Underground Water Harvesting Structure

Technical Manual

Ethiopian Institute of Agricultural Research
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Preface

This manual is prepared with the intention of providing local technicians and extension workers with practical guidelines on designing, constructing and maintaining underground water harvesting tank for the implementation of water harvesting schemes in any localities. The purpose of the manual is to improve agricultural production and prevent land degradation particularly to combat the desertification through community based-participation in drought prone areas.

The content of this manual is based on the outcomes of the verification study which was undertake from 2004 to 2008 on technologies for natural resources' conservation and restoration for the prevention of desertification, implemented at the Great Rift Valley in Oromiya. The task was a joint study between EIAR and J-Green in which later J-Green was substituted by JIRCAS.

The Water harvesting structure dealt in this manual is limited to dugout pond which is hemispherical type for collecting the runoff captured from a catchment. The hemisphere type WHT has been built by many organizations, since the middle of 1990s in Ethiopia. Other types of water harvesting tanks do exist; nevertheless, so long the principle of maintenance remains the same the manual is also relevant to any water harvesting structure and should be handled in similar manner.

Effort has been made to keep the manual a practical one using tables, diagrams, charts and photographs. It is believed that the manual will serve as a useful field guide for the implementation of water harvesting schemes. The local people should independently make sustainable effort to secure water. WHT is one effective and easy method to secure the water resources. However, many of the hemispherical WHT made of concrete or mortal and could not fully achieve their own purpose due to crack in the wall, or insufficient catchment area and so forth. Therefore, this manual provides relevant information in this regard.
## Acronyms and Abbreviations

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Description</th>
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<tr>
<td>A</td>
<td>Area</td>
</tr>
<tr>
<td>C</td>
<td>Runoff coefficient</td>
</tr>
<tr>
<td>CR</td>
<td>Water Consumption Requirement</td>
</tr>
<tr>
<td>CWR</td>
<td>Crop Water Requirement</td>
</tr>
<tr>
<td>DA</td>
<td>Development Agent</td>
</tr>
<tr>
<td>E</td>
<td>Irrigation efficiency</td>
</tr>
<tr>
<td>ea</td>
<td>Actual vapour pressure</td>
</tr>
<tr>
<td>EIAR</td>
<td>Ethiopian Institute of Agricultural Organization</td>
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<tr>
<td>Ep</td>
<td>Open water evaporation</td>
</tr>
<tr>
<td>es</td>
<td>Saturated vapour pressure</td>
</tr>
<tr>
<td>f(u)</td>
<td>Wind function</td>
</tr>
<tr>
<td>IR</td>
<td>Irrigation requirement</td>
</tr>
<tr>
<td>J-Green</td>
<td>Japan Green Resource Agency</td>
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<td>JIRCAS</td>
<td>Japan International Research Center for</td>
</tr>
<tr>
<td></td>
<td>Agricultural Sciences</td>
</tr>
<tr>
<td>N</td>
<td>Family size</td>
</tr>
<tr>
<td>NGO</td>
<td>Non-Governmental Organization</td>
</tr>
<tr>
<td>P</td>
<td>Precipitation</td>
</tr>
<tr>
<td>PVC</td>
<td>Polyvinyl Chloride</td>
</tr>
<tr>
<td>q</td>
<td>Unit discharge</td>
</tr>
<tr>
<td>r</td>
<td>Radius of a circle</td>
</tr>
<tr>
<td>t</td>
<td>Number of days</td>
</tr>
<tr>
<td>U₂</td>
<td>Wind speed at 2 meter height</td>
</tr>
<tr>
<td>V&lt;sub&gt;Ro&lt;/sub&gt;</td>
<td>Runoff volume</td>
</tr>
<tr>
<td>Vs</td>
<td>Capacity of WH tank</td>
</tr>
<tr>
<td>WHT</td>
<td>Water Harvesting Tank</td>
</tr>
<tr>
<td>π</td>
<td>PI</td>
</tr>
</tbody>
</table>
Introduction

Irrigation is the most obvious response to drought and improves agricultural production and productivity. Water harvesting can be considered as a rudimentary form of irrigation. Runoff can only be harvested when it rains. Instead of runoff being left to cause erosion, it is harvested and utilized to meet the demand. Water harvesting technique is low cost investment that could be used by many poor farmers for improved farming thus leading to improved livelihood and household food security.

