DESIGN, SIZING, CONSTRUCTION AND MAINTENANCE OF GRAVITY-FED SYSTEM IN RURAL AREAS

MODULE 4: CONSTRUCTION OF A GRAVITY FED SYSTEM

UPDATED 2008

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I. INTRODUCTION

The construction of a GFS involves the construction of various infrastructures as well as installation of pipeline. It is an important step that requires the use of construction techniques that should be implemented carefully if you do not want to have problems when the GFS is functioning. It is essential to use good quality construction materials mixed with the good proportions if we want to realize resistant and sustainable civil works.
Today the majority of the infrastructures composing a GFS are built with reinforced concrete because of its robustness and stability. Indeed, the reinforced concrete offers good resistance to the high temperatures, vibrations and heavy loads. The infrastructures of a GFS generally built using reinforced concrete are the spring catchment, header tank, break pressure tank, storage tank and tapstand.

The objective of this module is to provide the necessary minimum knowledge on the main construction materials to be used, as well as the technical implementation of various works composing a GFS.

II. CHOICE AND USE OF MATERIALS

II.1. MATERIALS

Materials used for the construction of the various infrastructures composing a GFS are as follows:

Cement - Sand - Gravel - Stone - Brick - Iron bars - Water.

II.1.1. Cement

Cement is a hydraulic binder used to combine elements such as sand and gravel. Good quality cement consists of fine powder and was stored in a dry place (if it is stored in a humid place, it will lose its binder properties).

The cement usually used by ACF in Indonesia (and especially in NTT province) is

- Tonasa (companies belonging to government) for work requiring a very good quality of cement
- Bosowa (from Sulawesi) for work requiring a lower quality cement

In NTT, ACF do not advice to use the cement brand "Kupang", which has a poor quality.

Cement can be used to make:

1. Mortar = cement + sand + water.
   Used for masonry, plastering, and various type of sealing.
2. Masonry = mortar + large elements (bricks or stones).
   Used mainly for retaining walls construction. Masonry can also be used for the construction of tapstand, valve box and spring catchments, when the gravel is not available on the spot and/or the distances to be covered by foot to bring gravel would be too important.
3. Concrete = cement + sand + gravel + water
   Used for the manufacture of a great number of works like spring catchments, tanks, tapstand and header tank.
4. Cement milk= cement + water
   Used only for plastering and ensuring the water tightness of concrete (to be used after several layers of mortar for finishing touch). It does not have any internal resistance to load.

II.1.2. Gravel

Gravel is a natural material collected from quarries, made out of crushed stones, or extracted from riverbeds. For the construction, river gravel (round and polished shape) is preferred to crushed gravel.

Gravel is used only in the making of concrete. The size of gravel to be used must vary according to the thickness of the construction and the desired type of reinforced concrete. To obtain a watertight concrete, ACF recommends a size of gravel from 6 to 25mm. Generally, for concrete construction, size of gravel must be lower than 1/5 of the thickness of the construction. River gravel must be sieved to obtain desired granulometry.

II.1.3. Sand

Sand is extracted from riverbeds or beaches (but then sands need to be cleaned carefully with fresh water to remove the salt, to avoid the iron bar to become quickly corroded inside the concrete) and sand grain have generally a diameter lower than 5mm. Sand is used to make mortar as well as concrete. To obtain a good quality construction, sand must be clean (all impurities such as soil, clay, leaves, etc. must be removed) and solid.
The size of the grains is also important: if the sand grains are too fine, it will weaken the concrete. To obtain a watertight concrete, ACF recommends using sand grain size from 0.1 to 5mm.

II.1.4. Stones

Stones are used for constructions for masonry, foundations and the making of gabions. Stones must be imperatively clean and solid. It is necessary to avoid the weathered stones that can crumble or break easily.

II.1.5. Brick

Bricks are used only for masonry. Bricks are made out of clay, or similar substances containing silica. Bricks that can be found in Indonesia are of baked clay, solid, and of have usually a size of 20cm x 10cm x 5cm. In NTT province, they usually are 15cm x 10cm x 5cm.

II.1.6. Reinforcement bars

Reinforcement bars are used for the making of reinforced concrete. Two types of bars can usually be found on the market:

- High-adhesion reinforcement bars, known as HA bars, which have serrations to ensure better adhesion to the concrete. However, in Indonesia, due to their high price, ACF usually does not use them for simple GFS work. However, for sensitive work such as dam or large size reservoirs, it is compulsory to use them. Bar are initially 10m long and diameter of 10, 12, 14, 16, 20, 25mm can be purchased.
- Smooth reinforcement bars. They present a lower adhesion to concrete then the HA bars, so they require greater anchorage lengths. Bars are initially 10m long and diameter of 6, 8, 10, 12mm can be purchased.

For the same diameter, if there is no budget constraint, high-adhesion reinforcement bars will be preferred to smooth bars because of their serrations, which guarantee a better adherence with the concrete.

To ensure a good adherence, it is important that bars have a clean surface, free from organic substances, oil, rust, etc.

Steels offer a good resistance to tension stress. The resistance of the reinforcement bars depends on their manufacture process, but has generally the values indicated in table 1:

Table 1: Resistance of reinforcement bars

Type of steel	Quality (international standard)	Max tensile resistance (tension for which steel yields)
Smooth bar	RS 24	2,400 kg/cm^2
High-Adherence bar	SD 30 SD 40	3,000 kg/cm^2 4,000 kg/cm^2

In Indonesia, two main types of smooth bars are available:

- "Standard". You can find precise diameter (6mm, 8mm etc…). Length is 12 m. They are one recommended by ACF
- "Banci". The diameters available are not precise, and the length of bars are not standard.

II.1.7. Water

Water is used in the making of mortars and concretes. The use of water has several functions: it allows hydrating cement, wetting the aggregates and ensuring a sufficient plasticity to the mixture obtained. Cement hydration is the name given to the chemical reaction that causes a phenomenon of solidification and hardening when water is added. To ensure a good cement hydration, water must be imperatively clean and contains no impurity.

II.2. CONCRETE

II.2.1. Introduction

Concrete is a mix of cement, gravel, sand and water. Thanks to water and cement, this mixture hardens during its curing period and becomes very resistant to compression stress (see table 2).

The resistance of a concrete depends mainly on the quality of materials used and their proportion. A mix with more cement gives a higher resistance to compression stress (see table 3), but the risk of formation of cracks during the curing period of the concrete increases.

Table 2: Increase of concrete resistance during hardening period.

Duration (day)	% of total resistance
3	20
17	45
28	60
3 months	85
6 months	95
1 year	100

Table 3: Variation of concrete resistance during 28 days according to the quantity of cement added to the mix.

Cement Proportioning (kg/m^3)	Resistance to Compression (kg/cm^2)	Resistance to tension (kg/cm^2)
300	210	20
350	250	22
400	280	24

II.2.2. Mixing the concrete

The proportions of the concrete mixture and the amount of required materials necessary to obtain 1 m^3 of concrete are given in table 4.

Table 4: Proportions of concrete mix

Type of concrete	Cement (kg)	Sand (L)	Gravel (L)	Anglo-Saxon denomination
Traditional	350	400	800	1 : 2 : 4
Foundation	200 – 250	400	800	1:2.5:5
Special works (for example hand dug well's cutting edge)	400	400	800	1 : 1.5 : 3

The Anglo-Saxon denomination such as “1:2:4” is valid only on volume (1 volume of cement for 2 volume of sand and 4 volume of gravel), but not for mass (kg). Volume can be measured with buckets. But be careful, a bag of 40kg of cement does not correspond to 40L. It should be known that:

- The density of cement is 1,440 kg/m3 and 1m3 = 1000L
- So, using the rule of proportionality on the right side, a bag of cement of 40kg represent X = 40 * 1000 / 1,440 = 28 L
- On the same way, you can calculate that a the volume represented by a 50kg bag of cement is X = 50 * 1,000 / 1,440 = 35 L
- On the same way, 350kg of cement correspond to 250L, or 7 bags of 40kg

1,440 kg	1,000L
40 kg	X L

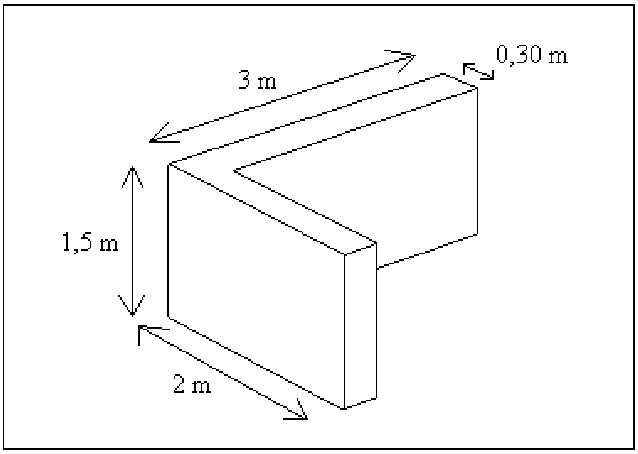
This proportionality rule can be used for many other purposes.

Remark: the correspondence between mass and volume is only true for pure water, which has a density of 1000 kg/m^3 (or 1kg/L), so 1L of water = 1kg

It is necessary to pay attention to the fact that when expended, aggregates of 1m^3 will correspond to 1.2 m^3. To obtain 1m^3 of concrete using a traditional mix (1:2:4), it would be necessary to put 350 kg (= 250L) of cement, 500 liters of sand and 1000 liters of gravel. But when mixed, this would represent more than 1m3. So the initial quantities of sand and gravel must be divided by 1.2 (500L of sand become 400L, and 1000L of gravel becomes 800L).

In the villages the buckets used to measure the quantities of sand and gravel are generally 5 liters.

<u>Example of calculation of a simple concrete structure</u>:



To make this traditional concrete construction: How much cement bag of 40 kg do we need?
How much 5L sand buckets do we need?
How much 5L gravel buckets do we need?

Result:

- Calculate the volume of the structure: V = (2 x 1.5 x 0.3) + ((3-0.3) x 1.5 x 0.3) = 2.12 m3
- Calculate number of cement bags necessary: 2.12 x 350 = 742 kg of cement = 18.6 bags of 40kg cement. We thus need approximately 19 cement bags of 40kg.
- Calculate the quantity of sand necessary: 2.12 x 400 = 848 liters of sand, or 170 buckets of 5L.
- Calculate the quantity of gravel necessary: 2.12 x 800 = 1,696 liters of gravel, or 340 buckets of 5L.

It is important to underline that the quantities calculated are theoretical. The quantities really used on site are often higher because of the losses. We thus add generally 10% to quantities calculated to have the required quantities on site.

II.2.3. Implementation and precautions

You have to work on an arranged surface (cemented ground, metallic plate…) where you first add cement, then sand then gravel, by moving the heaps each time. Once a homogeneous mixture is obtained, give the mix a "volcano" shape in which you pour the suitable quantity of water; it is important to let to the water the time to diffuse before mixing, which will give to the concrete its plasticity. A good concrete must be well mixed.
The concrete consistency depends on the quantity of water used. The more liquid is the concrete, the easiest it is to handle, but the lower will be its resistance once dry. It is thus necessary to define the water content according to the desired use of the concrete, and to obtain the right balance so that the material is at the same time resistant enough and easy to handle. The table 5 gives the estimation of the water quantity required to make 1m^3 of concrete, according to the desired quality of concrete:

Concrete quality	Water volume (liter) for 350 kg of cement	Concrete resistance at 28 days (kg/cm^2)	Ratio liter of water / kg of cement
Very firm	151	330	0.43
Firm	175	280	0.5
Plastic	200	240	0.57
Soft	221	210	0.63
Very soft	231	190	0.66

For example, to obtain a firm concrete, you use a ratio water (L) / cement (kg) of 0.5, which means that for a bag of cement of 40kg, you should add 40 * 0.5 = 20L of water. If you want a soft quality concrete, use a ration of 0.63, so for a 40kg bag of cement you should use 40 * 0.63 = 25.2L of water.

The water quantity to be used for concrete preparation also intervenes in the phenomenon called segregation, i.e. loss of homogeneity of the material, leading to loss of resistance. Indeed, if the necessary precautions are not taken, the concrete components, being of very different granulometry (gravels, sand, and cement), tends to separate: the heaviest ones at the bottom, lightest ones on the top.

Once the mixture is ready, fill the formwork. The filling must be made quickly, and should not exceed 2 meters height. While filling the formwork, the concrete must be vibrated to free the imprisoned air to make the concrete more compact and solid.
The hardening of the concrete is improved by moisture and high temperatures. Under normal conditions, we can make the following estimation:

- 30 minutes until 1 hour for the setting:
- 4 hours until the end of the setting: the concrete cannot be worked anymore,
- The concrete then start the hardening phase, which can last 6 months to 1 year to be completed.

The curing phase is a very important step that must be carried out carefully because it is during this phase that the concrete hardens. We must ensure that the concrete dries slowly, by moisturizing it regularly. Indeed, the concrete curing requires a certain humidity level so that the chemical hardening reaction is as slow as possible. It is important to underline that to moisture again a concrete that is already a slightly dry is not advisable. If the cement already dried, even slightly, without enough moisture, it has become crumbly, and to add water will not allow the cement to recover the hardness that it has already lost, since the chemical reaction of hardening has already taken place.
When the concrete is rather hard, you can remove the formwork. For the construction of infrastructures, formwork can be generally removed after 24 hours. For the infrastructure such as large reservoir for which the construction requires several steps, one step can be made each day. It is necessary to distinguish between the waiting time before removing the formwork (roughly 24h), and the waiting time before using the infrastructure, which is generally of 28 days (before filling a reservoir with water, for example).

