.50 cm x 3.75 cm (height x width)
3. Grade Fy = 2400-2600 ksc (34-36 ksi) and FU = 4,000-4,500 ksc (57-64 ksi)

Tie Wire: Use annealed (soft) galvanized wires of 24 or 26 gauge. Cut pieces of wire from meshes could also be used for tying.

Material Quantity Summary (45 cu. m.)

Items	Quantity	Unit
Coarse Sand	14	m2
Hollow Blocks	150	pieces
Cement	3267	kg
Sand	4.26	m2
Stone	5	m2
Water	1.67	m2
RB 6 mm	164	m
RB 9 mm	1452	m
Steel Channel (7.50 cm x 3.75 cm)	18	m
Chicken Mesh	123	m2
GI Pipe	2.7	m
Steel Plate	0.09	m2

Mix Proportions

Lean Concrete = 1:4:8 (Cement: Sand: Aggregate by weight)

Slab Concrete = 1:2:4 (Cement: Sand: Aggregate by weight)

Ferrocement Mortar = 1:2:0.4 (Cement: Sand: Water by weight)



UNHCR

Ferrocement Cast-in-place Water Tank (45 Cu.m.)

Designed by

ACECOMS

School of Civil Engineering (AIT)



Drawing Title:

Material Specification and BOM

Drawing No:

CD45-09

Scale: Not to Scale

Client: UNHCR

Date: March 2002

Ferrocement Cast-in-place Water Tank (75 Cu. M.)

Designed by:



ACECOMS, IFIC
School of Civil Engineering
Asian Institute of Technology (AIT)

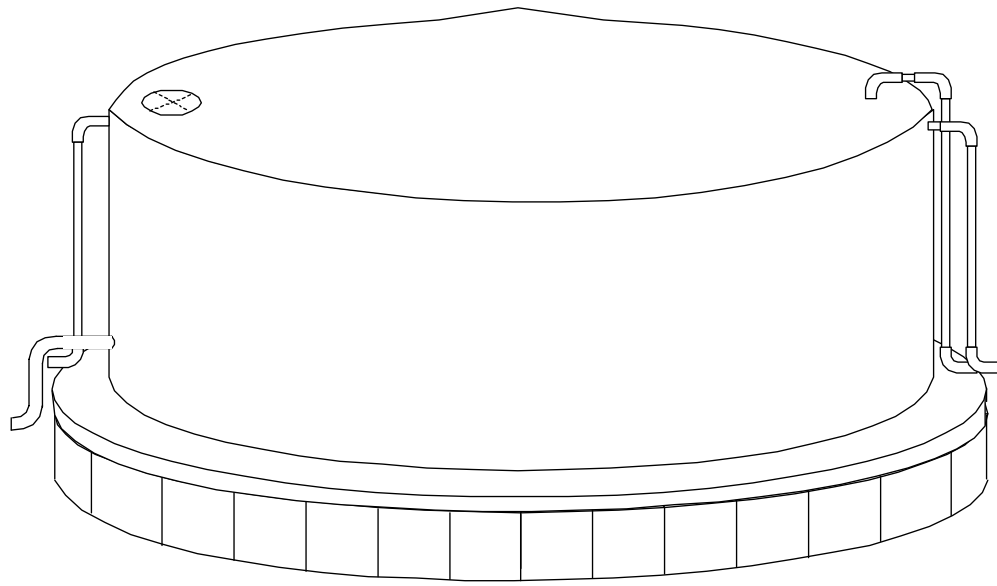


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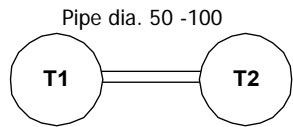


United Nations High Commissioner for Refugees (UNHCR)

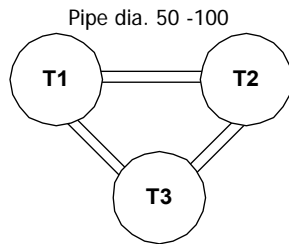
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Drawing Number	Title
CD75-01	Key Features
CD75-02	Plan, Elevation and Section
CD75-03	Foundation Details
CD75-04	Base Slab Details
CD75-05	Wall and Central Column Details
CD75-06	Roof Details
CD75-07	Reinforcing Steel Skeleton
CD75-08	Construction Tools and Steps
CD75-09	Material Specification and BOM



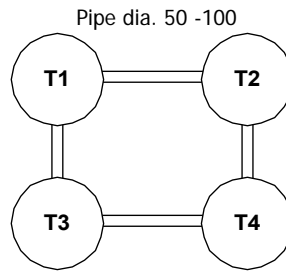
Single Tank



Plan - 2 Tanks

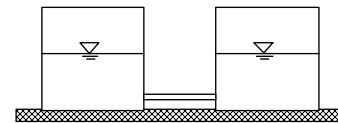


Plan - 3 Tanks

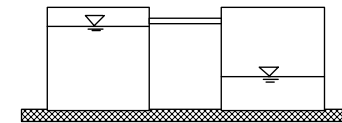


Plan - 4 Tanks

Examples for Connecting Multiple Tanks



For Same Water Head



For Different Water Head
(Overflow Type Connection)

Note: - RB = Round Bar
 - GI = Galvanized Iron
 - All dimensions are in millimeter
 - Foundation height depends upon water head required

Key Features

Capacity	75 Cu. m
Diameter	6700
Height	2700 (2200+500)
Foundation	Compacted Sand/ Soil (thk. = 500) Retained by Hollow Blocks/ Masonry Bricks
Base Slab	Reinforced Concrete (thk. = 120)
Wall	Ferrocement (thk. = 30) Stiffened by Embedded Steel Channels
Roof	Ferrocement (thk. = 30) Stiffened by Embedded Trusses
Central Column	GI Pipe (Diameter = 150) Filled with Mortar
Access Opening	Diameter = 600 (in Roof)
Pipe Work	Intel, Outlet and Over Flow Pipes
Finishing	<ul style="list-style-type: none"> • Inside Plastering Only • Outside Ordinary Paint • No Special Paint/Additives

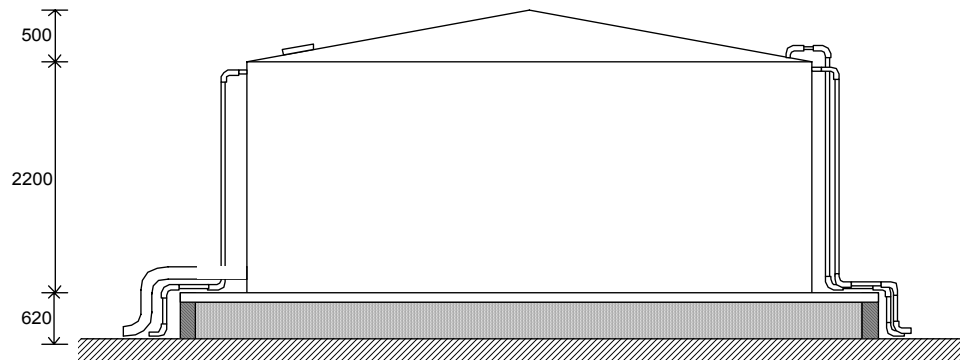


**Ferrocement Cast-in-place Water Tank
(75 Cu.m.)**

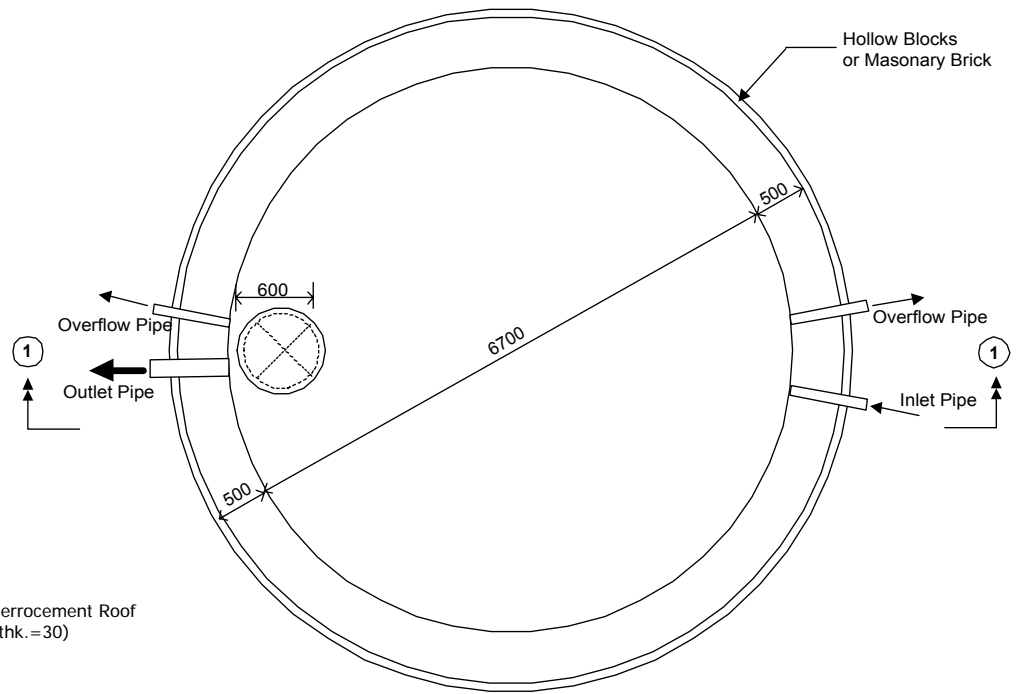
Designed by
 ACECOMS
 IFC
 School of Civil Engineering (AIT)

Drawing Title:
Key Features
 Scale: Not to Scale
 Client: UNHCR

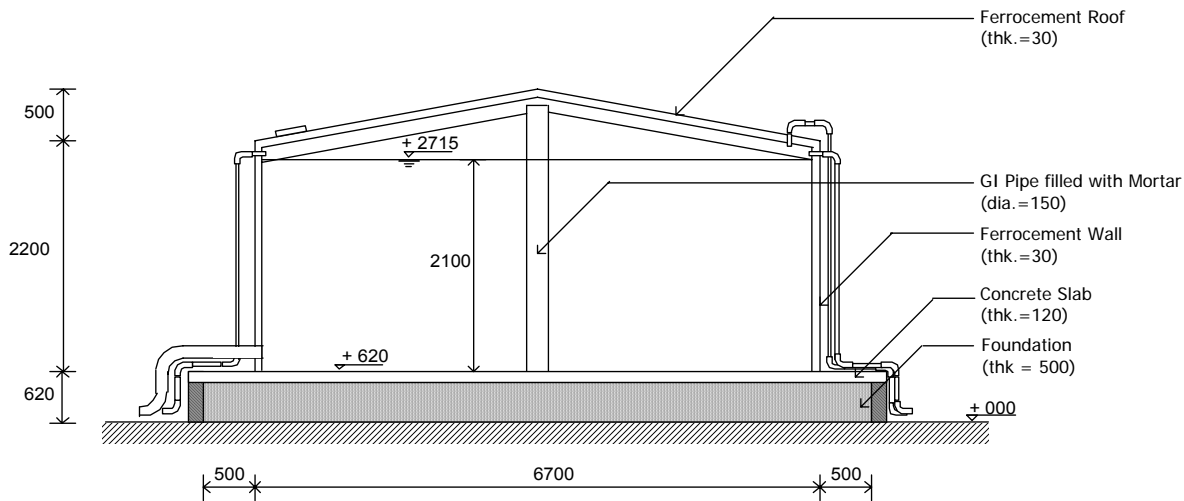
Drawing No:
CD75-01
 Date: March 2002



Elevation



Roof Plan



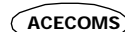
Section 1-1

Note: - RB = Round Bar
 - GI = Galvanized Iron
 - All dimensions are in millimeter
 - Foundation height depends upon water head required