Water harvesting techniques could help increasing the productivity of arable and grazing lands that suffer from inadequate rainfall, increase yields of rainfed farming, minimize the risk of crop failure in drought affected areas, combat desertification by improving natural vegetation, improve forage and pasture crops, supply drinking water for animals and people.

In order to meet the water demand for various purposes, sustainable systems of water harvesting and managing techniques should be developed. Indigenous experiences should be encouraged and applied at village and household levels.

Water Harvesting Structures

Water Harvesting Tanks (WHT) are containers where runoff water is detained from the time it is collected until it is used. The runoff water harvested could be stored either in the above ground WHT such as tanks made of concrete or metal sheet, ponds, reservoirs or underground WHT. The different types of WHT are distinguished by the shape. Some of the selected and most common WHT shapes are
Underground Water Harvesting Structure

- Spherical
- Hemispherical
- Dome
- Bottle
- Cone
- Cylindrical
- Rectangular

WHT compared to other forms of Hemispherical and trapezoidal WHTs are widely used by a large farmer because of its simplicity to construct it. In this manual emphasis is given to hemispherical type of WHT. However, before coming to a decision to construct the WHT the quantity of water required should be assessed.

Assessment of Water Requirements

The WHT is constructed to store and secure the needed amount of water to serve the intended purpose during the dry season. Each household farmer requires water for different purpose (Table 1).

Table 1. Water requirement for different purpose

<table>
<thead>
<tr>
<th>Description</th>
<th>Consumption rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tomato</td>
<td>400 - 600 mm/season</td>
</tr>
<tr>
<td>Onion</td>
<td>350 - 550 mm/season</td>
</tr>
<tr>
<td>Beans</td>
<td>300 - 500 mm/season</td>
</tr>
<tr>
<td>Potato</td>
<td>700 - 1000 mm/season</td>
</tr>
<tr>
<td>Maize</td>
<td>500 - 800 mm/season</td>
</tr>
<tr>
<td>Human</td>
<td>10 lit./day</td>
</tr>
<tr>
<td>Cattle</td>
<td>27 - 40 lit./day</td>
</tr>
<tr>
<td>Sheep and goat</td>
<td>5 lit./day</td>
</tr>
<tr>
<td>Donkey and horse</td>
<td>16 lit./day</td>
</tr>
<tr>
<td>Camel</td>
<td>50 lit./day</td>
</tr>
<tr>
<td>Chicken</td>
<td>0.15 lit./day</td>
</tr>
</tbody>
</table>
Design Procedure of WHT

To decide the capacity of the WHT community water requirements are computed as follows:

**Irrigation water requirement**

\[ IR = \frac{A \times CWR}{1000 \times E} \]

Where IR is the irrigation requirement (m³); A is irrigable area (m²); CWR is the crop water requirement (mm) and E is irrigation efficiency (fraction).

**Human and livestock water requirement**

\[ CR = \frac{Nq t}{1000} \]

Where CR is human and livestock consumptive requirement (m³); N is the family size (number); q is the consumptive rate (lit./day) and t is the number of days.

**Expected water losses**

Losses occurred as a result of climatic and soil characteristics and management practices.
Evaporation losses
Losses involved due to climatic variability and could be obtained from the nearby meteorological station or could be computed from modified Penman equation which is expressed as:

$$Ep = f(u)(e_s - e_a)$$

Where $Ep$ is the evaporation from free water surface (mm/day); $f(u)$ is a function of wind velocity expressed as $0.26\times(1.0 + 0.54\times U_2^2)$ where $U_2$ is wind velocity at 2 m height (m/sec) and $(e_s - e_a)$ the saturation vapour pressure deficit (mbar).

To minimize excessive evaporation losses avoid using large exposure areas of shallow depth water WHT and cover with necessary materials such as corrugated iron sheet or roof touch materials.

Seepage losses
These are losses occurred as a result of soil permeability characteristics and could be computed from Darcy (1856) equation if necessary. Seepage losses could be avoided by using lining materials such as polyethylene sheet, reinforced concrete and stone lining.

Siltation
Inflowing of water normally carries considerable amount of silt. The silt tends to reduce the capacity of the WHT. To reduce or avoid the silt intensity either treats the catchment with grasses or increase the number of silt trap. In any case, part of the WHT is occupied with silt and is considered as a loss. For best management assume 5 percent of the capacity as dead storage.