To obtain a good quality concrete, the following precautions should be taken:

- To avoid important contraction and segregation of the concrete, never add too much water to the mix
- Always protect the concrete from the sun and wind (cover the concrete with plastic sheeting, cement bags, bamboo mat...) and always moisturize all the surfaces and the formwork to ensure a slow drying,
- Always respect formwork removal times and the waiting time before using the infrastructure,
- Never wait more than 24 hours between two successive concrete pours. The surface between the two parts should be cleaned and rough.
- Vibrate vigorously the concrete to make it compact, but do not vibrate too long to avoid segregation.

Good joints between two successive concrete pours are very important for the solidity and impermeability of the work. The conditions for a good joint are: a correct angle of joint, a well-prepared contact surface as well as a very short delay between two successive pours. (see table 6). The correct angle of joint varied depending on the type of stress undergone by the structure (see figure 1). For a load bearing wall or partition wall under vertical stress, joints are perpendicular, whereas for a floor or water tank wall (thus with horizontal effort), angle sides are preferable. To guarantee a good adhesion, it is necessary to roughen the surface (with a chisel for example) to provide a key. Then we brush the rough surface to remove rubble and dust, and we moisture it before pouring the next concrete.

Table 6: Resistance of the joint between 2 parts of the infrastructure that were concreted at a different time

Delay between successive pours	Joint resistance
1 day	325 kg/cm^2
7 days	210 kg/cm^2
18 days	65 kg/cm^2

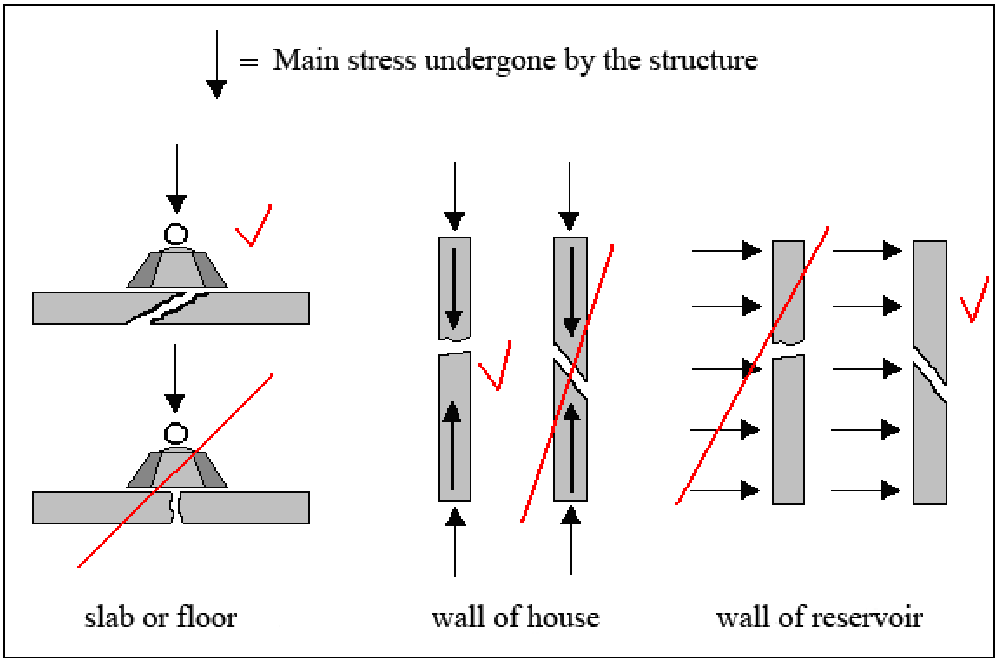


Fig.1: Joint angle depends on the direction of the main stress undergone by the structure.

To improve the quality of the concreting process, it is possible to add chemical additives. There are a great number of additives for the concrete: water proofing agent, setting accelerator, liquefier and plastifier…
For the construction of spring catchments and tanks, two problems often occurs:

- The foundation of the catchment needs to be done under the water. By using a traditional mix of concrete, there is a risk that the concrete will be washed away before getting dry. It is necessary to add to the mix an additive that will accelerate the setting. If no additive is present, then try to divert the flow of the spring using planks for all the concrete setting duration.
- Traditional mix of concrete is not 100% water tight (and even porous if not enough sand is added to the mix). For the infrastructures that requires a high level of water tightness, it is necessary to add specific cement additive that will increase the usual

water tightness of the concrete. If no additive is available, you can use a higher quality cement, or a mix of concrete containing more cement than usual.

ACF has identified several types of cement additives in Indonesia:

- In NTT, the cement additive easily available in Kupang and used by ACF is called ADDITON H.E. SPECIAL. It is available in 1.25kg plastic can, for around 20,000 Rp. It cumulates three properties, with different dosage according to the use:
    - Fast hardening (in 7 days the conceret has the same resistance as in 28 days)
    - Improved quality of concrete(80cm^3/cement bag of 50kg)
    - Making water proof concrete (200cm^3/cement bag of 50kg

- "Damdex": widely available and used by civil work contractors in Jakarta and Java. This additive is expensive (40,000 Rp / 1L bottle) but combines three properties: accelerated hardening, increased water tightness and increased binding effect and concrete resistance. The proportions are different according to the use:
    - To block a leaking hole, use 1 volume of Damdex for 3.5 volume of cement, and do not add any water.
    - For waterproof wall/slab coating, use 1 volume of Damdex for 2 volume of cement and 1 volume of water, and apply two layers of the mixture.
    - For solid, fast drying and better waterproof concrete, use 0.5% to 2% of Damdex per weight of cement, according to the required strength, and add it to the mix.

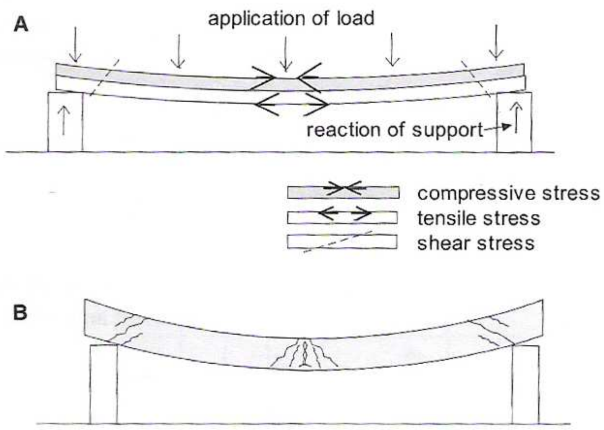
- A lot of products of the civil work company SIKA are available in Jakarta and Surabaya. They offer a wide range of product, like for example:
    - "SikaCim Accelerator", for accelerated hardening (can be used for exemple to block a leak while water is running out of it)
    - "Sika Multiseal", for increased water tightness

II.3. REINFORCED CONCRETE

The reinforced concrete consists of concrete and steel bars: it presents thus a combination between the physical properties of these two materials: resistance to compression effort of the concrete and resistance of tension effort of the steel. Reinforced concrete infrastructures are very resistant, and also economical because it requires small thickness of concrete (thus less cement, sand gravel etc…).

II.3.1. Reinforcement

To reinforce the concrete, you must add inside steel bars to create a reinforcement: steels bars are positioned to undergo the tension stress and to distribute the stress evenly inside the structure. Iron wire is used to bind steels bars between them.



We differentiate steels bars according to their role:

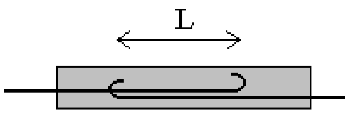
- Main steels: they are located in the zones of tensile stress (areas of tensil stress are usually located on the opposite side of the side where the stress is applied, as shown in the figure on the right)
- Distribution steels: they distribute evenly the efforts, limit the risk of cracks and facilitate the assembly of the main steels,

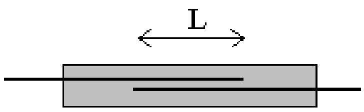
The transmission of the stresses from concrete to steel bars and vice versa is done thanks to the adherence of the steel bars. To guarantee the good adherence between concrete and steel bars, it is necessary to:

- Have a clean surface
- Ensure a good vibration of the concrete when pouring it
- Respect a sufficient length of anchorage of steels inside the concrete
- Ensure that the bars inside the concrete are located at more than 3cm from the surface.

The anchoring lengths to be respected are as follows:

- Steel bars must overlap in the concrete over a minimum length L, called anchoring lenght:



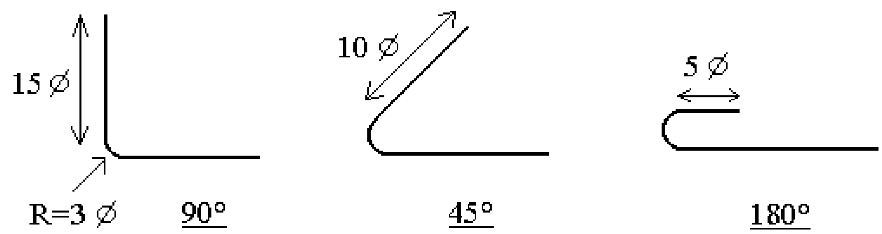


Curved   Non-curved

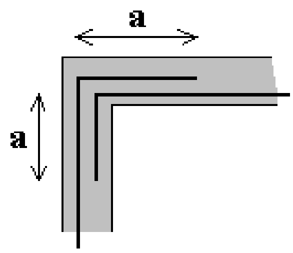
L depends on ø = diameter of the bar:

	High adherence steel bar	Smooth steel bar
Curved	L = 30 x ø	L = 40 x ø
Non-curved	L = 50 x ø	L = 60 x ø

- *The angle of the anchoring curves must be done in the following way:*



- *The anchoring lengths at the edges that undergo bending moment or tensile stresses must be as follows:*

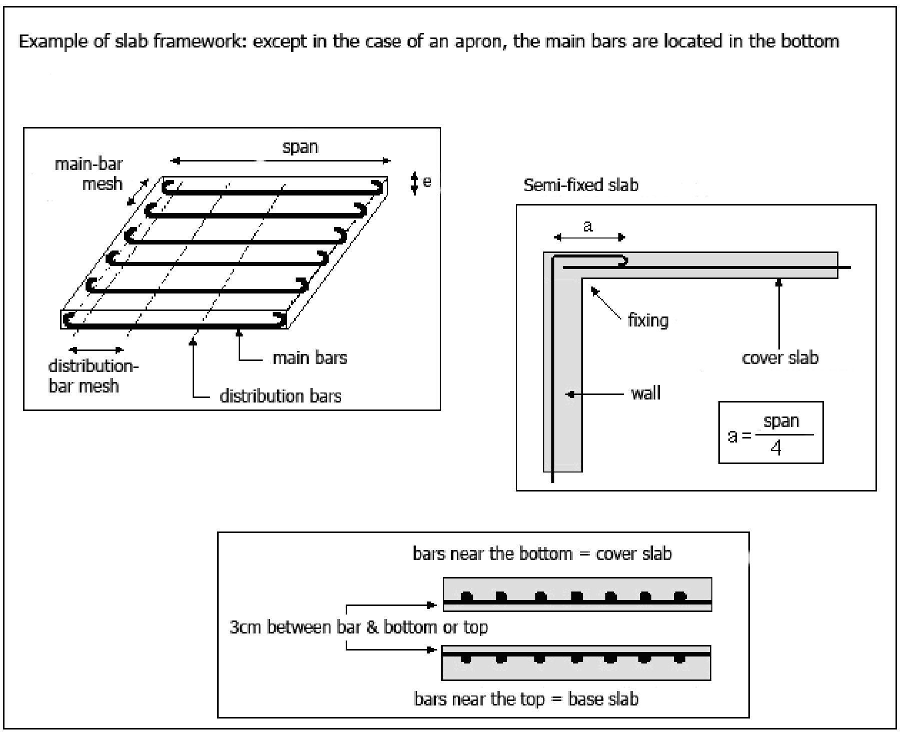


a = wall length / 4
= minimum 15 - 20 cm
= minimum 40 cm for tanks

II.3.2. Framework scheme

The objective of this paragraph is to give general information regarding the design of the framework (= reinforcement bars scheme) of various types of reinforced concrete infrastructures.
A more detailed framework scheme will be given in the following chapter (chapter III) for each reinforced concrete infrastructures usually needed for a GFS.

→ **Slab**



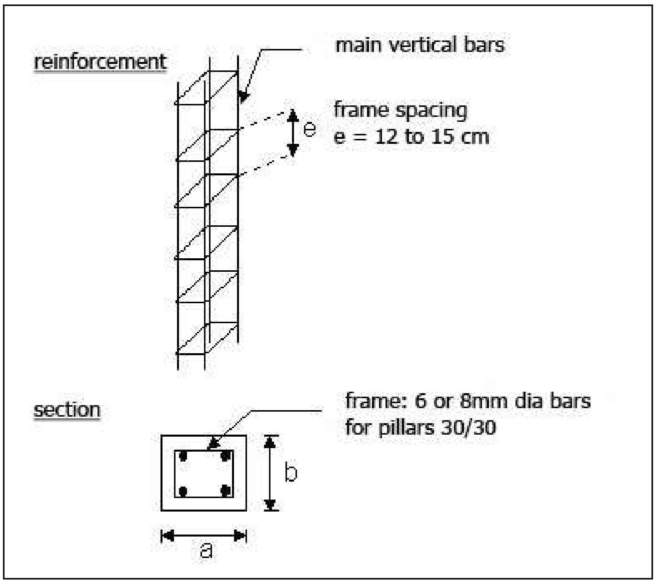
The slab thickness (e) must be at least 7cm. In general, we can give the following values for the thickness:

- Slab on 2 walls: e = from 1/20 to 1/30 of the span,
- Slab on 4 supports: e = 1/20 of the span,
- Slab on 4 walls: e = from 1/30 to 1/40 of the span.