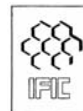


**Ferrocement Cast-in-place Water Tank
 (75 Cu.m.)**

Designed by



School of Civil Engineering (AIT)



Drawing Title:

Plan, Elevation and Section

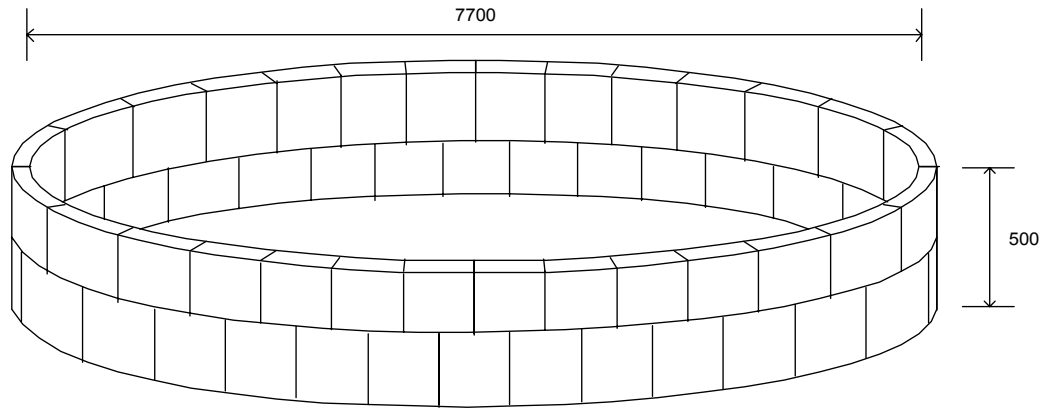
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Client: UNHCR

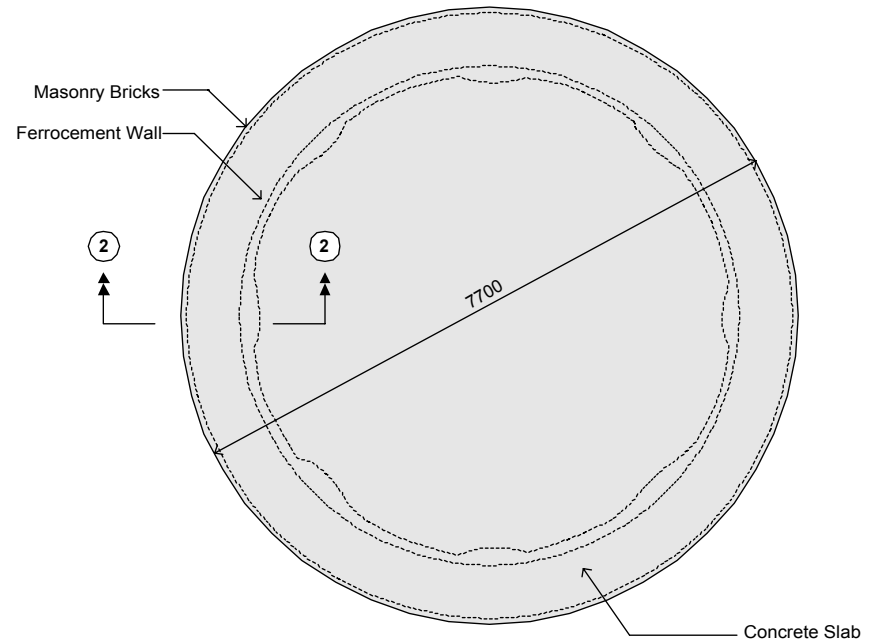
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CD75-02

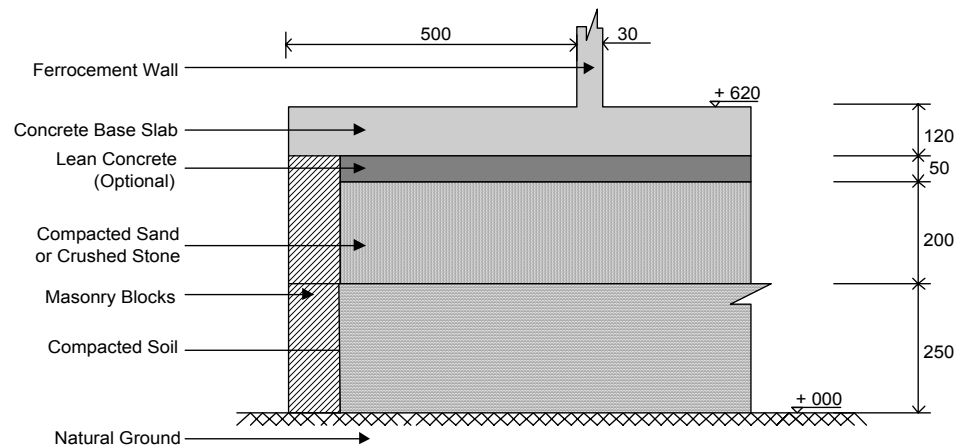
Date: March 2002



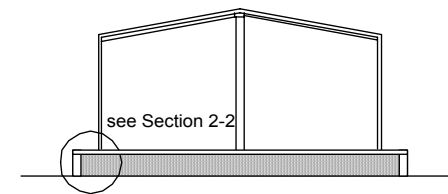
Masonry Brick Layout



Foundation Plan
(Level + 620)



Section 2-2: Foundation Detail



see Section 2-2

Note: - RB = Round Bar
- GI = Galvanized Iron
- All dimensions are in millimeter

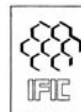


Ferrocement Cast-in-place Water Tank
(75 Cu.m.)

Designed by



School of Civil Engineering (AIT)



Drawing Title:

Foundation Details

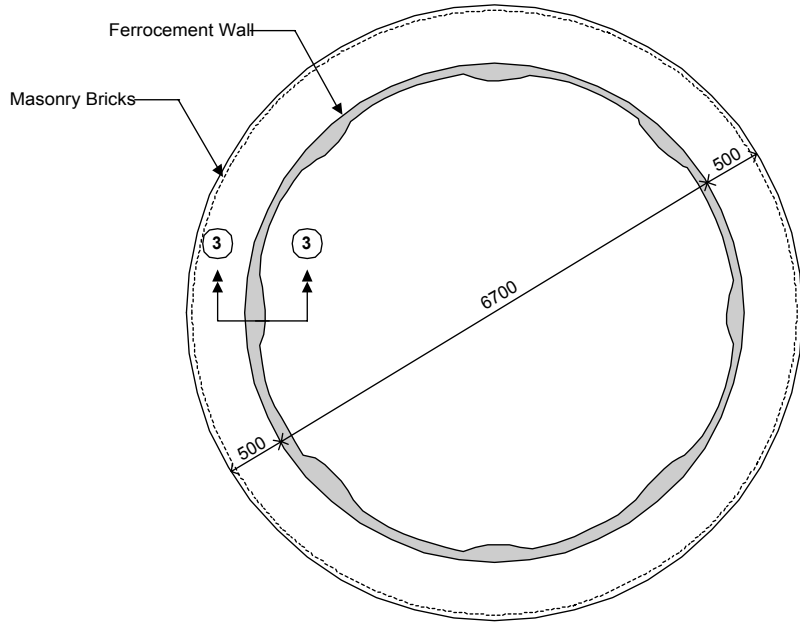
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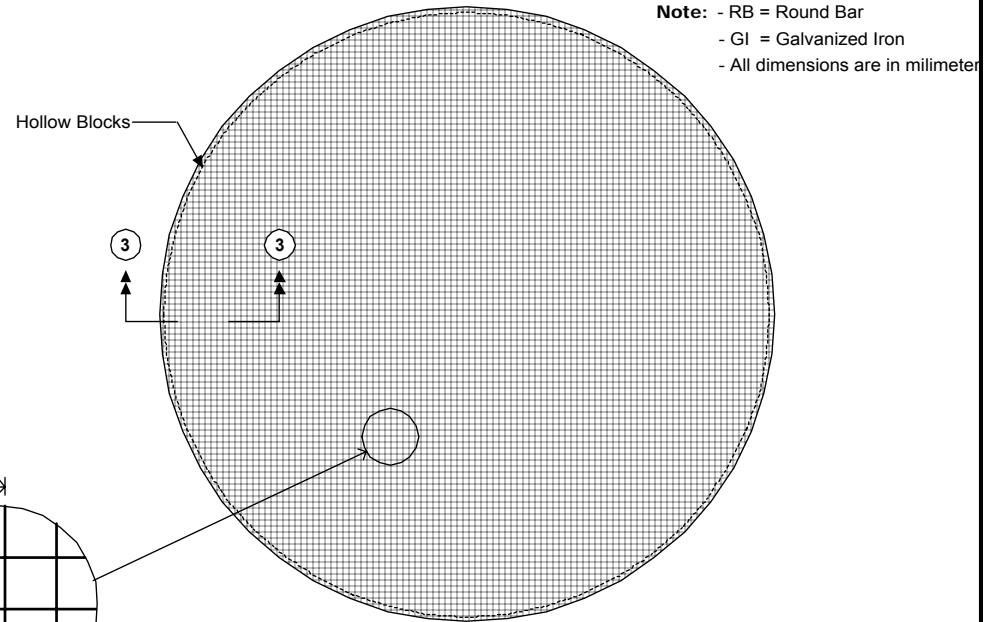
Drawing No:

CD75-03

Date: March 2002

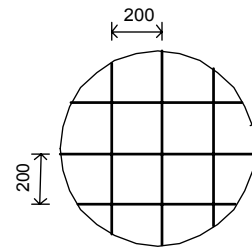


Water Tank Plan

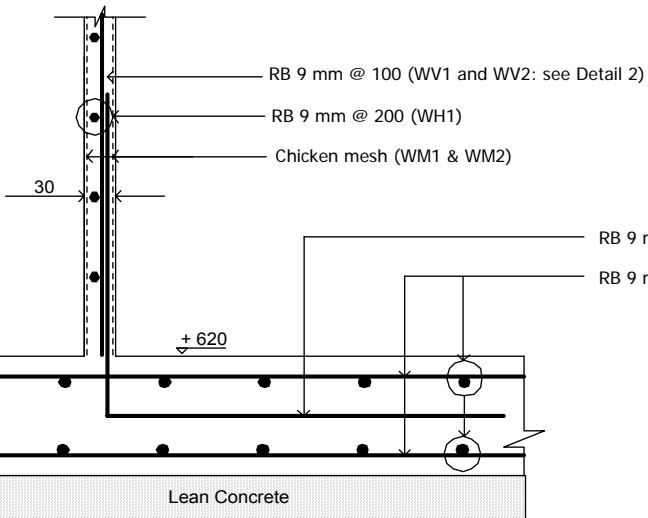


Base Slab Reinforcement Detail

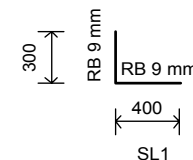
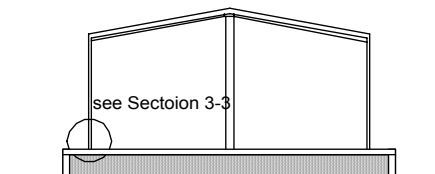
Note: - RB = Round Bar
 - GI = Galvanized Iron
 - All dimensions are in millimeter



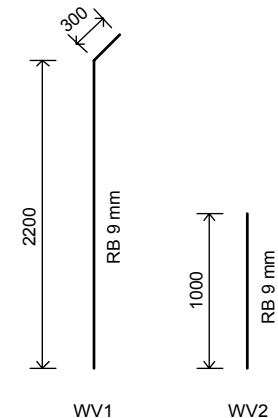
RB 9 mm @ 200 #
 (ST1 & SB1: 2 Layers)