Management losses
These losses take place during conveyance and applications. The losses vary depending on the circumstance permit to effectively use...
water. If not able to speculate, assume for best managed at least losses of from 20 to 25 percent of the total water requirement.

The total estimated losses should be added up to the estimated water requirement for fixing the capacity of WHT.

**Estimation of runoff collected from catchments**

The volume of water that can be obtained from the available catchment can be estimated from the following equation:

\[
V_{RO} = \frac{P \times A \times C}{1000}
\]

Where \(V_{RO}\) is volume of water obtained from the catchment (m\(^3\)); \(P\) is precipitation (mm); \(A\) is catchment area (m\(^2\)) and \(C\) is runoff coefficient (fraction) that can be expressed as:

\[
C = \frac{R}{P}
\]

Where \(R\) is the runoff occurred from the catchment (mm) and \(P\) is the precipitation (mm). The values for \(C\) could be found from soil and water conservation reference books. Some of \(C\) values are given in Table 2.

Table 2 Runoff coefficient values

<table>
<thead>
<tr>
<th>Catchments type</th>
<th>P- values for different rainfall amounts</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>250 – 500</td>
</tr>
<tr>
<td>Roof</td>
<td>0.80 – 0.90</td>
</tr>
<tr>
<td>Concrete floor</td>
<td>0.75 – 0.85</td>
</tr>
<tr>
<td>Stone riprap</td>
<td>0.70 – 0.80</td>
</tr>
<tr>
<td>Compacted soil</td>
<td>0.15 – 0.30</td>
</tr>
<tr>
<td>Plastic covered</td>
<td>0.85 – 0.95</td>
</tr>
<tr>
<td>Scattered vegetation</td>
<td>0.08 – 0.15</td>
</tr>
<tr>
<td>Good vegetation cover</td>
<td>0.06 – 0.10</td>
</tr>
</tbody>
</table>
If the estimated runoff is not sufficient to secure the required amount of water, the capacity of WHT is limited by the available runoff obtained from the catchment.

**Capacity of WHT**

To determine the capacity of hemispherical type WHT the following equation can be used

\[ V_s = \frac{2}{3} \pi r^3 \]

Where \( V_s \) is the capacity of hemispherical type WHT (m³) and \( r \) is the radius of the WHT

**Construction Procedures**

**Site selection**

The first important point to consider in the construction of water harvesting structure is the site selection.

- Select suitable topography in terms of slope and drainage requirement. The runoff water collected from the catchment should be easily diverted and should have condition for draining the excess runoff;
- Investigate surface and sub-surface soil condition;
- Avoid soils with easily permeability such as sand and silt dominant soils;
- Avoid soils with cracking characteristics such as heavy clay soils
- Avoid soils with unstable ground, such as gullies or landslides, or near deep-rooted trees;
• Select a catchment that produce sufficient runoff water to meet the designed storage capacity;
• Avoid using catchment sites that collect runoff from unclean areas where excrements and garbage are most common;
• The storage site should be located in on marginal and unused lands; and
• The catchment selected should have the characteristics to generate as little sediment as possible.

**Construction materials**

The following items must be secured and prearranged before commencing the construction of WHT.

- String/rope
- Cement
- Page
- Meter
- Digging hoes
- Shovel spade
- gravel
- plastic hose
- sand
- steel rods
- barrel
- water
- nails
- buckets
- sprit level
- ladder
- wheel barrow
- wooden boards

**Hemispherical type tank construction**

The storage tank should have silt trap for trapping sediment and debris, inlet pipe, storage tank and the overflow pipe or the spillway. Within storage thank the three important distinguishable parts are base, side/wall and cover/roof and all need to be watertight. The base distributes the weight of the water evenly over the subsoil below. The sides or walls support pressure forces from the water and the cover prevent water losses by evaporation.
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Fig. 1. Typical hemispherical water WHT

Steps in constructing the structure

- Select suitable construction site;
- At the selected site, hammer one wooden peg;
- Tie a rope to the center wooden peg and make a loop at desired length; (radius) and put a nail through the loop and draw a circle;

Figure. 2 creating loop and making a circle
Underground Water Harvesting Structure

- Level the area and clear the site to a depth of 10-15 cm
- Locate the position of silt trap 3 m away from the storage tank. Wisely take sufficient dimensions of silt trap as the circumstance permit the dimensions of the silt trap increases, the effectiveness of de-silting will also be increased.