Main steels are located as follows:

- Above the slab for an apron (= floor slab), except in the tanks case because of the vertical pressure created by water,
- At the bottom of the slab for a cover slab or an elevated slab

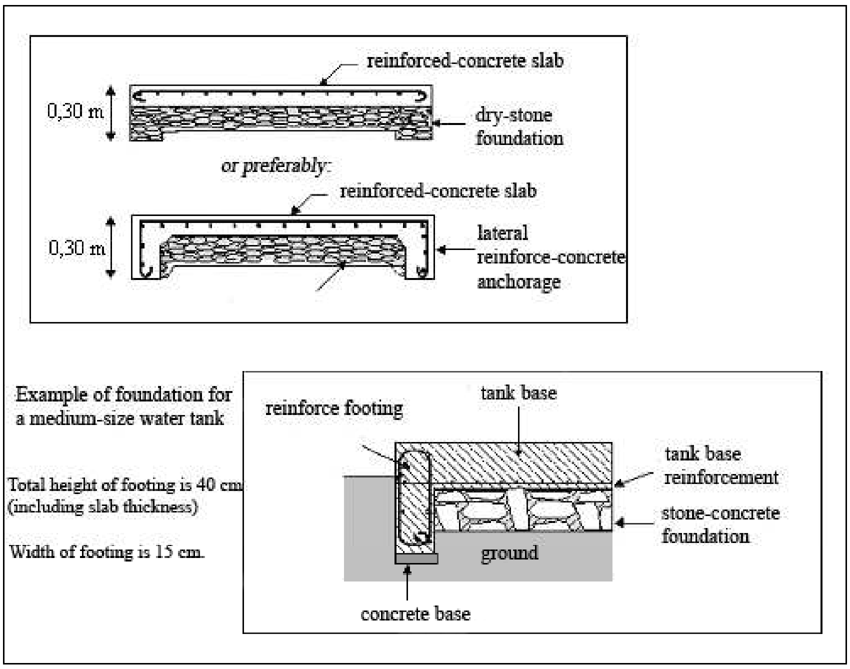
→ **Pillars**



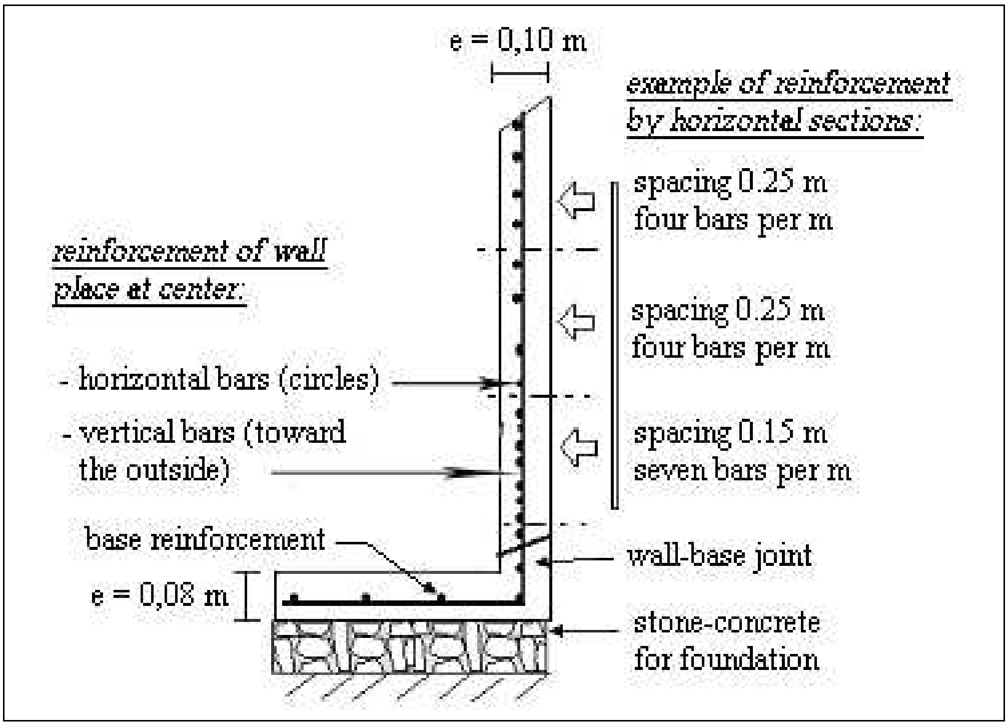
As rough sizing we will take as a minimum:

a = 1/20 of the beam height

→ **Foundations**



→ **Circular tank**

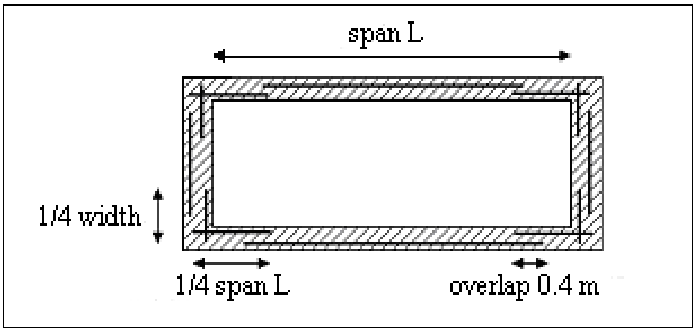


Horizontal reinforcement (circles) is essential to resist to the pressure exerted by water on the walls of this type of tanks. In the case of water storage tanks, the more you go to the top of the tank's wall, the lower is the pressure of water against the wall, so the bigger should be the space between reinforcements (however, you should not increase the space between the circles more than three times the wall thickness).

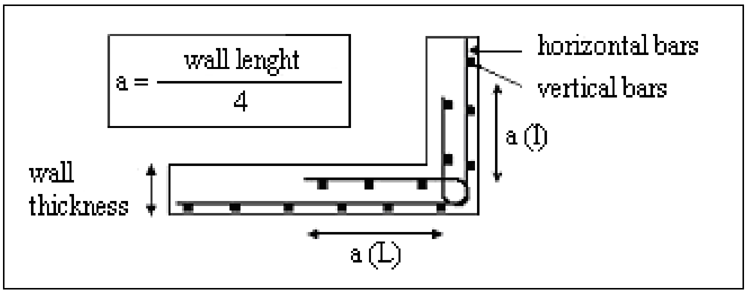
For the reinforcement of circular tanks of important capacity, you can use the same configuration as for rectangular tanks of important capacity (see below).

→ **Rectangular Tank**

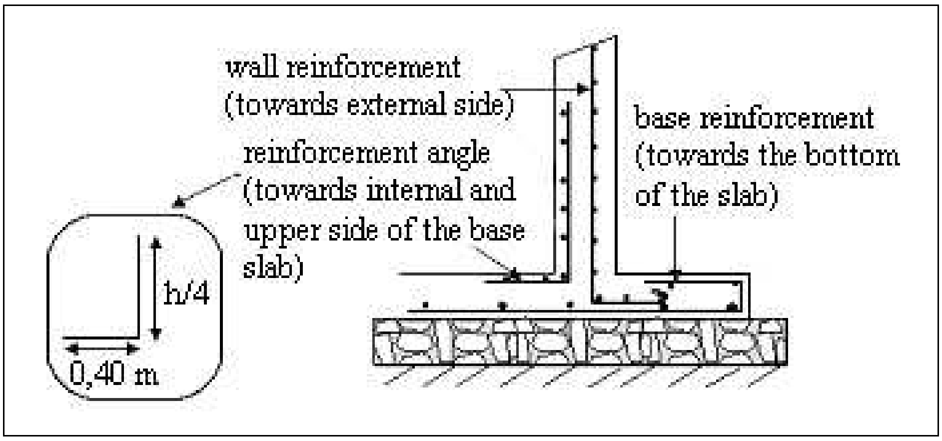
Horizontal cross-section of walls reinforcement:



For the small tanks (wall length lower than 2m) we use the following configuration, with minimum a = 40cm:



For the rectangular tank of important capacity, we use the following framework configuration:



II.3.3. Reinforcements sizing

Generally, we can estimate the necessary quantity of steel bars the following way:

- 75 - 90 kg of steel bars each m^3 of concrete,
- 15 kg of wire per ton of steel bar

For the traditional GFS infrastructures such as spring catchments, header tank, tapstand and break pressure tank, the sizing of the steel reinforcement (diameter and mesh) is always more or less the same because the dimensions of these infrastructures never change a lot. The standard reinforcements sizing for this type of infrastructures will be given in the following chapter (chapter III).
On the other hand, for the storage tanks, reinforcement sizing depends on the capacity of the tank and can vary greatly according to the flow of the spring and the number of people to be covered. It is thus essential to know how to size precisely the framework for this type of infrastructure. Tables that allow sizing circular and rectangular storage tank are given in the following paragraphs,

→ **Circular tank**

- *Horizontal reinforcement by sections of 1 meter starting from the top*

Wall thickness (cm) Diameter (m)	10 cm 1.5 - 2 m	10 cm 2 – 2.5 m	10 cm 2.5 - 3 m	10 cm 4.5 - 5 m	10 cm 6 m
Height* (m)	Diameter of irons used (mm) and mesh (cm)				
0 – 1 m	Ø8 / 25	Ø8 / 25	Ø8 / 25	Ø8 / 25	Ø8 / 25
1 – 2 m	Ø8 / 25	Ø8 / 25	Ø8 / 25	Ø8 / 15	Ø10 / 17.5
2 – 3 m		Ø8 / 15	Ø8 / 15	Ø10 / 12.5	Ø12 / 15
3 – 4 m			Ø8 / 15	Ø12 / 12.5	Ø12 / 10

* by choosing a given height we can calculate easily the tank capacity:

$$\text{capacity} = \text{height} \times 3.14 \times r^2 = \text{height} \times 3.14 \times \text{diameter}^2 / 4$$

Standard examples of tank capacity are given to the following table:

Capacity (m^3)	2	5	10	45	90
Height (m)	1	1.45	1.7	2.65	3.25
Diameter (m)	1.75	2.25	2.75	4.75	6

- *Vertical Reinforcement (distribution reinforcement)*

- Bottom of the tank to the middle height Ø8 / 10 cm
- From middle height to the above of tank Ø8 / 20 cm

In practice, you just have to stop one steel bar out of two starting from half way up.

- *Apron reinforcement*

Ø6 / 15 cm – square mesh or Ø8 / 30 cm – square mesh

- *Cover slab reinforcement*

Internal diameter of tank (m)	Diameter of reinforced concrete (mm)	Mesh (cm)	Slab thickness (cm)
2 m	Ø 6	25 cm	8 cm
3 m	Ø 6	17 cm	8 cm
4 m	Ø 8	17 cm	10 cm
5 m	Ø 8	10 cm	10 cm
6 m	Ø 10	11 cm	10 cm

→ **Rectangular tank**

Capacity and dimensions of tank						
Capacity (m^3)	3	5	10	20	45	70
Height (m)	1.5	2	2	2.5	3	3
Width/length (m)	1.5 / 1.5	2 / 2	2 / 3	2 / 4	4 / 4	4 / 6
Wall thickness (cm)	10	10	11	11	14	14
Wall vertical reinforcement						
Diameter / mesh (cm)	Ø12 / 15	Ø12 / 10	Ø12 / 10	Ø16 / 12	Ø16 / 9	Ø16 / 9
Horizontal reinforcement						
Diameter / mesh (cm)	Ø8 / 17	Ø8 / 13	Ø8 / 13	Ø12 / 19	Ø12 / 15	Ø12 / 15
Apron reinforcement						
Diameter / mesh (cm) with the choice: Ø6 or Ø8	Ø6 / 15 Ø8 / 30	Ø6 / 15 Ø8 / 30	Ø6 / 15 Ø8 / 30	Ø6 / 15 Ø8 / 30	Ø6 / 15 Ø8 / 30	Ø6 / 15 Ø8 / 30
Cover slab: thickness and reinforcement						
Thickness (cm)	8	10	10	10	10	10
Diameter / mesh (cm)	Ø8 / 15	Ø8 / 15	Ø8 / 15	Ø8 / 15	Ø10 / 15	Ø10 / 15

II.4. MASONRY

II.4.1. Estimated quantities of material needed, and concrete mix

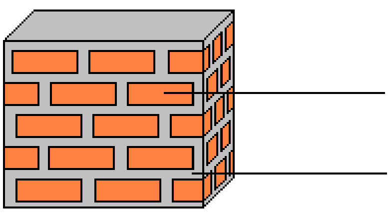
To make masonry, we use mortar (cement, sand and water). The mortar is also used for the coatings. According to the use of the mortar, you have to use a different ratio of sand/ cement. The proportionings generally used for $1m^3$ of mortar are given in table 7.

Table 7: Mortar mix for 1m3

Type of mortar	Cement (kg)	Sand (liter)	Anglo-Saxon denomination
Strong mortar (rough coating, masonry mortar)	400	1,200	1 : 4
Very strong mortar (smooth coatings, sealing)	500	1,200	1 : 3

Bricks or stones quantities for masonry are as follows:

For the brick masonry:

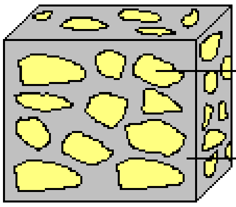


0.75 m^3 of bricks = approximately 1,200 bricks of dimension 18 x 8 x 4.5 cm

0.25 m^3 of mortar

1 m^3

For the stone masonry:



Example of calculation for a simple structure:

Let us take the same structure as the one illustrated on the exercise of paragraph II.2.2.