Section 3-3: Slab Detail



Detail 1



Detail 2



**Ferrocement Cast-in-place Water Tank
 (75 Cu.m.)**

Designed by
ACECOMS
 School of Civil Engineering (AIT)



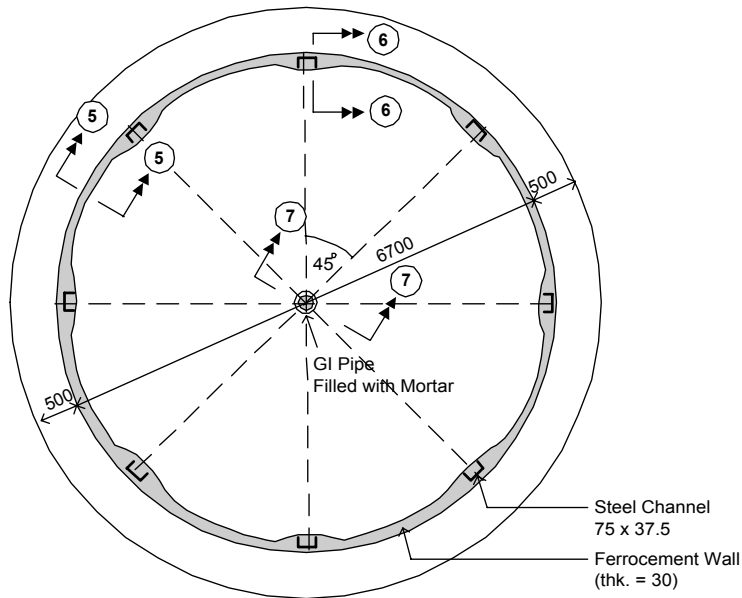
Drawing Title:
Base Slab Details

Drawing No:
CD75-04

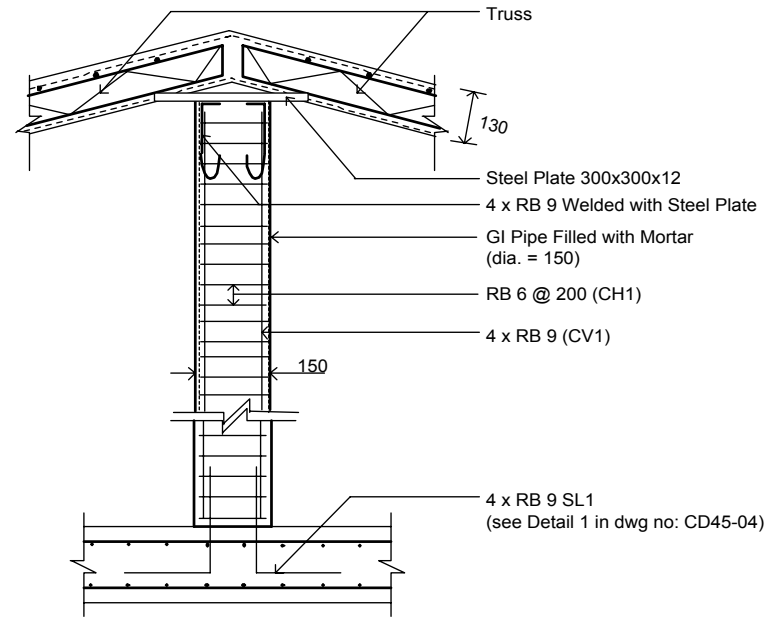
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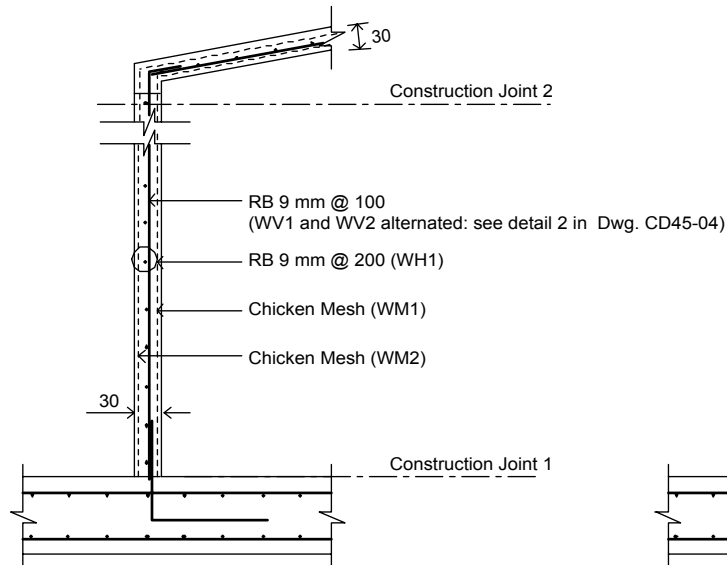
Date: March 2002



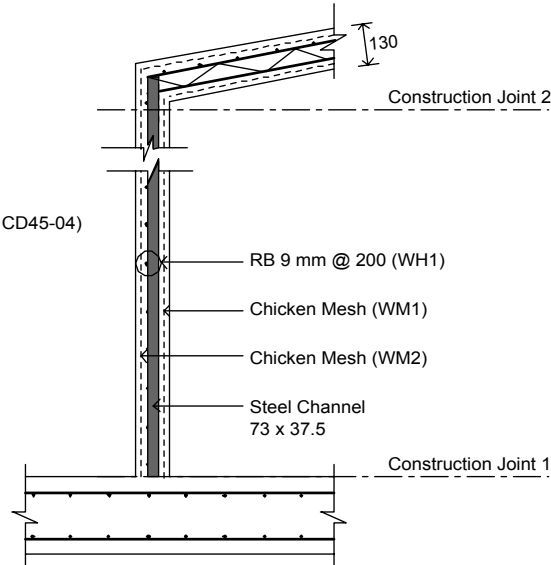
Section 4-4: Water Tank Wall Section



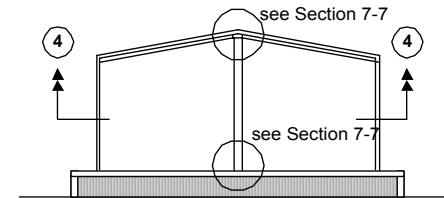
Section 7-7: Central Column Detail



Section 5-5



Section 6-6



Note: - RB = Round Bar
 - GI = Galvanized Iron
 - All dimensions are in millimeter



**Ferrocement Cast-in-place Water Tank
 (75 Cu.m)**

Designed by

ACECOMS



School of Civil Engineering (AIT)

Drawing Title:

Wall and Central Column Details

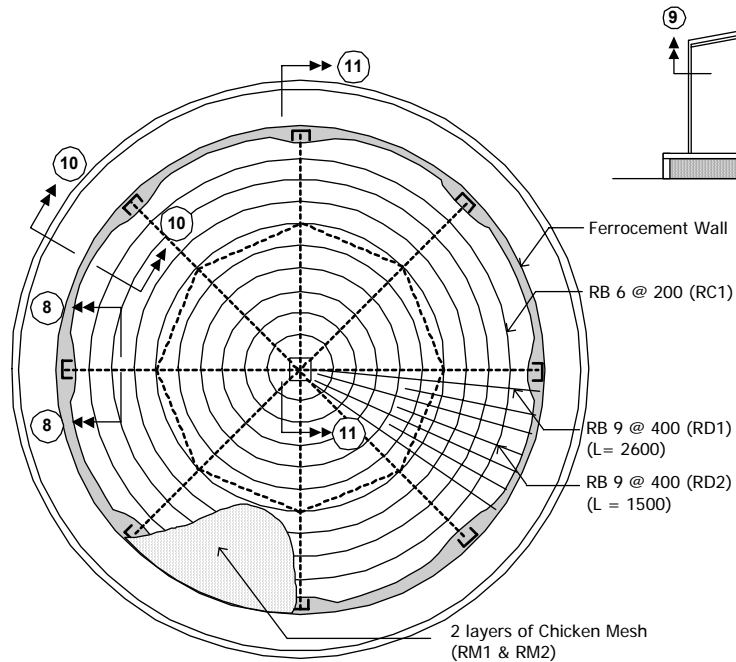
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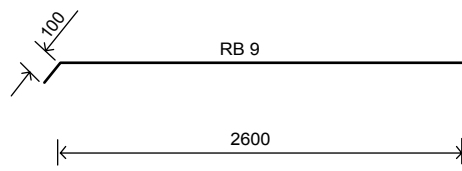
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Date: March 2002

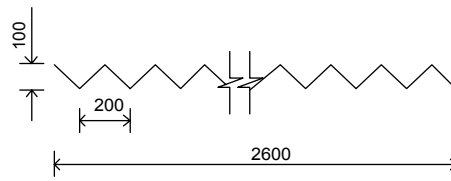


Section 9-9: Roof Framing Plan

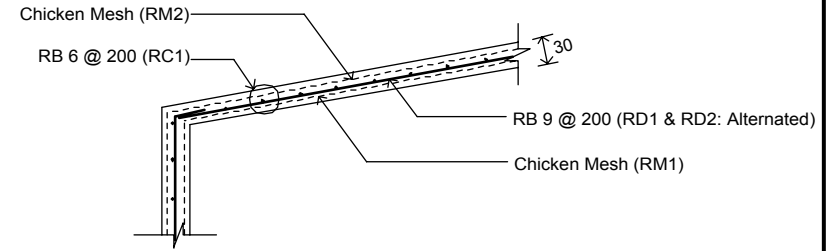
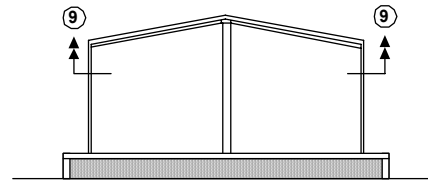
- Steel Channel 75 x 37.5
- Truss (see Section 11-11)



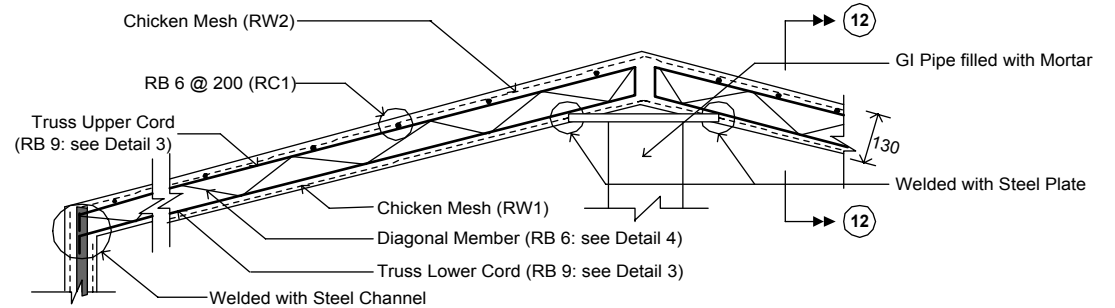
Detail 3: Truss Upper and Lower Cord Detail



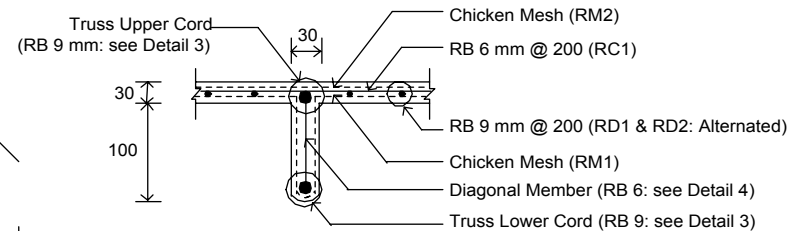
Detail 4: Diagonal Member Detail Welded to Upper and Lower Chord