Put a wooden pole across the center peg. Put a nail at the center of the wooden pole. The nail should be exactly at the position of the center peg.

- The wooden pole should be placed firmly. Then, remove the center peg and tie the plastic rope to the nail on the wooden pole;
- Using the radius rope at all times, remove the soil inside the marked circle. The inside part of the hemisphere (the wall and floor) should be excavated uniformly (Figures 4 and 5).
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Figure 4. Excavation of the tank

Figure 5. Excavation for the construction of basement/foundation
• The wall could be made with stone lining or chicken mesh wire. If chicken wire is to be used, first apply 1.5 cm thick cement-sand mixture (1:3) on the wall. The chicken mesh wire is then fixed on the mortar plastered. Apply again 1.5 cm cement-sand mixture (1:3) followed by 2 cm of same ratio a day after. Finally, finish with cement coating and slurry for water proofing (Figures 6,7,8 and 9).

• Connect the silt trap with the storage tank using PVC or concrete pipe;

• Construct one layer of masonry ring 30 cm high and 30 cm thick on the upper profile of the hemisphere;

• While constructing the masonry ring, put an over flow pipe in an appropriate place;

• Apply one layer of 2 cm thick cement-sand (1:3) mortar plaster to the wall of the tank;

• Prepare roofing structure for the tank constructed;

• After completing the construction of roof structure, apply the second time coating of plaster (1:3) 2 cm thick to the wall of the tank. This time the sand should be sieved for the use of plastering;

• Apply a coat of cement slurry (nil) to all portion of the tank with brush after two days from the second time mortar plaster coatings; and

• Cover the roof with the available and affordable construction material and the tank must be watered twice a day for about 21 days to avoid cracks during the drying up of the concrete;

Figure 6. Filling the base with hard core and boulder stone on top and blinding lean concrete 1:3:6 ratios
Figure 7. Placing steel reinforcement bars on the top of the lean concrete

Figure 8. Filling with concrete (1:2:4) on the top of reinforcement steel bars
Safety

Where water harvesting structure is implemented due attention is given to the following things.

- Malaria and waterborne diseases a major threat to people who leave near by the storage tank. Protect the WHT from malaria and waterborne diseases using chemicals or other means as deemed necessary;
- Life saving fences should be constructed around the water harvesting structure to keep away teenagers and animals from an open storage tank; and
- Provide a ladder or steps to get into the storage tank when necessary. Otherwise use appropriate water lifting device.
Water Lifting

Once the runoff is stored in water harvesting structure, it should be used for different purpose when the need arises. However, water abstraction would not be simple as the water drawdown increases from full state. Therefore, water lifting devices are required in order to abstract the water from the storage tank. Now days, there are different ways of abstracting water from the storage tank in which the use of rope and bucket is the simplest one. Other simple hydraulic or motorized pump could be used. The choice depends on circumstance of the farmer. However the use of ladder or foot steps is not recommended for safety reasons.

Cracks and Leakages

Problems such as cracking and leakage in water tanks are often attributed to the following reasons:

- Poor design (shape, dimension, etc.) which does not consider the type of soil and construction materials;
- Inappropriate selection of construction materials with respect to their type and quality;
- Poor workmanship;
- Poor quality and handling of cement;
- Incorrect mix of mortar and concrete and loose mixing place;
- Lack of optimum curing period;
- Lack of compaction and appropriate basement or foundation; and
- Drying of tanks for long period

Potentially, these problems can often be overcome with proper training and supervision. When deciding on a particular design, it is always important to consider the cost and availability of materials.
Maintenance

Water not sufficiently available in a lined WH tank for two reasons:
Tank leaking: This is when water in the WHT is reducing before using it. Suspect a leakage due to cracking. Therefore, repair immediately to secure the required amount of water.

Whenever water is not sufficiently stored from the runoff, the inflow into water harvesting structure is limited either by the capacity of drainage bund or percolation rate of the soil is too high or the intake structure is deteriorated. Therefore, after investigating the cause, improve and maintain either the drainage bund or upgrade intake structure as required.

Figure 10. Before repairing the crack
Steps in protecting the catchment area

- All the runoff cannot enter into WHT
- The inflow to WHT is insufficient where the catchment undulates.