1. To realize this construction in brick masonry (with strong mortar):
   - How many bricks do we need (brick dimension is 18 cm x 8 cm x 4.5 cm?
   - How many cement bags of 40kg do we need?
   - How many 5L buckets of sand do we need?

2. To realize this construction in stone masonry (with strong mortar):
   - How much m3 of stones do we need?
   - How much cement bags of 40kg do we need?
   - How much 5L buckets of sand do we need?

Result:

1. - Calculate volume of work: V = (2 x 1.5 x 0.3) + ((3-0.3) x 1.5 x 0.3) = 2.12 m^3
   - Calculate the number of bricks necessary: 1,200 x 2.12 = 2,544 bricks. We thus need approximately 2,800 bricks by taking account of the 10% losses (broken bricks).
   - Calculate the volume of mortar necessary: V = 2.12 x 0.25 = 0, 53 m^3
   - Calculate the number of cement bags necessary: 0.53 x 400 = 212 kg of cement = 5.3 cement bags of 40kg. We thus need 6 cement bags.
   - Calculate the quantity of sand necessary: 0.53 x 1,200 = 636 liters of sand = 128 buckets of 5L.
2. - Calculate the volume of work: V = (2 x 1.5 x 0.3) + ((3-0.3) x 1.5 x 0.3) = 2.12 m^3
   - Calculate the volume of stones necessary: 0.7 x 2.12 = 1.5 m^3.
   - Calculate the volume of mortar necessary: V = 2.12 x 0.35 = 0.74 m^3
   - Calculate the number of cement bags necessary: 0.74 x 400 = 296 kg of cement = 7.4 cement bags of 40kg. We thus need approximately 8 cement bags.
   - Calculate the quantity of sand necessary: 0.74 x 1,200 = 888 liters of sand = 178 buckets of 5L.

II.4.2. Use and precautions

The mixture must be homogeneous and carried out on arranged and cleaned surface. We generally proceed by turning the heap of sand to which the the cement has been added, until total homogenization. It is wise to wet only the quantity of mortar to be used during the next half of hour: mortar can hardly be worked after this period.

The water quantity to be added depends on the cement proportioning and the moisture of sand used. Roughly, 200 liters of water are necessary to obtain $1m^3$ of mortar mixed at 300 kg/m^3. Practically, you should add enough water to obtain a plastic mortar: to check if the quantity of water is enough, smooth some mortar with a trowel: the mortar must be shiny, but water should not run. If you put too much water the mortar will crack. Like the concrete, the mortar must be protected from the sun and the wind to avoid it to dry too fast. Once dry, mortar should not be wet or mixed again.
For stone masonry, it is important to work with clean stone that have been previously wet.

II.5. GABION

The gabion is a wire mesh box filled with large stones.
The advantage of gabion is that it does not require gravel, sands or cement: it is thus easy to built on the spot (if large stone are available) and is especially well adapted to the places that are not easily accessible. The gabion has however the disadvantage of not being water tight and less resistant than concrete infrastructures.
During the construction of a GFS, the gabion is generally used as a retaining wall to protect the infrastructures (tanks, spring catchments and tapstand) or to change the location of riverbeds.

To make a gabion, it is necessary to have stones and iron wire of 2.5 or 3mm. It is necessary then to weave 6 wire mesh mats (or lattice) for each gabion (see figure 2). For the wire mesh mats manufacture, we use a plank of wood and 10cm nails: nails are nailed down the plank of wood according to the configuration represented in figure 3. To obtain 1 meter of lattice, it is necessary to cut 3.4 meter long piece of wire, to fold it in two and to roll it up around a pipe to obtain pieces of iron wire ready to be weaved (see figure 3).

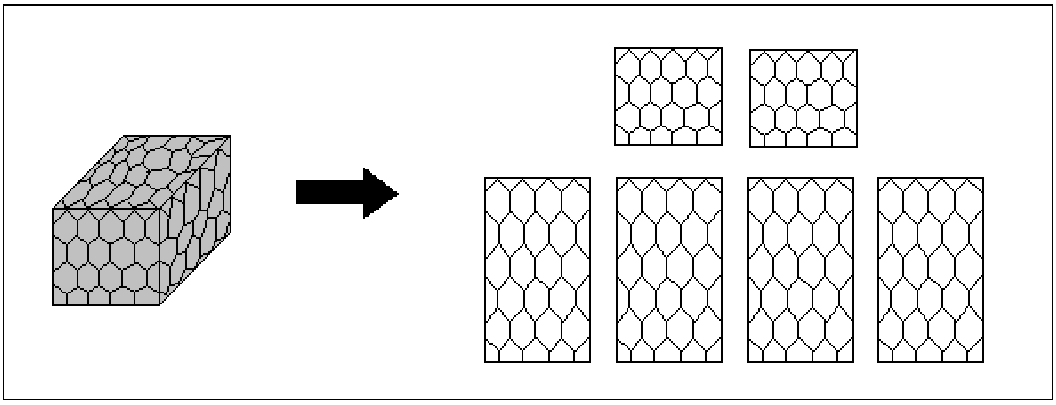


Fig.2: Gabions manufacture

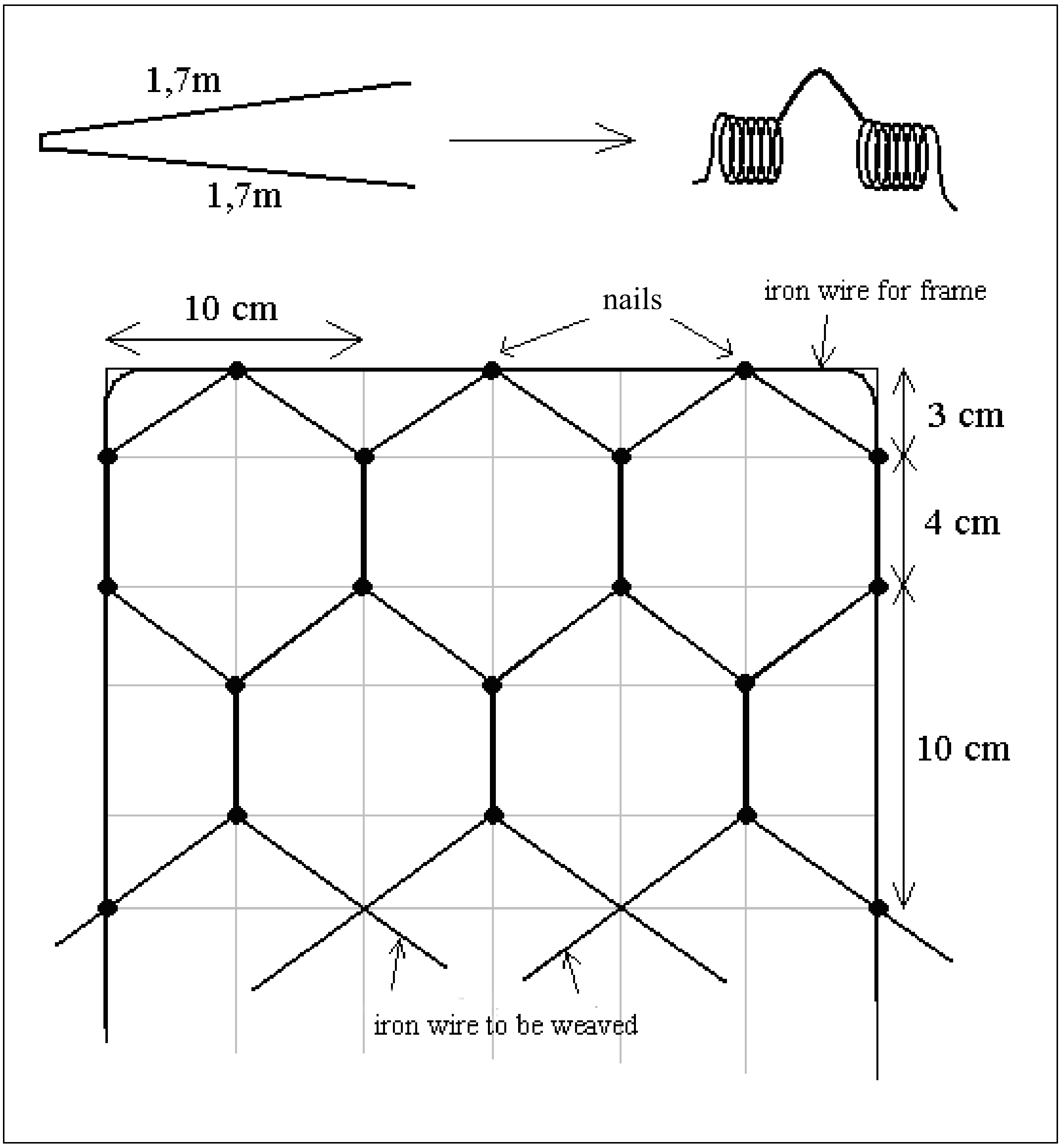


Fig.3: Wire mesh mat weaving

III. CONSTRUCTION OF THE INFRASTRUCTURES COMPOSING A GFS

III.1. SPRING CATCHMENT

The choice of the catchments technique is defined by the field visit, but also by the results of the excavation works. We proceed as follows:

- Cleaning of the water discharge area to visualize clearly the place where the water flow out of the ground
- Excavate towards the source of the water, taking care not to obstruct the flow
- Stop of the excavation well above the discharge area when the impermeable layer is reached:
  - → if the water discharge area is well defined and not very deep (less than 2m), you must construct a catchment box and a retaining wall to protect the work,
  - → if the the water discharge area is diffuse and/or deep, you must build a dam wall with a drain behind it
- Construction of the catchment's wall with correct positioning of water outlets and overflows always below the level of the initial water discharge location (pay attention to the possible variations between the dry and rainy season),
- Install flat stones on the bottom and fill the catchments with large and clean gravel (or small stones) which must be covered with a plastic cover to prevent infiltrations of surface water. Cast concrete on the top of the plastic cover to close the catchment box,
- Install inspection manhole on the drain and catchement box level, large enough for a man to be able to enter and clean this part. This is very important, as catchments usually get clogged with time, and villagers should be able to unblock them.
- Installation of protection perimeter: drainage ditch to keep away surface water and fence to keep away animals

Constructions, especially the drain dam wall or catchments box, can be made in masonry, gabion or reinforced concrete.
For reinforced concrete constructions, irons of 8mm (mesh of 15cm) or 10mm (mesh of 20cm) should be used for the framework. For the formwork, planks of wood, bamboos or trunks of banana trees can be used according the availability.
In case gabion are used to built the dam wall, it is necessary to cover the inside walls with clay to make them a completely waterproof, and to cover completely the catchment box with clay.

Drains are composed by round peebles of 5 to 10cm, installed behind the wall or in a gabion. A PVC pipe with large holes can be installed in the middle of the drain to decrease the headlosses and facilitate the water flow. To prevent mice or other small animals from going inside the catchment box through the overflow pipe, this one must be located at a minimum height of 25cm from the ground and its inlet must be at a minimum length of 20cm from the wall.

Examples of spring catchments are given on figure 4 (catchments in gabion) and 5 (catchments in reinforced concrete).

Reinforced concrete constructions will be preferred because they guarantee an easy maintenance (catchment box easily accessible). Gabion constructions must be avoided when possible because they rarely have inspection doors and are buried in the ground.

Three rules must be imperatively respected to build a spring catchment:

Catchments should never be subject to back-pressure: the water level in catchment box or in the drain must always be lower than the water discharge area level before work. Catchments must allow draining the aquifer layer by authorizing a drawdown of the piezometric level, but not to increase the pressure, which could make the spring disappear. A stake can be used (planted quite far in order not to disturb the excavation works) to keep the reference of the initial level of the water discharge. This level is used as reference mark during work construction: the outlet and the overflow pipes have must be always located below this level. Still to avoid an accidental back-pressure, the installation of an overflow pipe is obligatory; if you do not have any information on the spring maximal flow, the overflow must be oversize (two pipes of 2" for example).

The dam must be constructed on an impermeable ground: the excavation should not be stopped before reaching the substratum (rocky watertight layer). It sometimes represents large works, but it is essential to prevent water from flowing under the catchments few weeks after the end of the construction work. The substratum is sometimes difficult to identify in the field: thus, you must consider it as a layer of soil less permeable on which water circulates without infiltrate.

Catchment must be protected: protection works should always be included in the catchments work, on the level of the drain cover (plastic cover) or the catchment box.