Section 10-10: Roof Slab Detail



Section 11-11: Truss Detail



Section 8-8: Truss Section

Note: - RB = Round Bar
 - GI = Galvanized Iron
 - All dimensions are in millimeter



**Ferrocement Cast-in-place Water Tank
 (75 Cu.m.)**

Designed by



School of Civil Engineering (AIT)



Drawing Title:

Roof Details

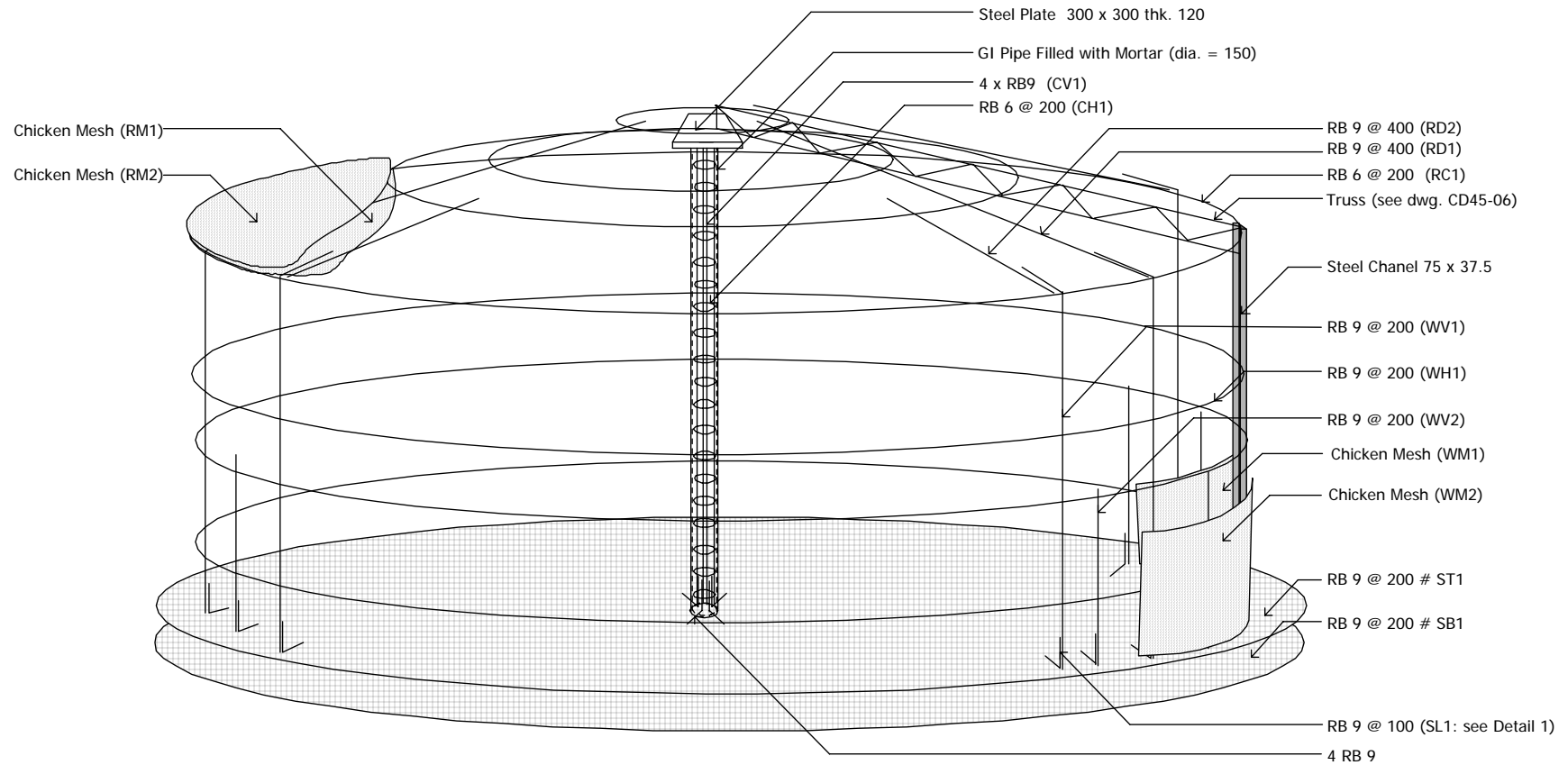
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Client: UNHCR

Drawing No:

CD75-06

Date: March 2002



Note: Only Selected Typical Elements Shown

Note: - RB = Round Bar
 - GI = Galvanized Iron
 - All dimensions are in millimeter



**Ferrocement Cast-in-place Water Tank
 (75 Cu.m.)**

Designed by



School of Civil Engineering (AIT)



Drawing Title:

Reinforcing Steel Skeleton

Scale: Not to Scale

Client: UNHCR

Drawing No:

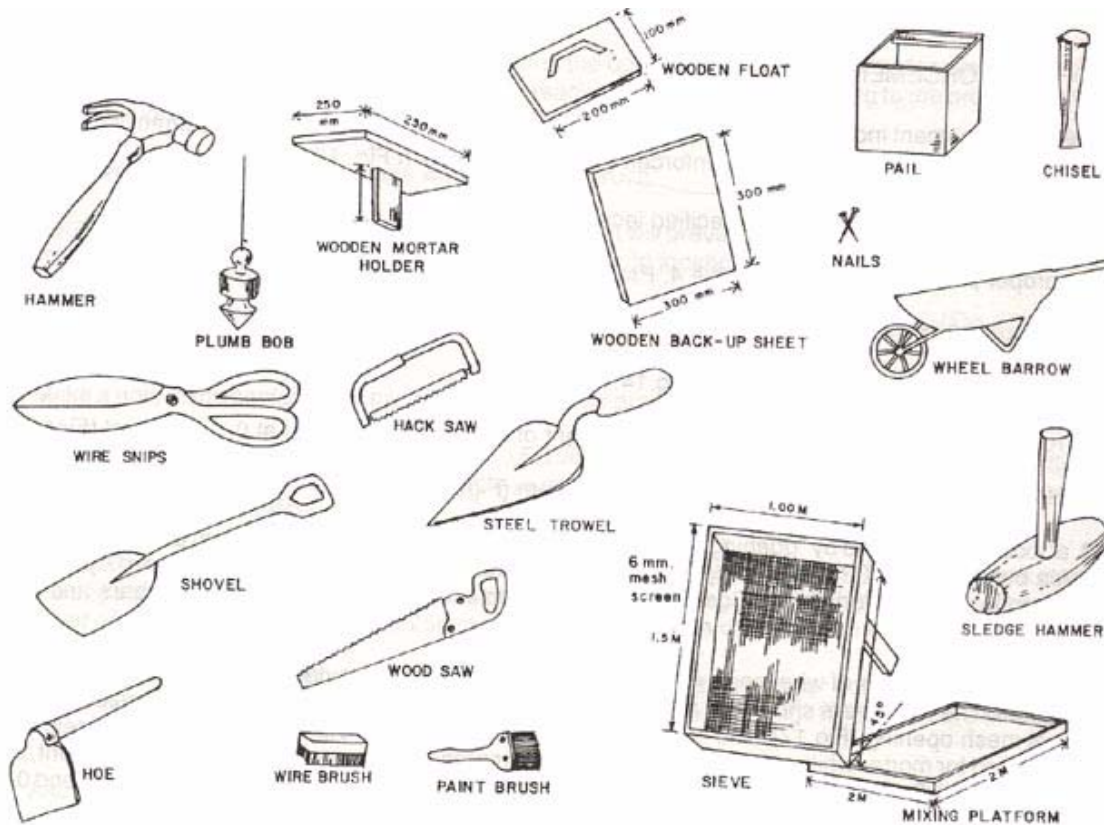
CD75-07

Date: March 2002

Construction Main Steps

- Step 1: Selection of Site
- Step 2: Site Clearance
- Step 3: Preparation of Foundation
- Step 4: Preparation of Lean Concrete Base
- Step 5: Preparation of Base Slab Reinforcement
- Step 6: Laying Base Slab Reinforcement
- Step 7: Erecting L-bars Along the Wall-Base Junction
- Step 8: Placing Vertical Dowel/ Plate/ Bars for Central Column
- Step 9: Casting the Base Slab
- Step 10: Erection of Vertical Reinforcement and Stiffeners for Wall
- Step 11: Keeping Openings for Construction and Pipe Works
- Step 12: Fixing Wire (Chicken) Mesh (WM1 and WM2)
- Step 13: Preparation and Fixing the Central Column
- Step 14: Plastering the Wall
- Step 15: Preparation of Roof Shallow Truss
- Step 16: Fixing Roof Trusses (Roof Stiffeners)
- Step 17: Placing Roof Reinforcements
- Step 18: Fixing the Roof Mesh
- Step 19: Providing Openings in the Roof
- Step 20: Plastering Roof Trusses
- Step 21: Temporary Formwork for Plastering of Roof Surface
- Step 22: Plastering Roof Surface
- Step 23: Plastering Temporary Openings
- Step 24: Finishing the Surface

[For Construction Procedure Details Refer to "How to Manual"]



Ferrocement Construction Tools



Ferrocement Cast-in-place Water Tank
(75 Cu.m.)

Designed by

ACECOMS

School of Civil Engineering (AIT)



Drawing Title:

Construction Tools and Steps

Scale: Not to Scale

Client: UNHCR

Drawing No:

CD75-08

Date: March 2002

Material Specification

Cement: Use ordinary Portland cement Type I or II for tropical countries and Type II for cold climates

Sand:

1. Use well graded sand. Sand that is too fine or too coarse is not suitable
2. Separate sand from stone using 6.4 mm (1/4 inch) mesh screen.
3. No organic or chemical impurities. If quality is in doubt, wash with clean water.
4. Desirable sand grading is as follow:

Sieve	Percent passing
3/8 in (9.5mm)	100
No. 4 (4.75mm)	95 to 100
No. 8 (2.36 mm)	80 to 100
No. 14 (1.18mm)	50 to 85
No. 30 (600um)	25 to 60
No. 100 (150um)	2 to 10

Water:

1. Water fit for drinking is suitable.
2. Salty water should never be used.

Wire Mesh:

1. Must be easy to handle and flexible enough to be bent around corners.
2. Galvanized wire mesh is preferred as it is less likely to rust or corrode.
3. Use 0.5 mm to 1.00 mm diameter with 10 mm to 25 mm mesh opening.
4. Free from grease, oil, rust and anything that might reduce bond.

Skeletal Steel :

1. Free from grease, oil detergents, organic matter, cracks of blow holes.
2. Bars are acceptable if no cracks appear after the following field test:
"Bend bar into U shape and then straighten it out. Bend it again in U shape in the opposite direction and straighten it out."
3. Grade SR24: Yield strength = 2400-2600 ksc

Steel Channel:

1. Free from grease, oil detergents, organic matter, cracks of blow holes
2. Size 7.50 cm x 3.75 cm (height x width)
3. Grade $F_y = 2400-2600$ ksc (34-36 ksi) and $F_U = 4,000-4,500$ ksc (57-64 ksi)

Tie Wire: Use annealed (soft) galvanized wires of 24 or 26 gauge. Cut pieces of wire from meshes could also be used for tying.

Material Quantity Summary (75 cu. m.)