Bund-guiding water into WHT will be built to collect the water efficiently. Such a bund is supposed to be flushed when only soil is used as the material. Then, it is recommended building the bunds with stone (figure 12).

**Step 1** Standing near or on silt trap, undulation of catchment is grasped.

**Step 2** Dig trenches along edge of designed catchment area in order to lead the water and to prevent spilling of water from the catchment area. (The depth is about 10cm)

**Step 3** Stones are collected. (The size is larger than fist)

**Step 4** Stones are lined along the trench.

**Step 5** Smaller stone (gravels) are filled in a crevice of stones.
Figure 12. Maintenance of drainage basin
Control of maintenance of drainage basin

It is supposed that percolation loss is considerably large until the water comes into WHT where the slope in catchment area is gently, because the duration of water running on surface is long. The water hardly comes into WHT where the gradient of catchment area is not toward slit basin.

In those cases, it is necessary to improve and/or to preserve catchment area to collect water efficiently. However, the pavement is the most effective way to reduce the percolation loss but it is expensive.

The stone bunds

The direction of gradient in catchment area should be checked with standing near or on silt trap, the gradient can be checked over the ruler held horizontally in hands. If the catchment slants to right-hand, the bund guiding water is built in right-hand side of catchment area (Figures 13 and 14).

It is effective that bund is built like fun layout extending from the silt trap. In addition, the efficiency of collecting water will be improved when two rows of bund are built in parallel.

Bunds are easily flushed when they are built with only soil only; therefore, it is recommended building bund with stone. Larger stones are the fist arranged in straight line and the crevice is filled with smaller stones like seal.
Figure 13. Water harvesting system before placing the bund guiding water into WHT
Repair of crack

Cleaning and checking cracks

Step-wise procedure: Step 1: Drain out water from the tank (Figure 15).
Step 2: Clean the inside tanks
Remove silt, stone, garbage etc, and clean the inside tanks. If the area inside the tank is hot, do not work for long time (Figure 16).
Step 3: Check the cracks. Use ladder to go inside the tank for inspection (Figure 17).

Step 4: Observe the size and appearance of crack.
Crack repairing
After cleaning WHT, Repair method of a crack is determined according to the flow chart 'selection of repair method' taking the condition of crack into account. Following points are considered as the cause of a crack.

- Impurities contained in aggregate material;
- Uneven of lining thickness; and
- Insufficient supporting force of foundation.

These causes come from the immaturity of construction technology. Three repair methods are introduced in order that the farmer managing WHT and a Development Agent (DAs) can easily adopt using cement supplied commonly.

Crack adjudication
The shape of crack becomes net or honeycomb pattern when Impurities contained in aggregate material (Figure 18), this crack may be caused by Alkali-aggregated reaction). The crack is also caused by shrinkage while drying concrete (Figure 19). The breadth of both cracks is less than 0.5mm.

Figure 18. Impurities in cement.
Internal water pressure etc. is a cause of crack that appears in transverse and/or longitudinal direction (fig 20) circumference crack and longitudinal crack caused by insufficient bearing capacity in foundation and water pressure). The breadth of both cracks is over 0.5mm.
Cracking clay leads the collapse of the surface (Figure 21). Such a collapse will be caused by the lack of foundation treatment.

Figure 21. Collapse of wall caused by expansive clay

A crack is surveyed with regard to breadth, length, and depth in order to select the suitable repairing method (Figure 22).

Figure 22. Measurement of crack
Principles of pressure

No balance

Water pressure

\[ \text{Water pressure} > \text{ground pressure} \rightarrow \text{crack} \]

Good balance

Water pressure

\[ \text{Water pressure} = \text{ground pressure} \rightarrow \text{no crack} \]

Figure 23. Pressure distribution in storage tank
Surface coating and construction method

Materials and tools
Prepare cement, watering can, brush, trowel, pitcher, and basin (Figure 24).

Figure 24. Materials and tools required for surface coating
**Procedure**

**Step 1.** Surface washing and watering

When coating on dry surface with nil, the material will be absorbed by dry surface and a crack will occur after drying (Figure 25).