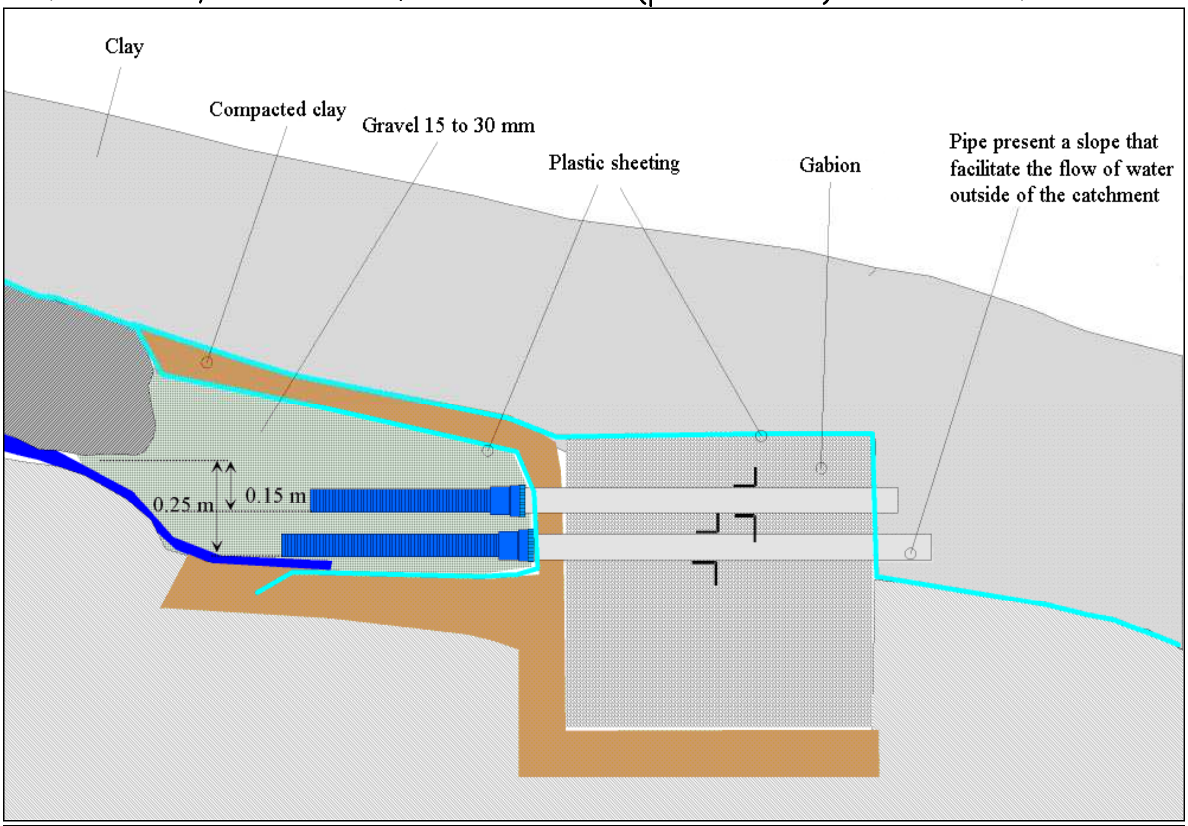


Fig.4: "Gabion type" spring catchments

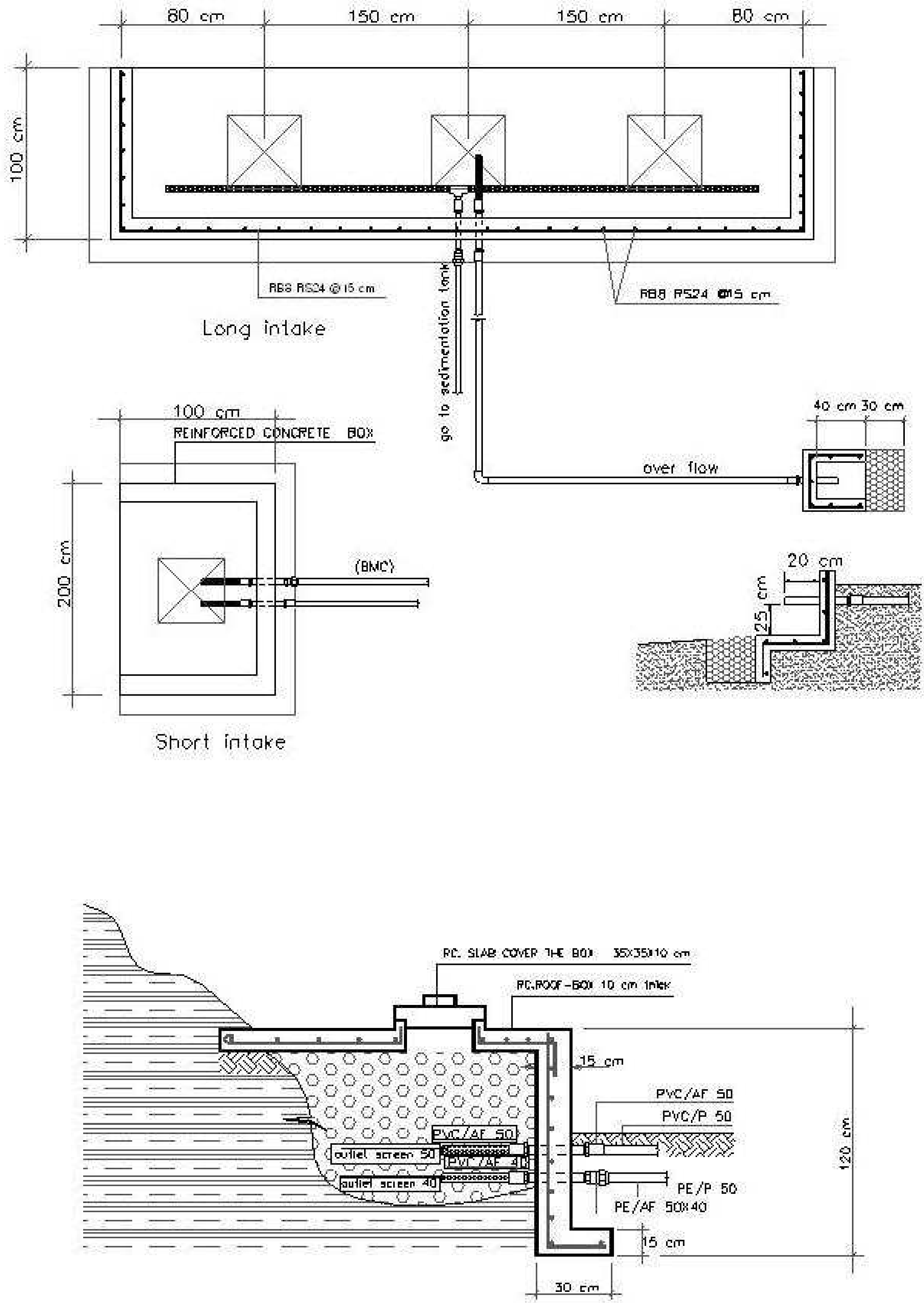


Figure 5 A Spring Catchment

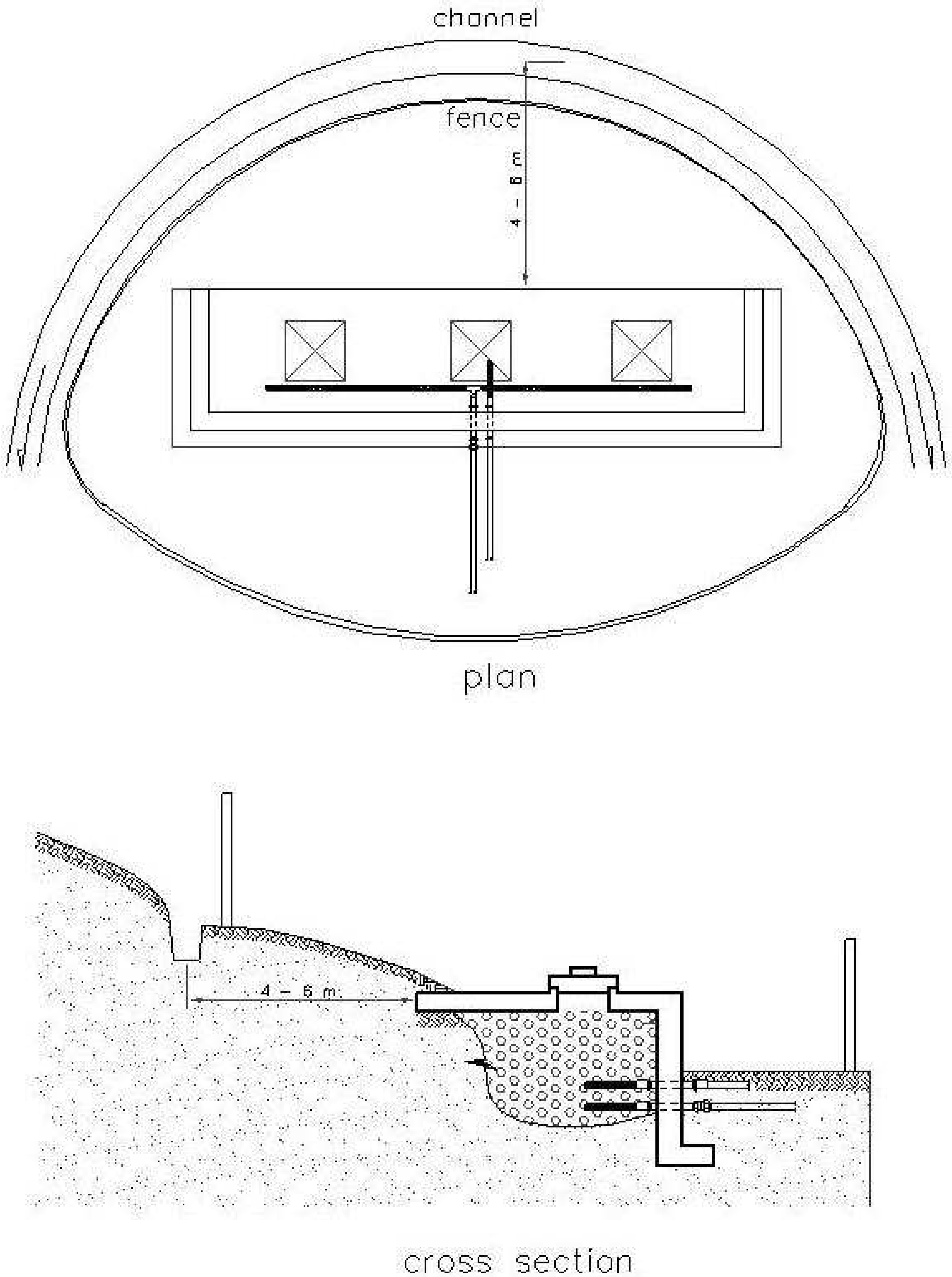


Figure 5 B Spring Catchment

III.2. STORAGE TANK

The tank is made in reinforced concrete or plastic (use of plastic tank pre-manufactured). Reinforced concrete construction will be preferred but when the site is too far and that the distances to be covered by walking are too important, the use of pre-manufactured plastic tank is essential. The shape of tank can be rectangular or cylindrical. The cylindrical forms will be preferred for the large capacity tanks.

For a storage tank it is necessary to install:

- Water inlet equipped with adjustable stop cock valve (regulating),
- Water outlet equipped with ball valve (open/close) and air-bleeding pipe,
- Washout valve equipped with ball valve (open/close)
- Overflow pipes,
- Inspection manhole and ventilation pipe

For reinforced concrete construction, you must proceed as follows:

- Foundations construction: excavate 15cm of soil and fill it with dry stones. For the large capacity reservoir (> 5m3), the installation of reinforced concrete foundation walls will be necessary,
- Pouring of concrete on a thickness of 5cm (isolating layer),
- Construction of apron and tank walls. Wooden planks must be used for the formwork. For the circular tanks we will use a pre-manufactured wooden formwork like illustrated in figure 6; an example of reinforcement for cylindrical tank is given in figure 7,
- Construction of cover slab with inspection manhole,
- Construction of valve box next to the reservoir, to protect the valve. The box must be large enough to operate the valve, or change them if they are broken.
- Protection area around the tank (fence)

An example of reinforced concrete tank is given in figure 8.