Items	Quantity	Unit
Coarse Sand	21	m ²
Hollow Blocks	180	pieces
Cement	4553	kg
Sand	6	m ²
Stone	7	m ²
Water	2.4	m ²
RB 6 mm	242	m
RB 9 mm	1976	m
Steel Channel (7.50 cm x 3.75 cm)	18	m
Chicken Mesh	168	m ²
GI Pipe	2.7	m
Steel Plate	0.09	m ²

Mix Proportions

Lean Concrete = 1:4:8 (Cement: Sand: Aggregate by weight)

Slab Concrete = 1:2:4 (Cement: Sand: Aggregate by weight)

Ferrocement Mortar = 1:2:0.4 (Cement: Sand: Water by weight)



Ferrocement Cast-in-place Water Tank
(75 Cu.m.)

Designed by

ACECOMS

School of Civil Engineering (AIT)



Drawing Title:

Material Specification and BOM

Scale: Not to Scale

Client: UNHCR

Drawing No:

CD75-09

Date: March 2002

Ferrocement Cast-in-place Water Tank (90 Cu. M.)

Designed by:



ACECOMS, IFIC
School of Civil Engineering
Asian Institute of Technology (AIT)

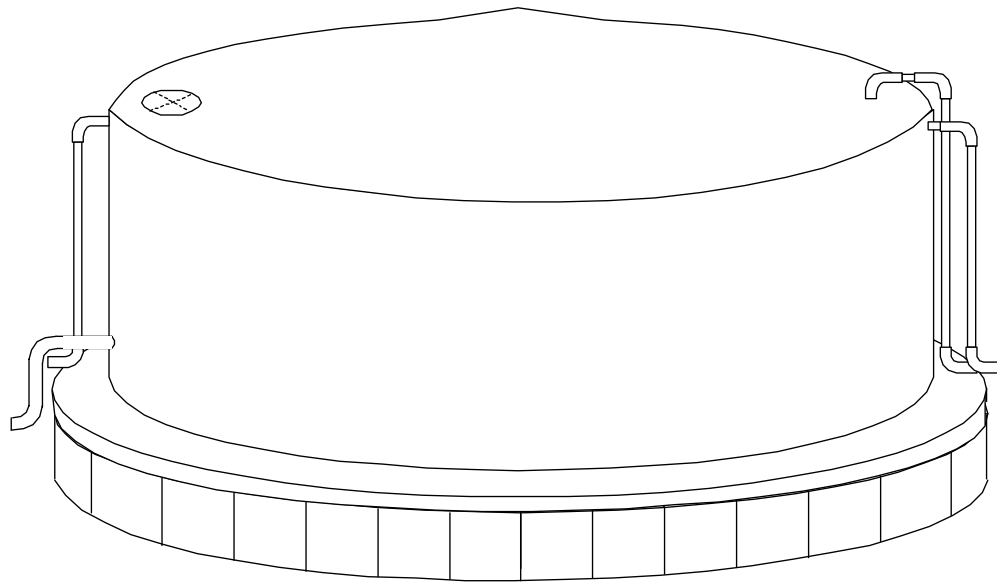


Designed for:



United Nations High Commissioner for Refugees (UNHCR)

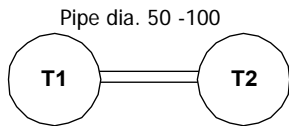
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CD90-01	Key Features
CD90-02	Plan, Elevation and Section
CD90-03	Foundation Details
CD90-04	Base Slab Details
CD90-05	Wall and Central Column Details
CD90-06	Roof Details
CD90-07	Reinforcing Steel Skeleton
CD90-08	Construction Tools and Steps
CD90-09	Material Specification and BOM



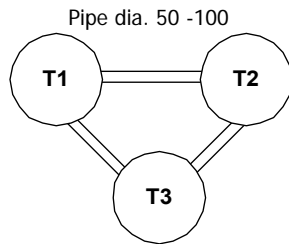
Key Features

Capacity	90 Cu. m
Diameter	7300
Height	2700 (2200+500)
Foundation	Compacted Sand/ Soil (thk. = 500) Retained by Hollow Blocks/ Masonry Bricks
Base Slab	Reinforced Concrete (thk. = 120)
Wall	Ferrocement (thk. = 30) Stiffened by Embedded Steel Channels
Roof	Ferrocement (thk. = 30) Stiffened by Embedded Trusses
Central Column	GI Pipe (Diameter = 150) Filled with Mortar
Access Opening	Diameter = 600 (in Roof)
Pipe Work	Intel, Outlet and Over Flow Pipes
Finishing	<ul style="list-style-type: none"> • Inside Plastering Only • Outside Ordinary Paint • No Special Paint/Additives

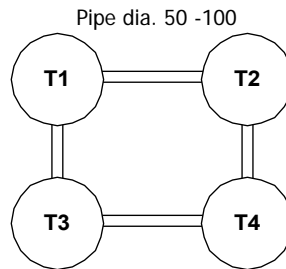
Single Tank



Plan - 2 Tanks

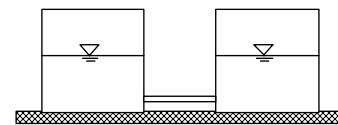


Plan - 3 Tanks

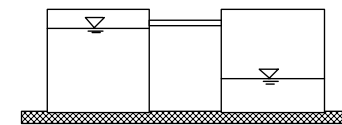


Plan - 4 Tanks

Examples for Connecting Multiple Tanks



For Same Water Head



For Different Water Head
(Overflow Type Connection)

Note: - RB = Round Bar
 - GI = Galvanized Iron
 - All dimensions are in millimeter
 - Foundation height depends upon water head required



Ferrocement Cast-in-place Water Tank
(90 Cu.m.)

Designed by

ACECOMS



School of Civil Engineering (AIT)

Drawing Title:

Key Features

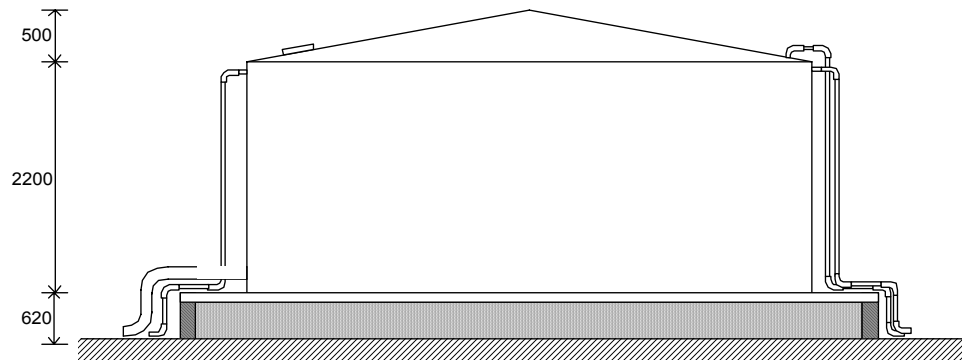
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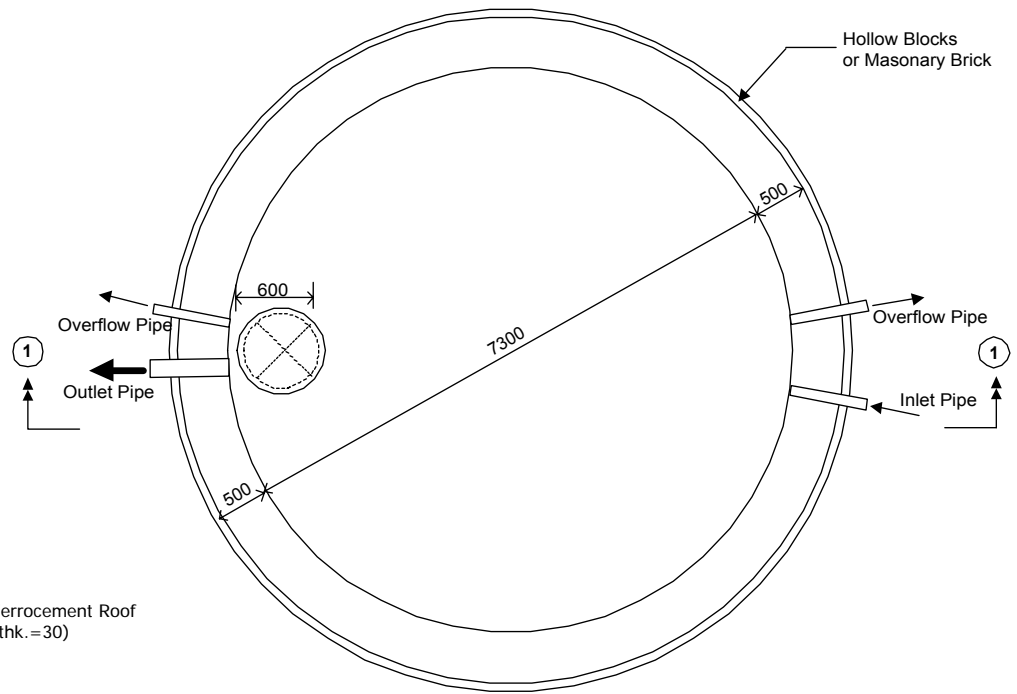
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CD90-01

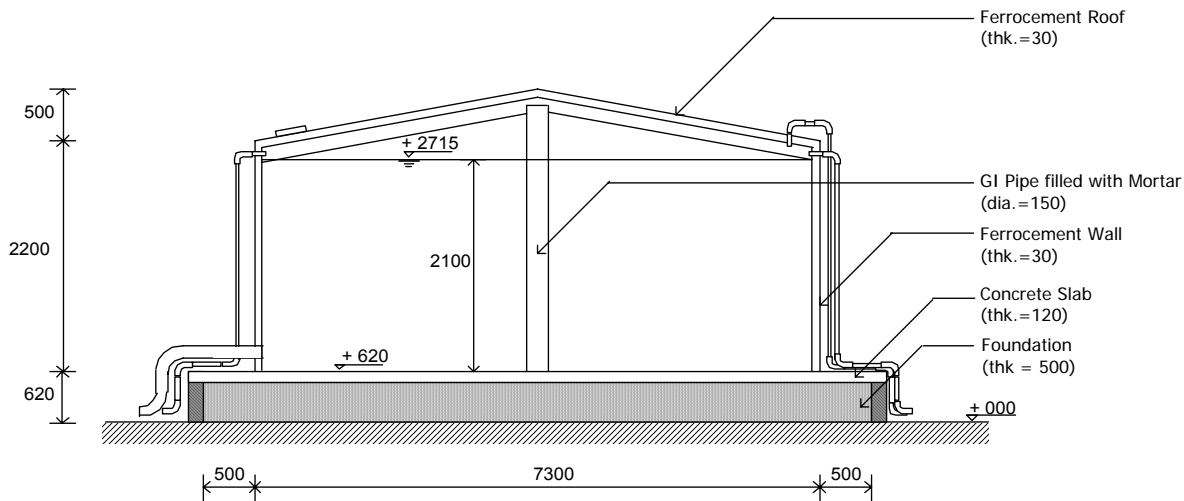
Date: March 2002



Elevation



Roof Plan



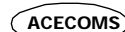
Section 1-1

Note: - RB = Round Bar
 - GI = Galvanized Iron
 - All dimensions are in millimeter
 - Foundation height depends upon water head required



**Ferrocement Cast-in-place Water Tank
 (90 Cu.m.)**

Designed by



School of Civil Engineering (AIT)



Drawing Title:

Plan, Elevation and Section

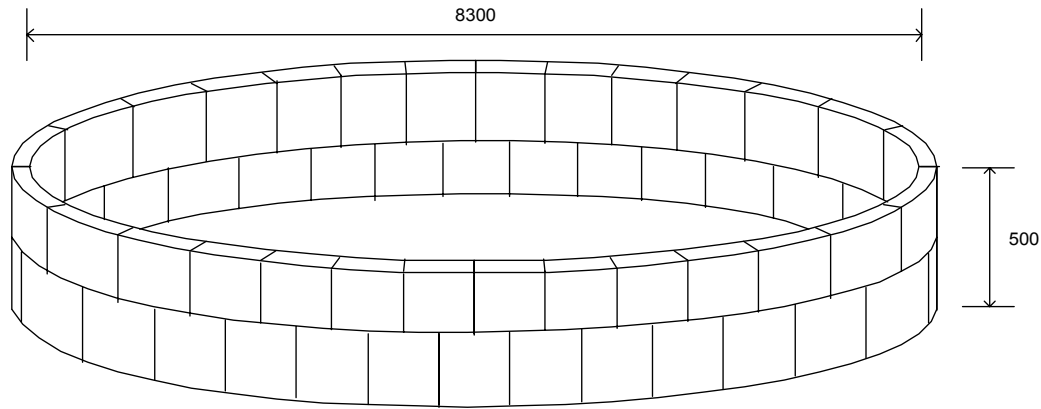
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Client: UNHCR

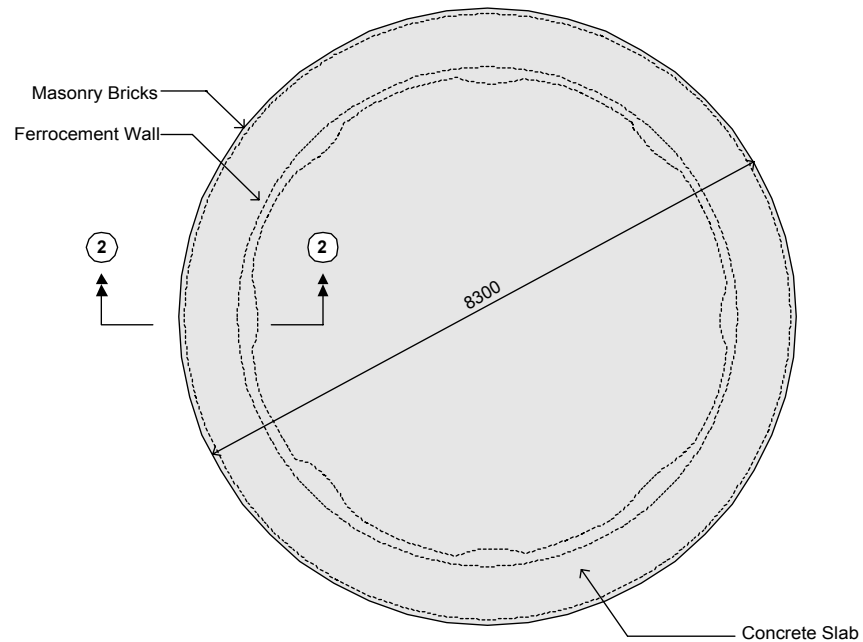
Drawing No:

CD90-02

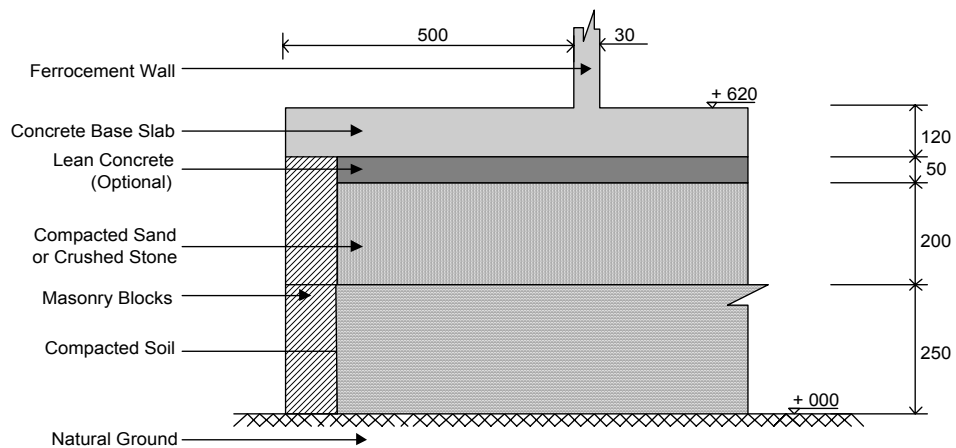
Date: March 2002



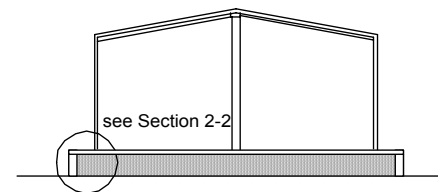
Masonry Brick Layout



Foundation Plan
(Level + 620)



Section 2-2: Foundation Detail



Note: - RB = Round Bar
 - GI = Galvanized Iron
 - All dimensions are in millimeter

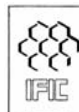


Ferrocement Cast-in-place Water Tank
(90 Cu.m.)

Designed by

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Drawing Title:

Foundation Details

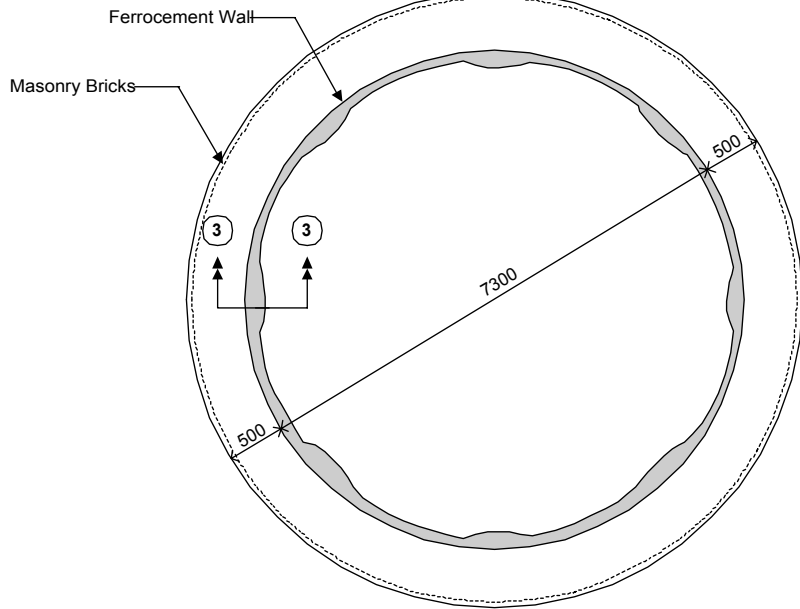
Scale: Not to Scale

Client: UNHCR

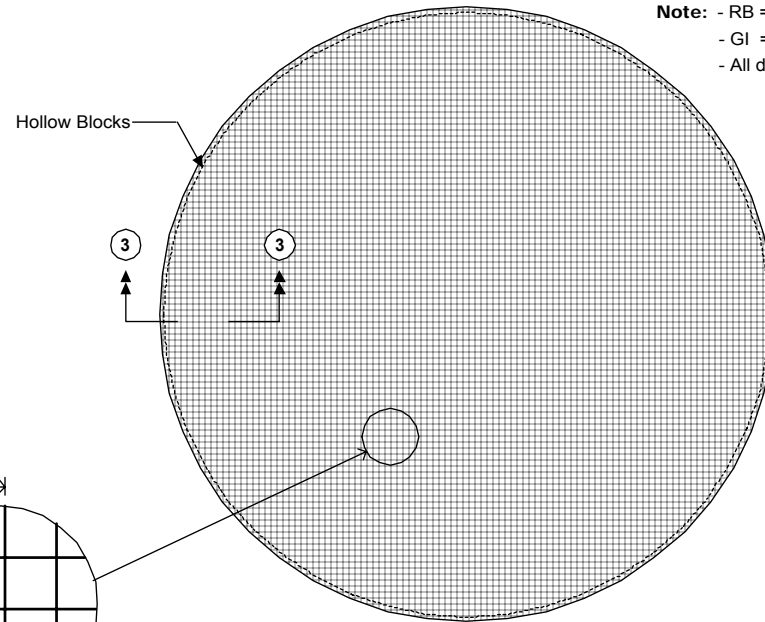
Drawing No:

CD90-03

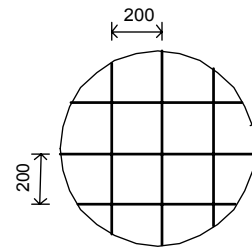
Date: March 2002



Water Tank Plan

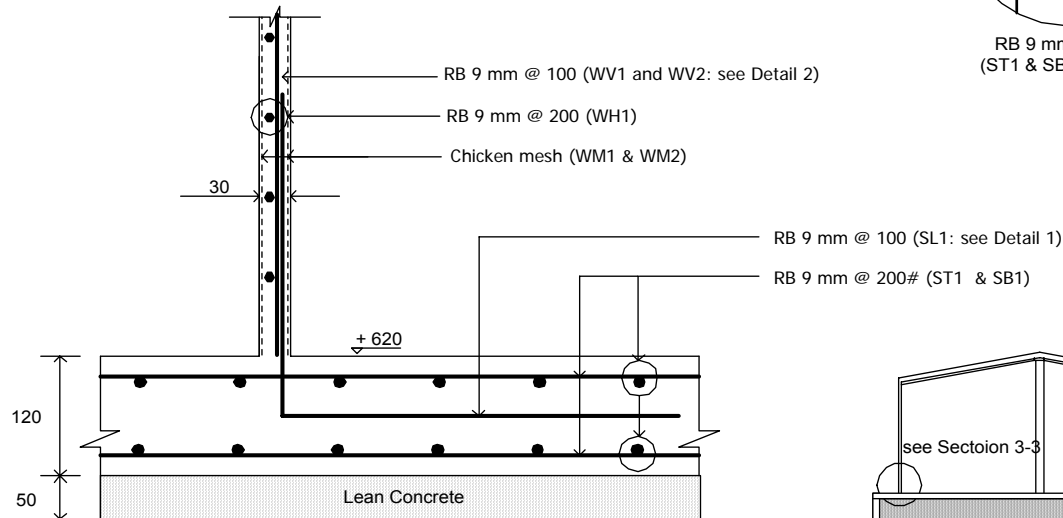


Base Slab Reinforcement Detail

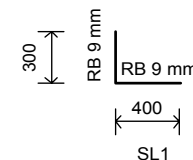
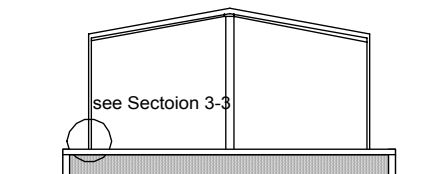


RB 9 mm @ 200 #
(ST1 & SB1: 2 Layers)

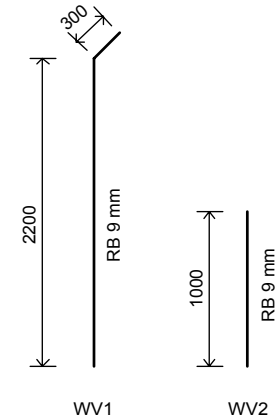
Note: - RB = Round Bar
- GI = Galvanized Iron
- All dimensions are in millimeter



Section 3-3: Slab Detail



Detail 1



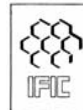
Detail 2



**Ferrocement Cast-in-place Water Tank
(90 Cu.m.)**

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Drawing Title:

Base Slab Details

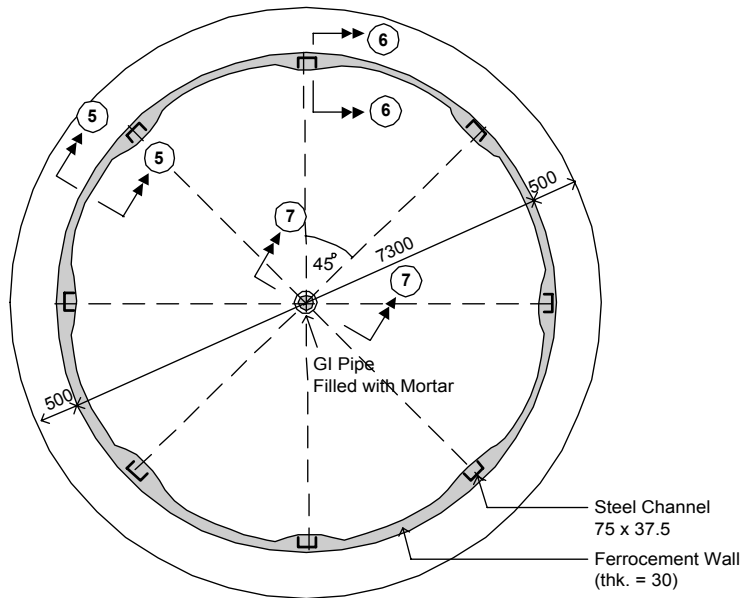
Scale: Not to Scale

Client: UNHCR

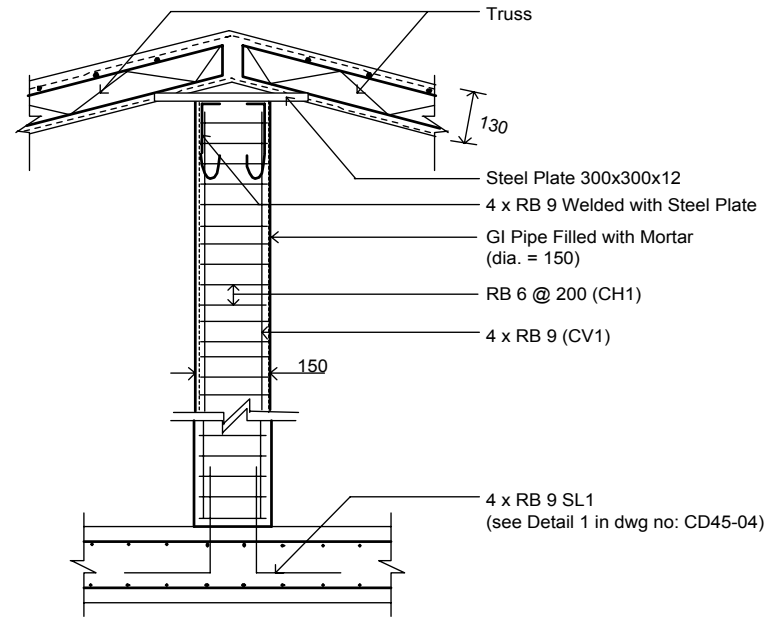
Drawing No:

CD90-04

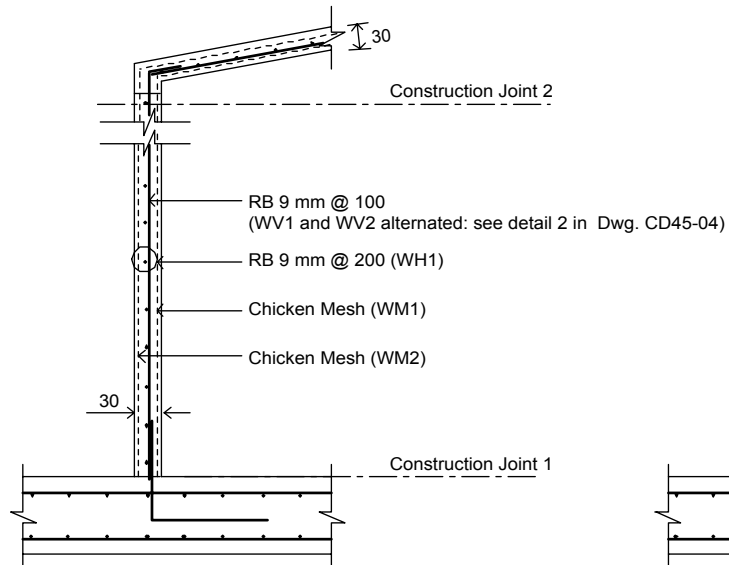
Date: March 2002



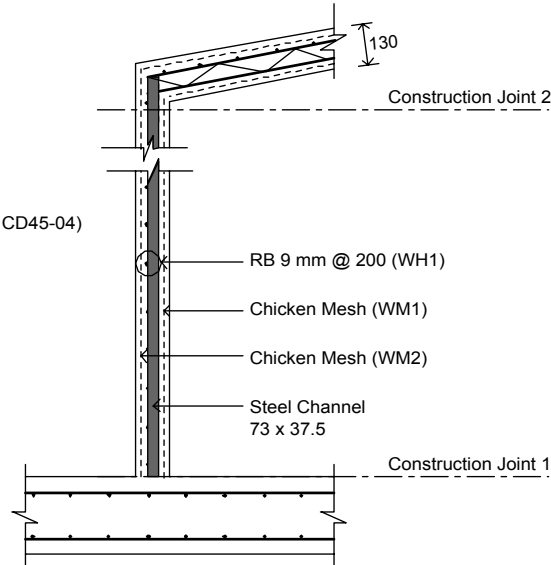
Section 4-4: Water Tank Wall Section



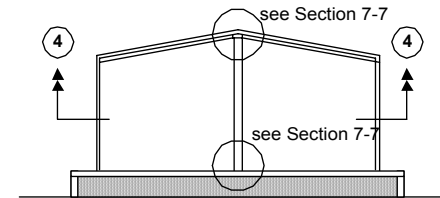
Section 7-7: Central Column Detail



Section 5-5



Section 6-6



Note: - RB = Round Bar
 - GI = Galvanized Iron
 - All dimensions are in millimeter



UNHCR

**Ferrocement Cast-in-place Water Tank
 (90 Cu.m)**

Designed by

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Drawing Title:

Wall and Central Column Details

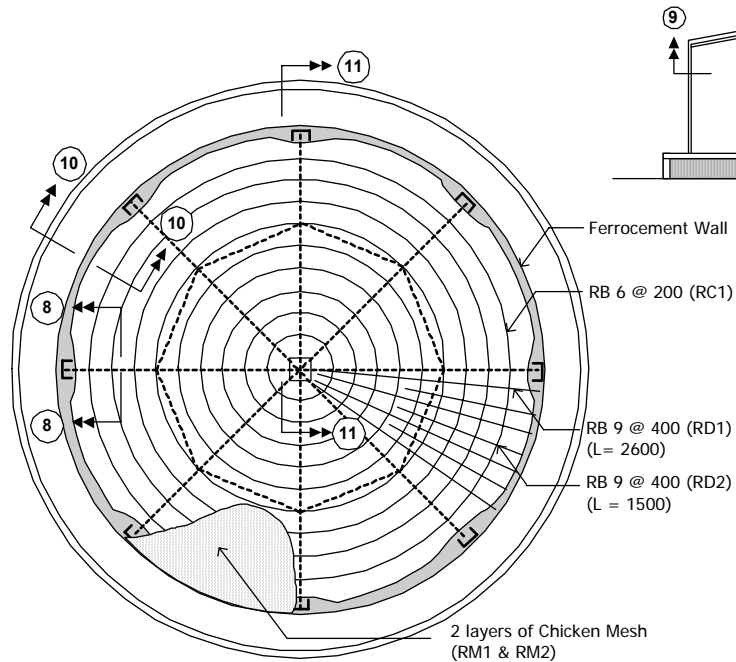
Scale: Not to Scale

Client: UNHCR

Drawing No:

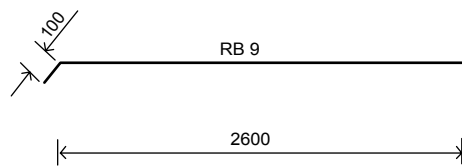
CD90-05

Date: March 2002

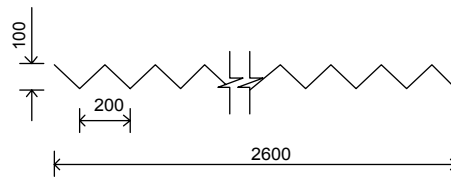


Section 9-9: Roof Framing Plan

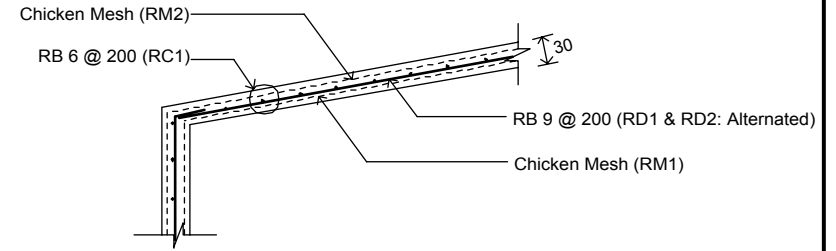
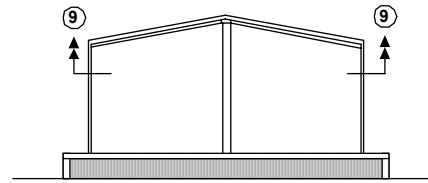
- Steel Channel 75 x 37.5
- Truss (see Section 11-11)



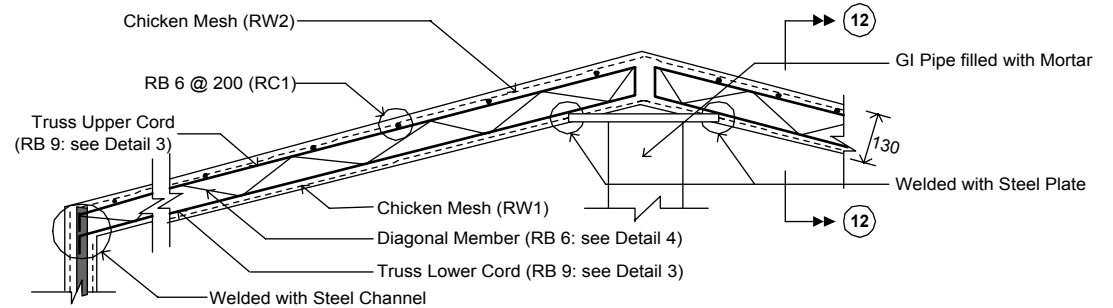
Detail 3: Truss Upper and Lower Cord Detail



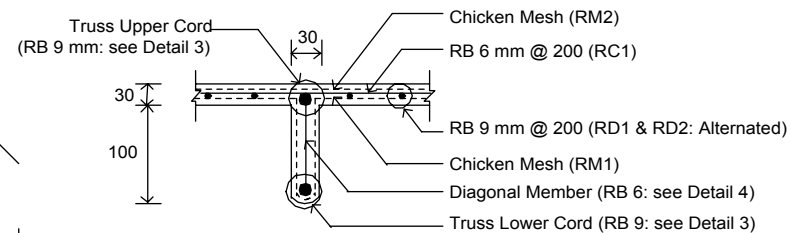
Detail 4: Diagonal Member Detail Welded to Upper and Lower Chord



Section 10-10: Roof Slab Detail



Section 11-11: Truss Detail



Section 8-8: Truss Section

Note: - RB = Round Bar
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**Ferrocement Cast-in-place Water Tank
 (90 Cu.m.)**

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Drawing Title:

Roof Details

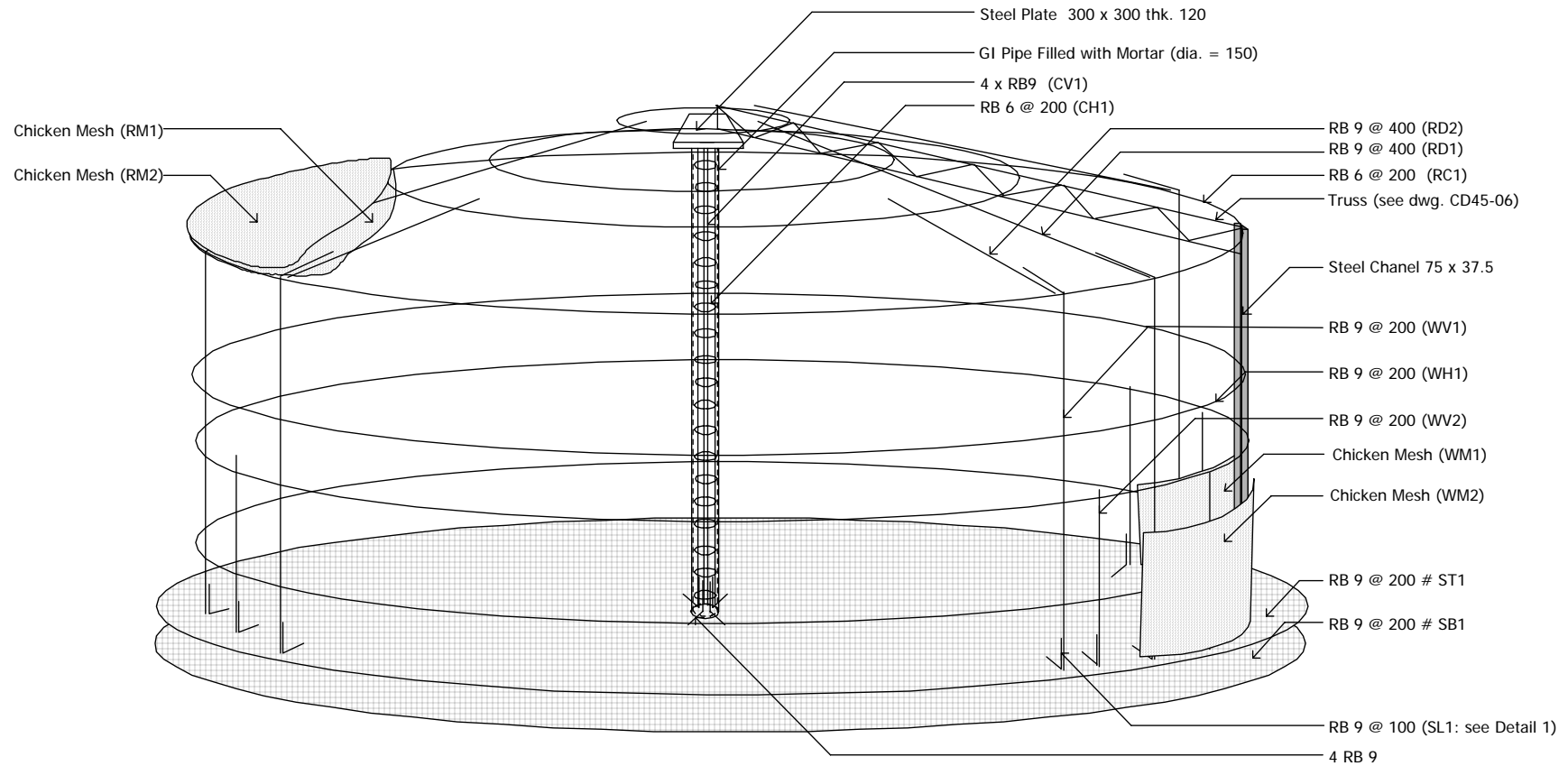
Scale: Not to Scale

Client: UNHCR

Drawing No:

CD90-06

Date: March 2002



Note: Only Selected Typical Elements Shown

Note: - RB = Round Bar
 - GI = Galvanized Iron
 - All dimensions are in millimeter



Ferrocement Cast-in-place Water Tank
 (90 Cu.m.)

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Drawing Title:

Reinforcing Steel Skeleton

Scale: Not to Scale

Client: UNHCR

Drawing No:

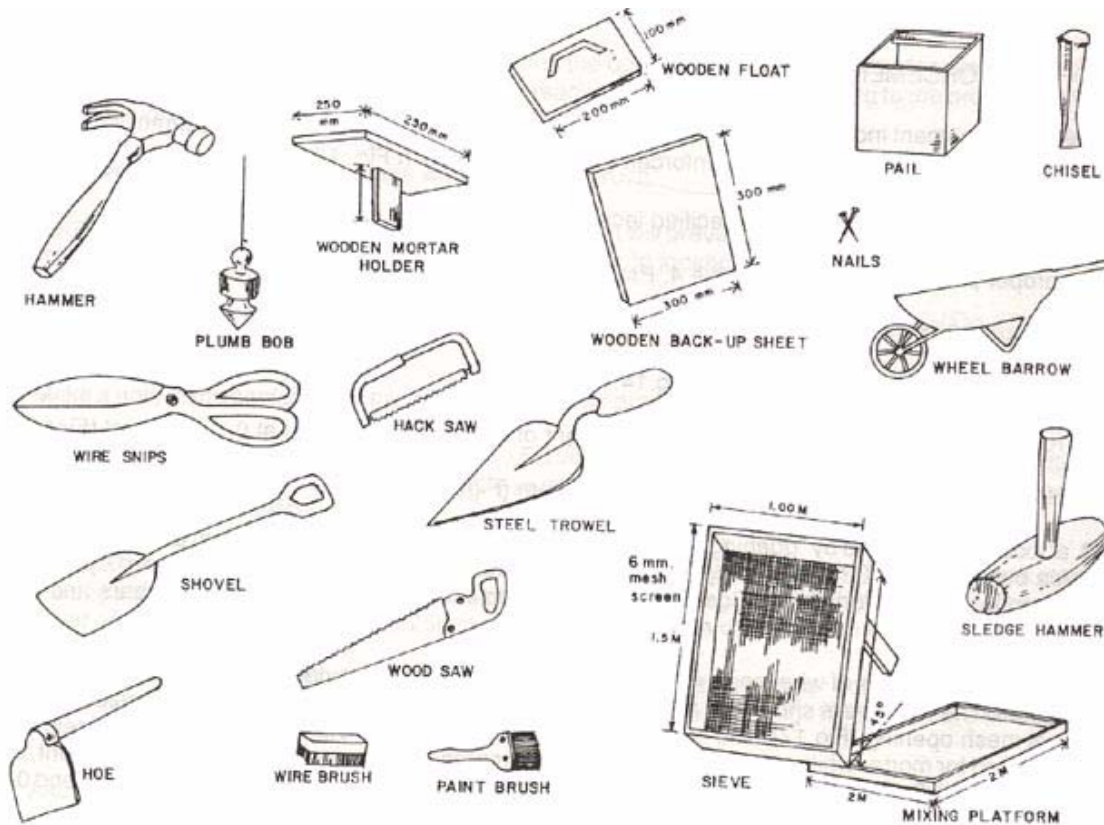
CD90-07

Date: March 2002

Construction Main Steps

- Step 1: Selection of Site
- Step 2: Site Clearance
- Step 3: Preparation of Foundation
- Step 4: Preparation of Lean Concrete Base
- Step 5: Preparation of Base Slab Reinforcement
- Step 6: Laying Base Slab Reinforcement
- Step 7: Erecting L-bars Along the Wall-Base Junction
- Step 8: Placing Vertical Dowel/ Plate/Bars for Central Column
- Step 9: Casting the Base Slab
- Step 10: Erection of Vertical Reinforcement and Stiffeners for Wall
- Step 11: Keeping Openings for Construction and Pipe Works
- Step 12: Fixing Wire (Chicken) Mesh (WM1 and WM2)
- Step 13: Preparation and Fixing the Central Column
- Step 14: Plastering the Wall
- Step 15: Preparation of Roof Shallow Truss
- Step 16: Fixing Roof Trusses (Roof Stiffeners)
- Step 17: Placing Roof Reinforcements
- Step 18: Fixing the Roof Mesh
- Step 19: Providing Openings in the Roof
- Step 20: Plastering Roof Trusses
- Step 21: Temporary Formwork for Plastering of Roof Surface
- Step 22: Plastering Roof Surface
- Step 23: Plastering Temporary Openings
- Step 24: Finishing the Surface

[For Construction Procedure Details Refer to "How to Manual"]



Ferrocement Construction Tools



Ferrocement Cast-in-place Water Tank
(90 Cu.m.)

Designed by

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Drawing Title:

Construction Tools and Steps

Scale: Not to Scale

Client: UNHCR

Drawing No:

CD90-08

Date: March 2002

Material Specification

Cement: Use ordinary Portland cement Type I or II for tropical countries and Type II for cold climates

Sand:

1. Use well graded sand. Sand that is too fine or too coarse is not suitable
2. Separate sand from stone using 6.4 mm (1/4 inch) mesh screen.
3. No organic or chemical impurities. If quality is in doubt, wash with clean water.
4. Desirable sand grading is as follow:

Sieve	Percent passing
3/8 in (9.5mm)	100
No. 4 (4.75mm)	95 to 100
No. 8 (2.36 mm)	80 to 100
No. 14 (1.18mm)	50 to 85
No. 30 (600um)	25 to 60
No. 100 (150um)	2 to 10

Water:

1. Water fit for drinking is suitable.
2. Salty water should never be used.

Wire Mesh:

1. Must be easy to handle and flexible enough to be bent around corners.
2. Galvanized wire mesh is preferred as it is less likely to rust or corrode.
3. Use 0.5 mm to 1.00 mm diameter with 10 mm to 25 mm mesh opening.
4. Free from grease, oil, rust and anything that might reduce bond.

Skeletal Steel :

1. Free from grease, oil detergents, organic matter, cracks of blow holes.
2. Bars are acceptable if no cracks appear after the following field test:
"Bend bar into U shape and then straighten it out. Bend it again in U shape in the opposite direction and straighten it out."
3. Grade SR24: Yield strength = 2400-2600 ksc

Steel Channel:

1. Free from grease, oil detergents, organic matter, cracks of blow holes
2. Size 7.50 cm x 3.75 cm (height x width)
3. Grade $F_y = 2400-2600$ ksc (34-36 ksi) and $F_U = 4,000-4,500$ ksc (57-64 ksi)

Tie Wire: Use annealed (soft) galvanized wires of 24 or 26 gauge. Cut pieces of wire from meshes could also be used for tying.

Material Quantity Summary (90 cu. m.)

Items	Quantity	Unit
Coarse Sand	25	m ²
Hollow Blocks	195	pieces
Cement	5078	kg
Sand	7	m ²
Stone	7	m ²
Water	2.62	m ²
RB 6 mm	279	m
RB 9 mm	2375	m
Steel Channel (7.50 cm x 3.75 cm)	18	m
Chicken Mesh	191	m ²
GI Pipe	2.7	m
Steel Plate	0.09	m ²

Mix Proportions

Lean Concrete = 1:4:8 (Cement: Sand: Aggregate by weight)

Slab Concrete = 1:2:4 (Cement: Sand: Aggregate by weight)

Ferrocement Mortar = 1:2:0.4 (Cement: Sand: Water by weight)



Ferrocement Cast-in-place Water Tank
(90 Cu.m.)

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Drawing Title:

Material Specification and BOM

Scale: Not to Scale

Client: UNHCR

Drawing No:

CD90-09

Date: March 2002