![Image of surface coated with nil](image.png)

**Figure 25. Surface coated with nil**

**Step 2.** Preparing nil

Mix equal amount of cement and water well. Duration of mixing needs to be more than three minutes. Composition ratio of 'nil' in volume \( \rightarrow \) water: cement \((1:1)\) (Figure 26).
Step 3: Coating with nil Coat the cracked surface with nil covering widely over the entire cracked portion. (About 3-5mm in thickness) (Figure 27).
**Step 4:** Spray water to keep the surface moist twice a day for about three days.

If surface is dry rapidly, a crack surely occurs. Then, spraying water should be continued for three days after coating to keep the surface moist (Figure 28) The frequency of spraying water is twice a day (in the morning and in the afternoon).

![Figure 28. Surface curing](image)

**Step 5:** Dry surface after three days of curing

**Step 6:** Completion

After drying, no crack is found, then the repair completes. When a crack is found, nil is coated again.

**Filling cracks and construction method**

**Materials and Tools required:** Prepare cement, sand, hummer, chisel, watering can, shovel, tub, trowel, pitcher, brush, and basin (Figure 29).
Construction Methods

Step 1
Notching the crack, and brushing the notched crack, and then cleaning the surface with water

- Cut the concrete with V shape 4cm along the crack;
- Clean up cut portion with the brush;
- The cut portion is washed with water; and
- Spray water on surface to improve the adhesion of cement. New mortar strongly adheres to the old mortar surface on damp surface of mortar (Figure 30).
Step 2. Preparing mortar
The ratio of cement and sand (1:3) is prepared in a bucket. The volume ratio of cement and sand is as shown in table above.

- Mix the sand and cement well to blend sand and cement evenly (Figure 31);
- Mix them more than three minutes;
- Gradually add water into the mixed soil and cement and mix them (Figure 32);
- Water is added carefully to obtain suitable hardness (Figure 33);
- Stop adding water in case that the mortar retains shape and does not drip when scooping mortar.
Table 3 Mixing ratio of cement and sand

<table>
<thead>
<tr>
<th>Material</th>
<th>Volume</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cement</td>
<td>5 L</td>
<td>1 bucket of 5L</td>
</tr>
<tr>
<td>Sand</td>
<td>15 L</td>
<td>3 buckets of 5L</td>
</tr>
</tbody>
</table>

Following materials and 10 liter water produce about 15 liter mortar.

Figure 31. Mortar preparation in a bucket

Figure 32. Filling cracks with mortar
Step 3. Mortar filling
- Fill a mixture of cement and sand into the void;
- Mortar is filled into the cut portion. Beat and press the mortar to stuff up the crack completely where the void behind the crack is large;
- Fill and plaster the mortar for hiding the crack portion; and
- Carefully fill the crack not to leave a void in the crack (Figure 34).

Step 4. Spray water to keep moist twice a day for three days after filling
Step 5. Hereafter, surface coating construction method is implemented
Step 6. Completion
Mending of cross section and back fill construction

Materials and Tools
Prepare cement, sand, small stone, hummer, chisel, watering can, shovel, tub, trowel, pitcher, brush, and basin (Figure 35).

Figure 35. Materials required for restoration the edge of the tank
Mending cross section and back fill construction

Step 1 removing the mortal or concrete widely including cracked portion (Figure 36).

![Diagram showing removing cracked portion up to the foundation]

Fig 36. Removing cracked portion

Step 2 Checking back filled material (type of soil) and void of foundation.

- Back filled stones are removed, and void, hole or crevasse in the foundation are checked. Stuffs with a moderate sized stone and/or concretes when the void or hole is open.
- It is noticed that stones are carefully removed where gradient is steep because upper side stone will slide down or worker will slip (Figure 37)
Foundation stones are arranged to stick to each other;
The gap between stones should be stuffed with stones that the size is about 2/3 of gap;
Mortar or concrete should be packed to fix stuffed stones; and
Cement and sand mixture is filled into the void among gravels So that finished concrete is similar in volume to gravels

**Step 4** Preparing concrete, filling and plastering with concrete
- The ratio of cement and sand and gravel is measured with a bucket;
- The volume ratio of cement and sand and gravel is 1:2:4; and
- The mixed concrete is plastered at about 5cm in thickness.

**Step 5** Spraying water to keep the surface moist twice a day for three days after filling

**Step 6** Drying for two days after three day’s sprinkling water to keep moist.

**Step 7** Brushing the surface of concrete and watering to make the surface damp.
Step 8  Hereafter, surface coating construction method is implemented.