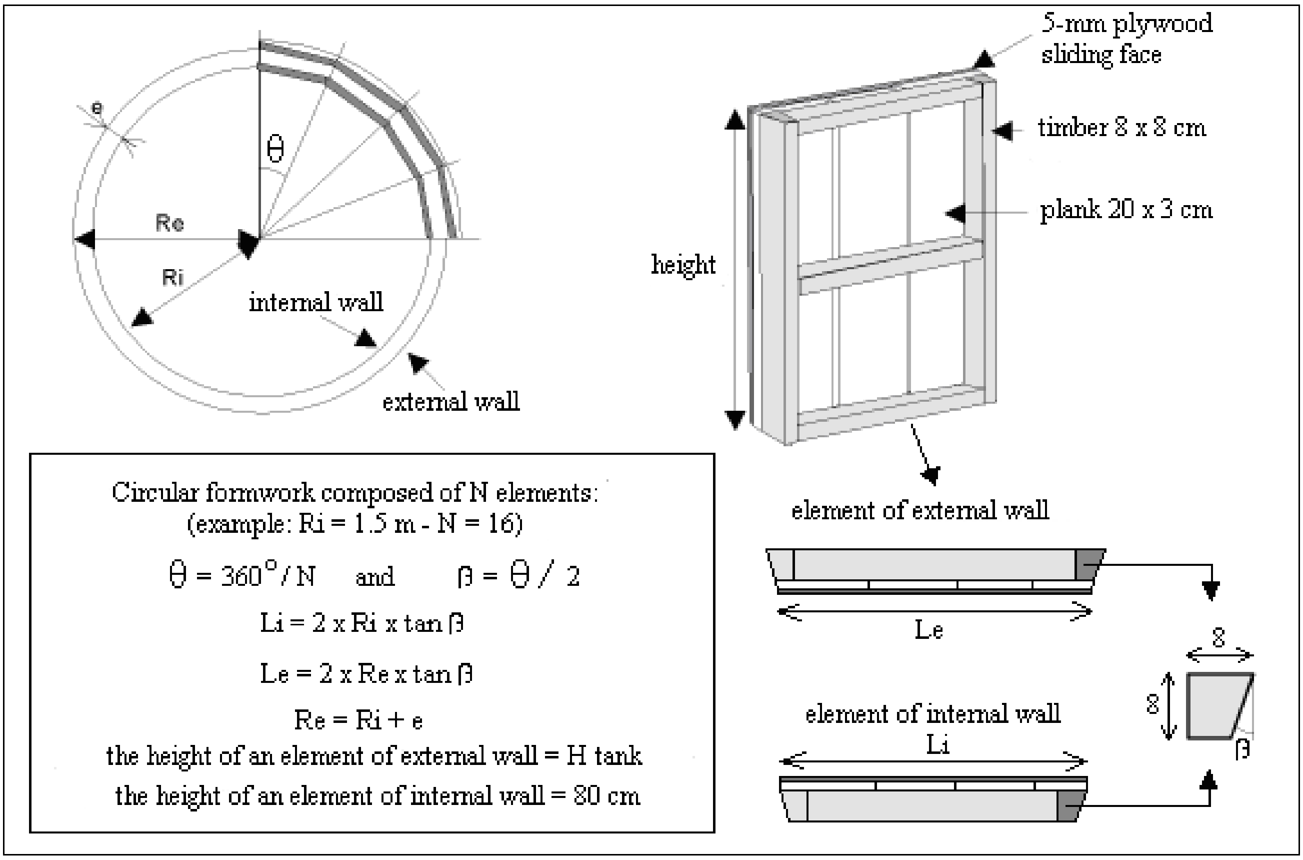


Fig 6: Formwork for cylindrical tank

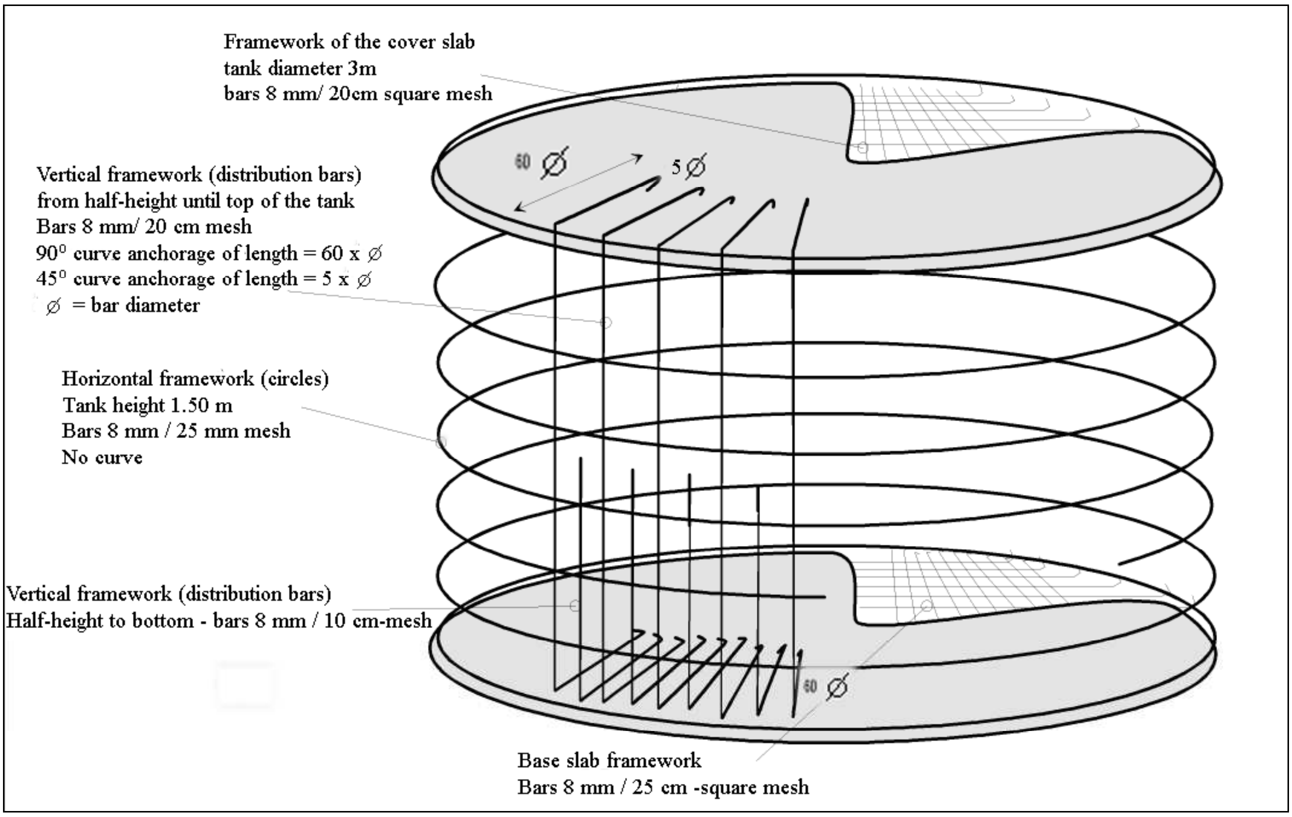
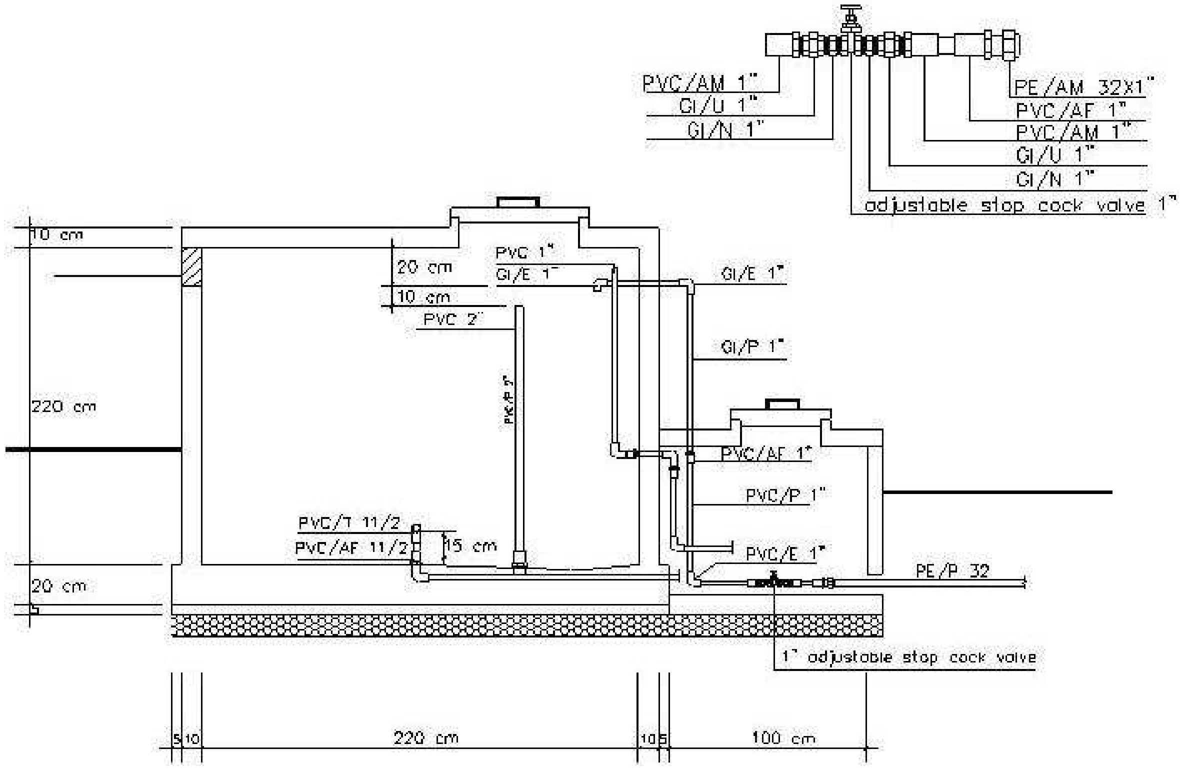


Fig7: reinforcement of a cylindrical tank of 3m of diameter



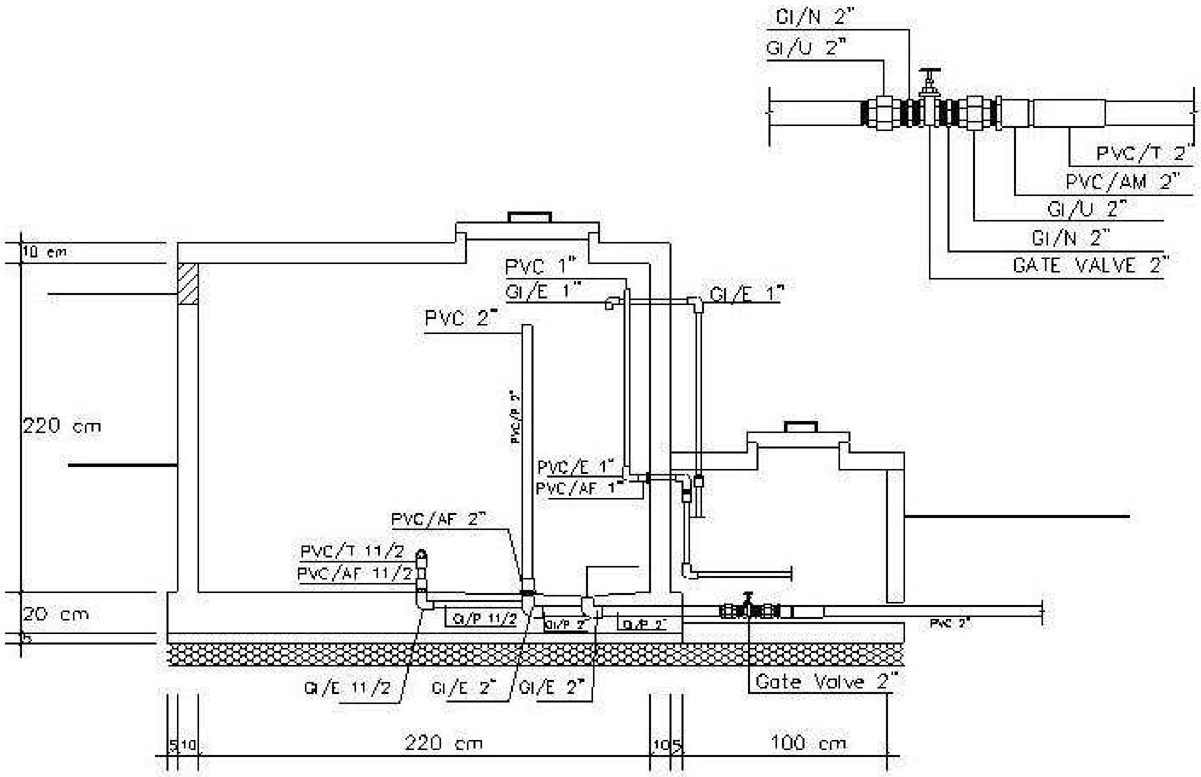


Figure 8 A Reservoir (RC)

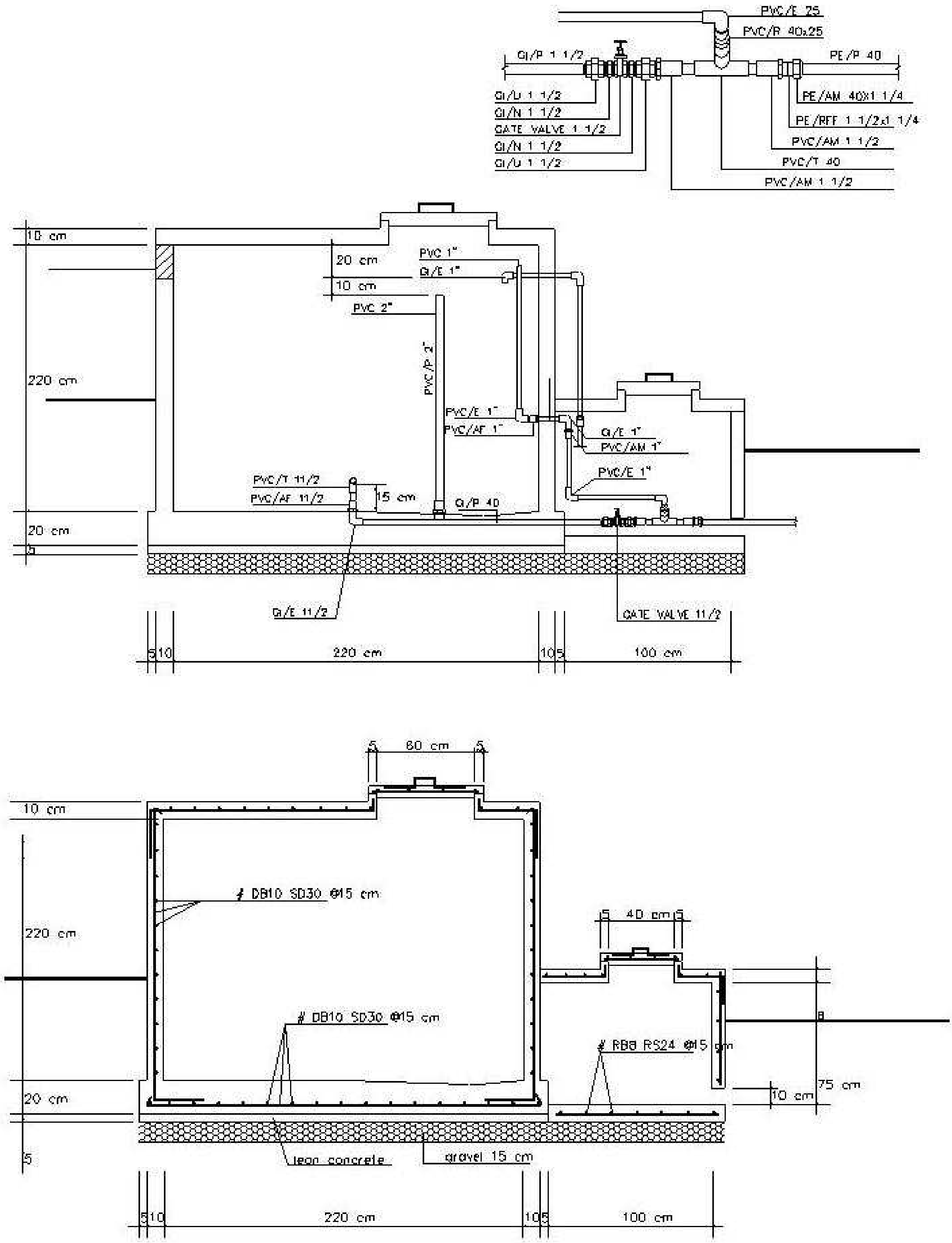


Figure 8 B Reservoir (RC)

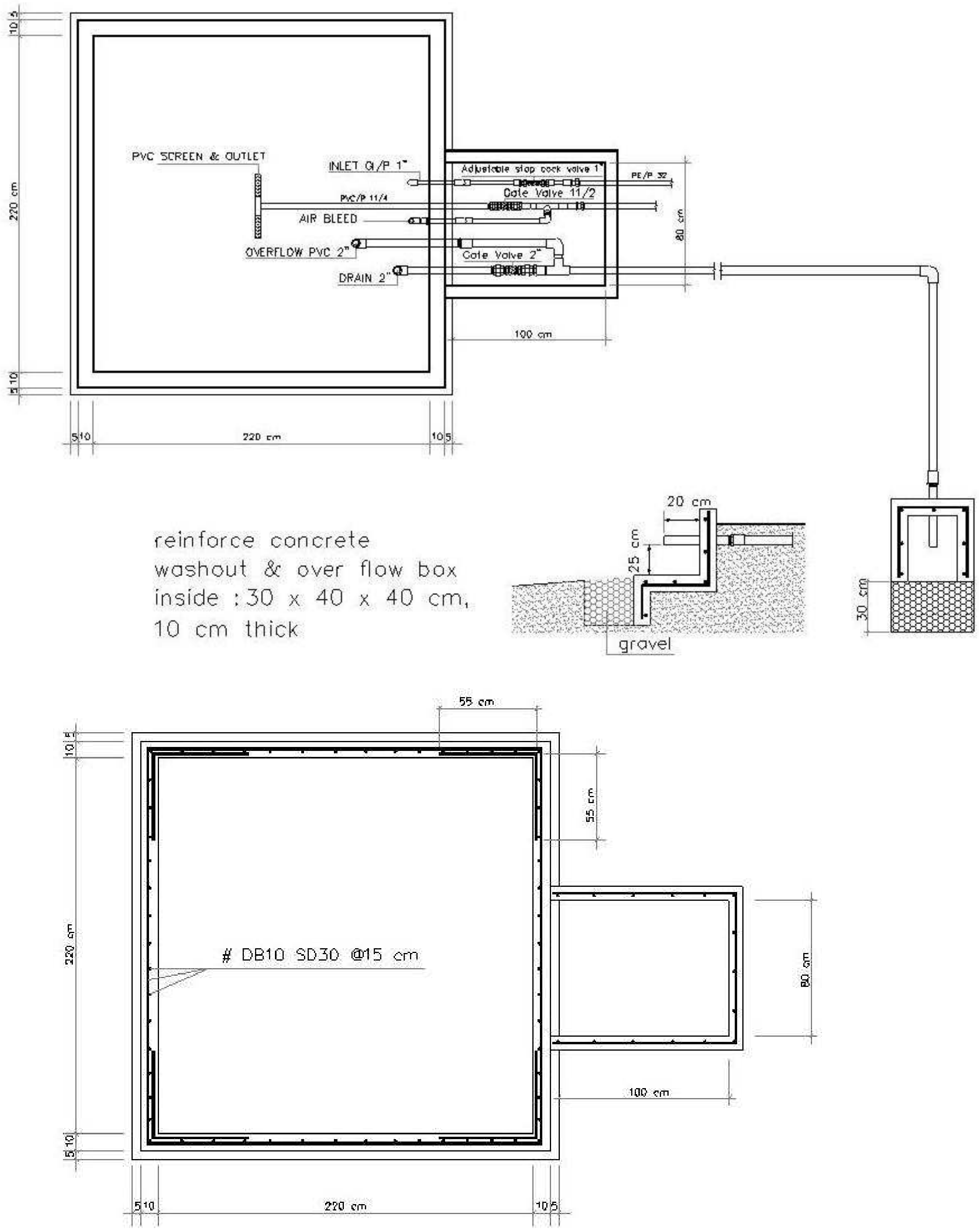


Figure 8 C Reservoir (RC)

For the pre-manufactured plastic tanks it is necessary to pay attention to protect the tank from sun and to avoid walls distortions... Tanks must be buried and installed on foundation of compacted clay. The structure must be solidified by installing PVC pipe reinforcement inside the tank and the lid must be closed with a joint (roll of rubber or tire tube). The backfilling must be done with clay and water to limit the walls distortions. Cover the tank with plastic sheeting and clay. If necessary, protect tanks with gabions.
The water outlet valve can be located near the tank as illustrated in figure 9. In this case, the valve box consists of a 4" PVC pipe, with the use of a long "key" to open and close the valve. Such system has the disadvantage to be very fragile because of the difficulty to steer the valve wheel. To avoid this problem, the valve can be placed far from tank to have only 1meter of height difference between valve and ground surface. A usual valve box (of reinforced concrete or masonry) can then be built.
To avoid distortion problems and transporting, ACF recommends not using a tank capacity of more than 2,500 liters.
An example of pre-manufactured plastic tank is given in figure 9.

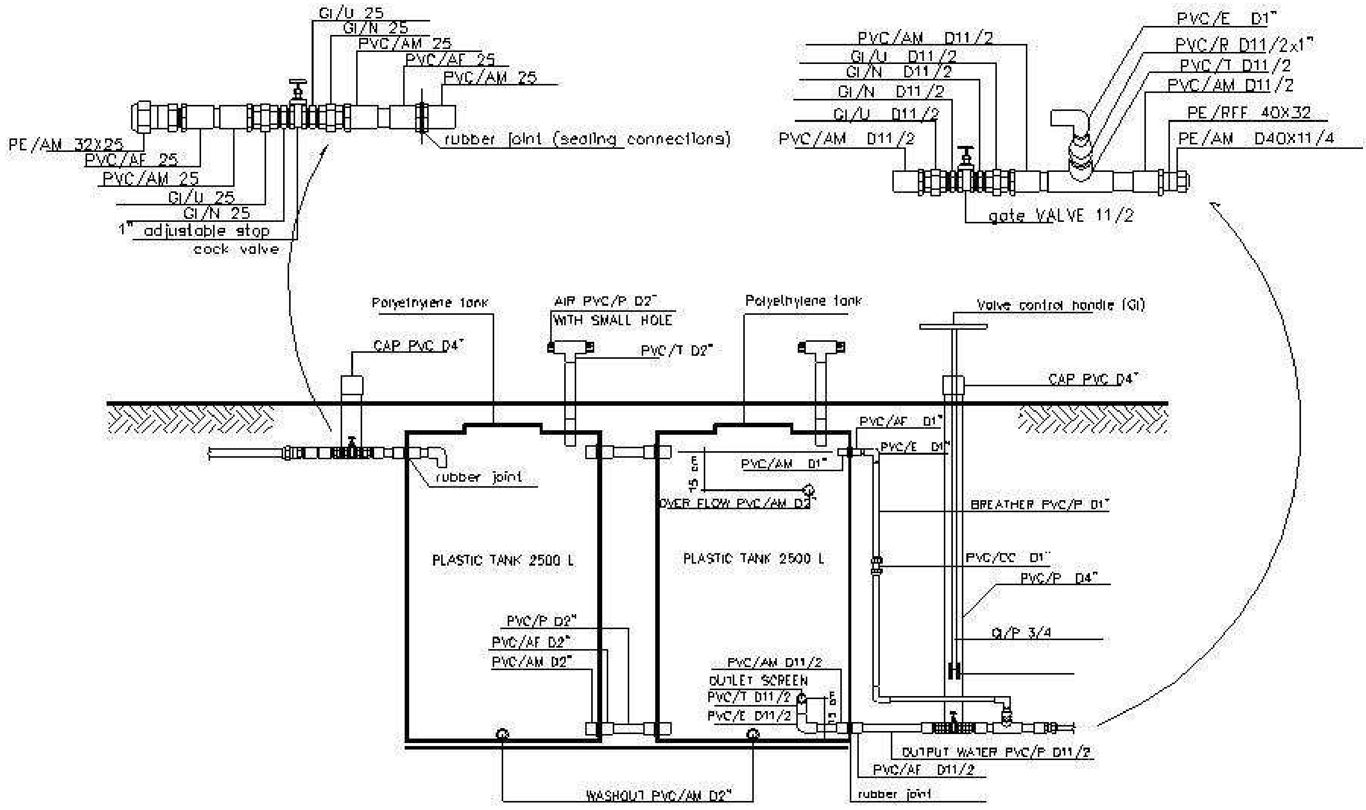


Figure 9A Reservoir (Plastic Tank)

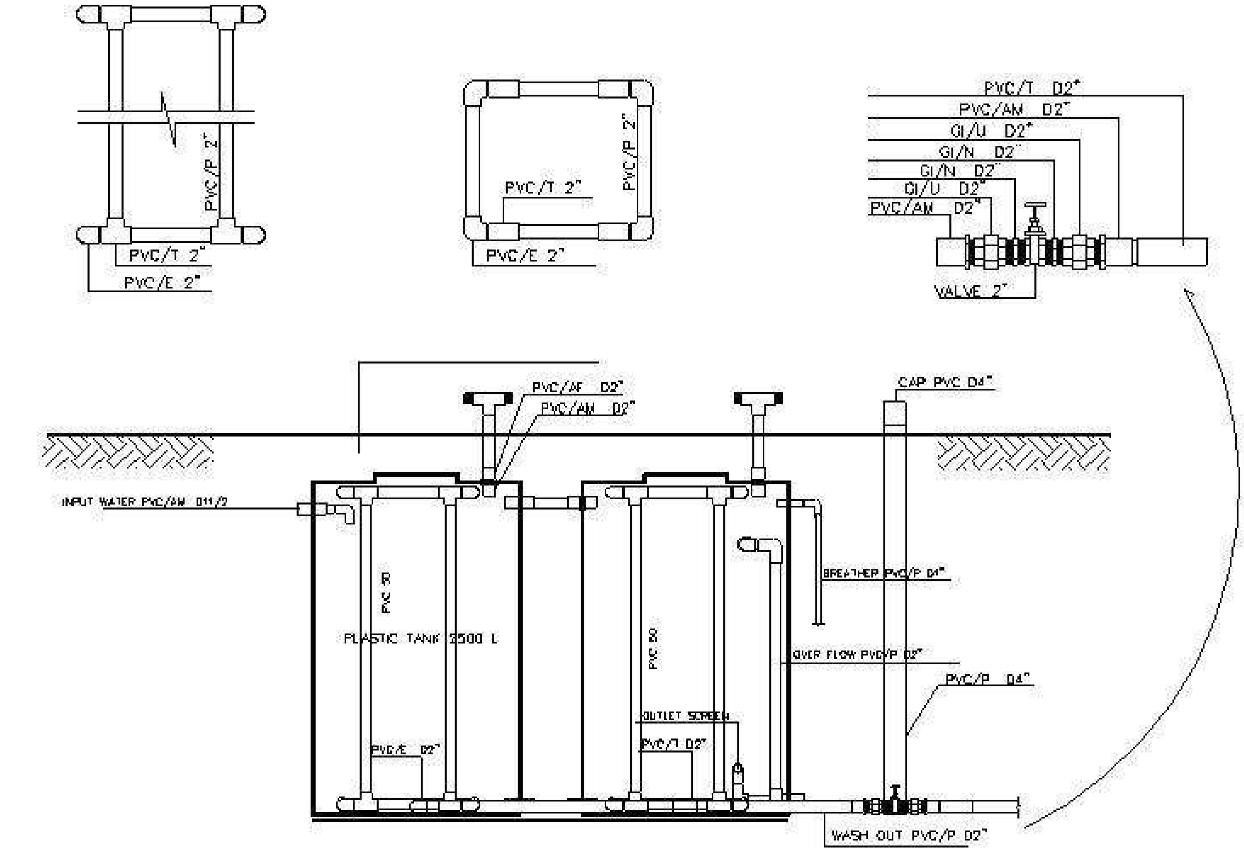


Figure 9 B Reservoir (Plastik Tank)