Step 9  Completion

**Water lifting equipment and safety measures**

Bucket will be easily broken due to bumping on the wall when the water level is low. Therefore, it is recommended to use water lifting equipment such as pedal pump. Moreover, it is necessary that mud and garbage be cleaned periodically in order to secure the stable storage (Figure 38).

Figure 38. Water lifting from WHT

Installation of a roof and a ladder are necessary. A roof prevents a fall accident and reduces evaporation loss. A ladder is used when cleaning WHT (Figure 39).
Underground Water Harvesting Structure

Figure 39. Safety measures

- Garbage and mud in WHT
- A ladder is needed to clean inside WHT
- It is a danger when falling!
Important Terms and Rules

Terms

Concrete: is a mixture of cement, coarse sand, crushed stones (aggregate) and water.

Mortar: is a mixture of cement, sand and water without crushed stones.

Nil: is cement slurry made from mixing cement and water, which can be used as a substitute for waterproof cement.

Stone-masonry: is using mortar to build with regular dressed stones and blocks.

Curing: is the process of assisting the hardening of mortar or concrete work by keeping it moist. If the curing process for three weeks stopped after seven days, the cement will have only about 50% of its potential strength.

Rules to follow in construction

Sand: The quality of sand influences the strength of concrete and plaster. Sand collected from roadsides and slow-flowing watercourses is unsuitable because it consists of fine sand particles and silt, which will shrink and crack in water tanks. The silt content of a sand sample is found by filling a transparent plastic container or bottle half water and half sand. Shake the bottle vigorously and leave it to settle for three hours. Then measure the height of sand and the height of silt over-laying the sand in the bottle. If the height of silt is more than about 1/12 (8%), then the silt content is too high for the sand to be mixed with cement.
Coarse sand is the most suitable for concreting foundations and first step plastering of tank. Coarse sand can be found near the outer bends of sand rivers where water has a higher velocity, which carries away the finer sand. Finer sand is suitable for mixing mortar for final plaster of tank. Before being mixed with cement, sand should always be sieved and all organic materials removed because grass straws or tiny branches will function as drainage pipes in water tanks when they have rotted away.

**Water**
The water to be used for mixing sand and aggregates with cement should be of good quality which does not containing, silt, salt, chemicals, etc. In general, saline and water containing salt must not be used for any cement work as well as for curing.

**Mixing mortar and concrete**
The following are important rules to correct mix and applications of concrete and mortar:

**Mixing of concrete and Mortar**
- Prepare a mixing ground 4 by 4 meters and remove all loose soils and vegetation. Compact the area and cover it with mortar (1:5) using only one bag of cement. The mixing ground has to be watered for a minimum of one day;
- Measure the required sand quantity (equivalent to one bag of cement) using gauge box and put on the mixing ground. For water tanks, use cement sand ratio of 1:3 (one part of cement and three parts of sand). For concrete lining of water tanks, use cement: sand: gravel ratio of 1:2:3 (one part of cement, two parts of sand and three parts of aggregate);
- Add the required bag of cement on the top of sand measured. Do not try to mix once for more than two bags of cement;
- For the first time, turn the heap of sand and cement into another heap on the leveled and cemented ground without water;
• For the second time, turn the heap back to its original position, again without water;
• For the third time, turn the heap back to its other position, without water. These turnings will give the mixture a gray color, which is the sign of proper mixing. If sand is still seen, repeat the mixing; a
• Add water but please note only to that part of the mixture, which will be used within half an hour. Do not add more water simply to make the mortar workable, because the lower the water content, the higher is the strength. The remaining part of the mixture must stay dry, and under cover to avoid wind blowing the cement away, until it is mixed with water just before the mixture is to be applied;
• In the case of concrete preparation, spread the mix uniformly on the cemented ground;
• Measure the required quantity of aggregate or gravel based on the cement: sand: aggregate ratio using the measuring gauge box and spread it uniformly on the top of cement sand mix; and
• Since manual mixing of concrete is a heavy duty task, start mixing some portion of the three materials uniformly by adding water. The same to mortar work add water only to that part of the mixture which will be used within half an hour. Do not add more water simply to make the concrete workable. The remaining part of the mixture must stay dry, and under cover to avoid wind blowing the cement away, until it is mixed with water just before the mixture is to be applied.
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