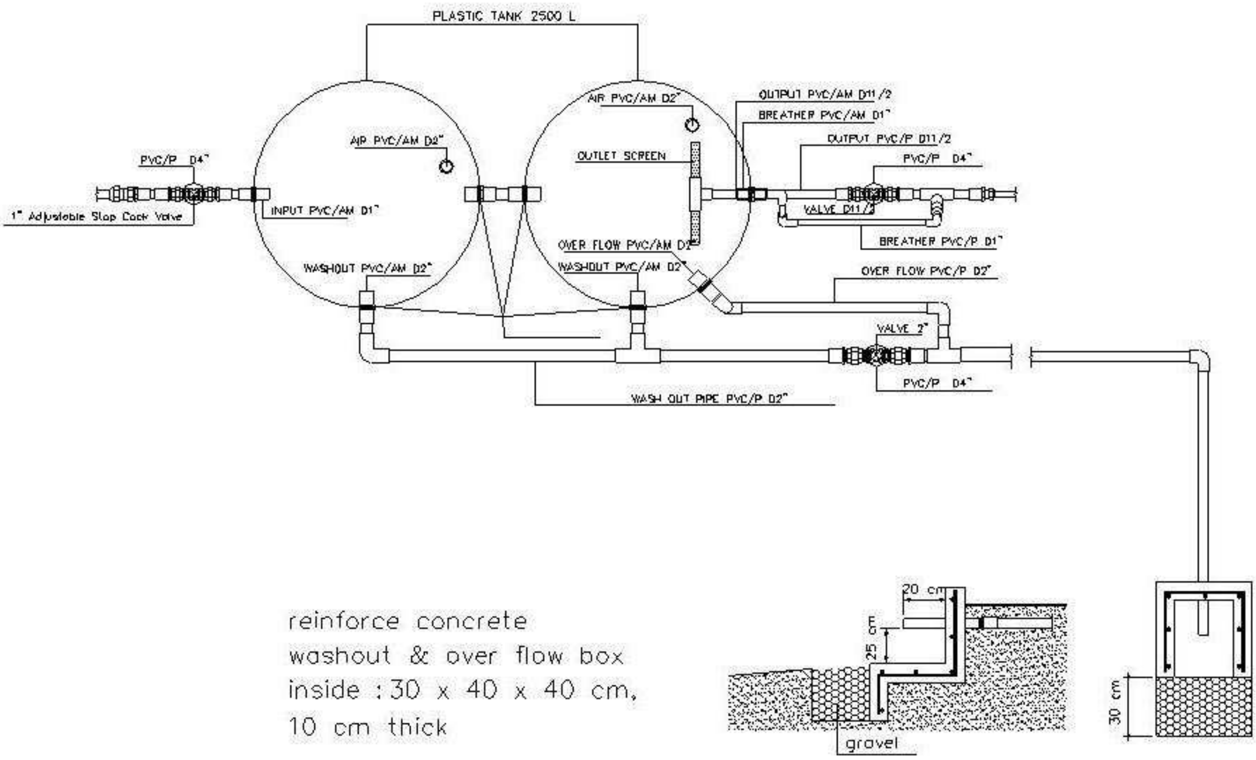


Figure 9 C Reservoir (Plastic Tank)

III.3. HEADER TANK AND BREAK PRESSURE TANK

The construction of header tank and break pressure tank is similar to the one of the low tank capacity: reinforced concrete construction with rectangular or cylindrical shape. Pre-manufactured plastic tank instead of concrete ones can be used in very remote areas only accessible by foot, because they are lighter to carry than cement bags.

These types of tank must always be equipped with:

- Water inlet with regulation valve (only for the break pressure tank)
- Water outlet equipped with ball valve (open/close) and air-bleeding pipe,
- Washout valve equipped with ball valve (open/close)
- Overflow pipes,
- Inspection manhole and ventilation pipe

The installation of a sill inside the tank is recommended to break the dynamic pressure and to allow good oxygenation of the water.

Examples of header tank / breakpressure tanks are given in figure 10 (plastic tank), 11 (reinforced concrete with cylindrical shape) and 12 (reinforced concrete with rectangular shape).

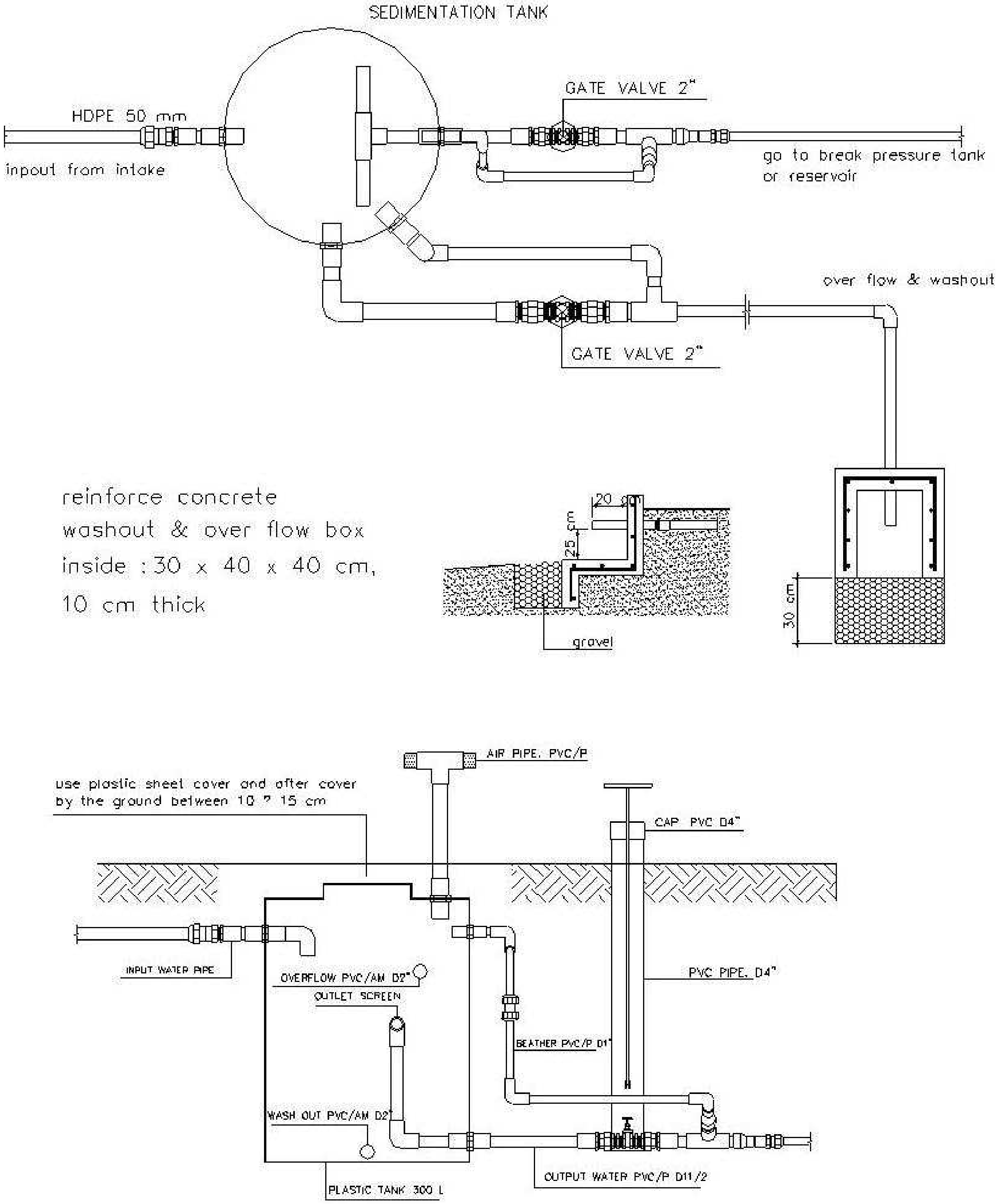


Figure 10 A Sedimentation tank (Plastik Tank)

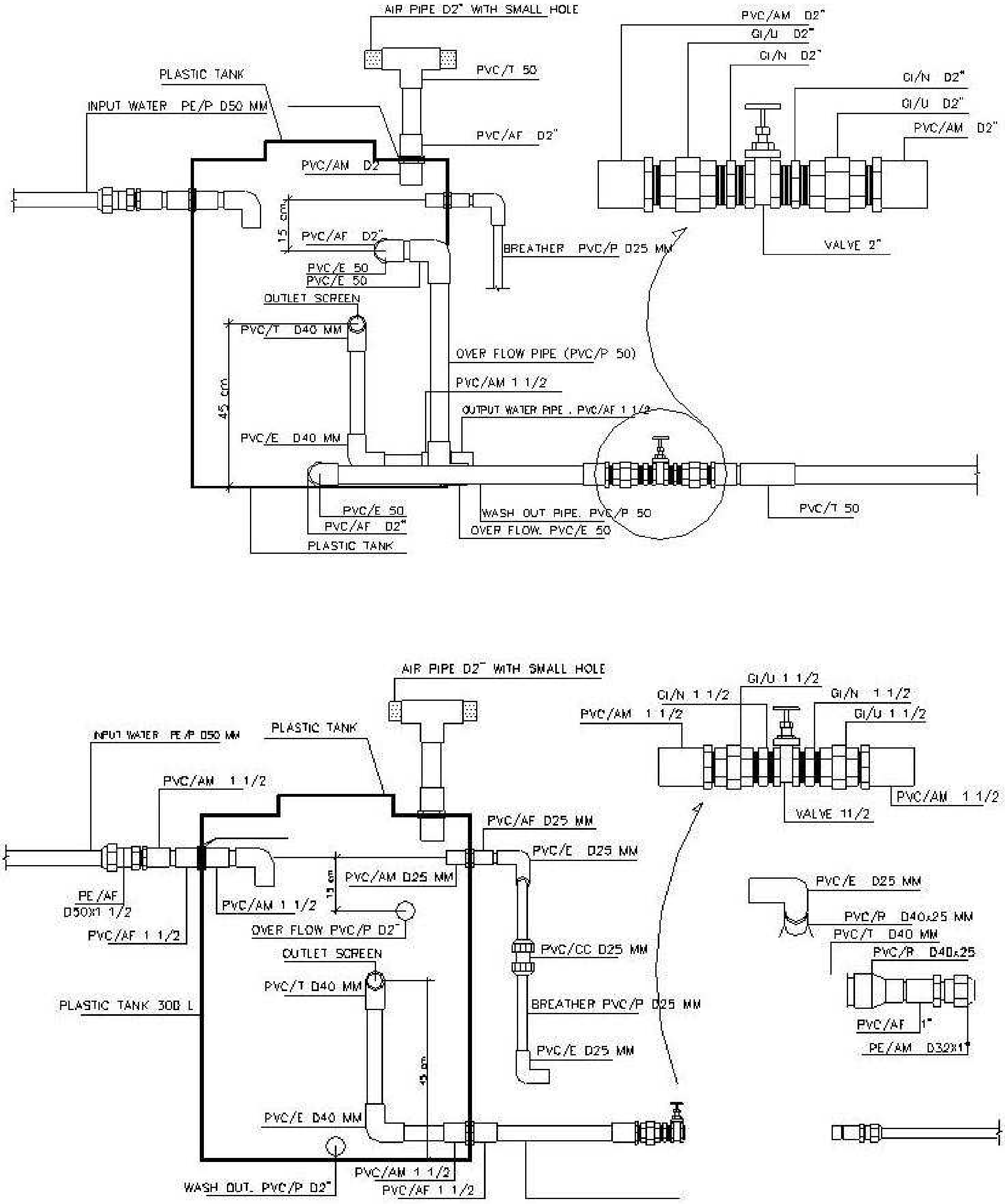
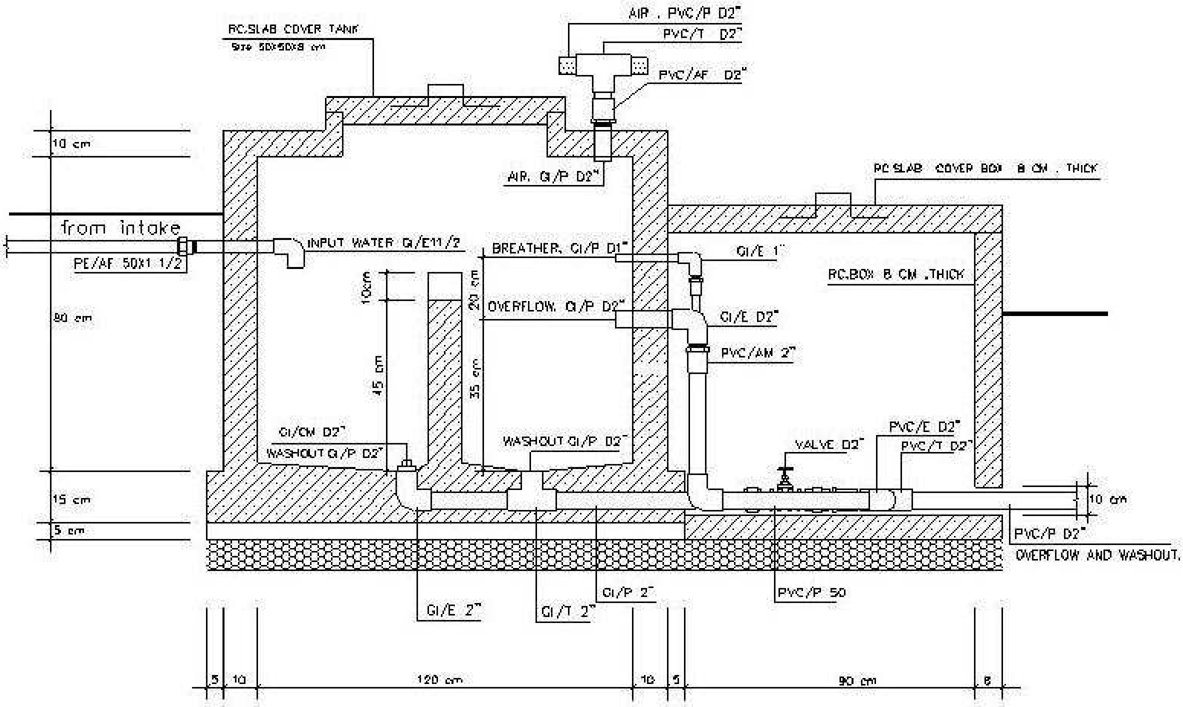


Figure 10 B Sedimentation tank (Plastic Tank)



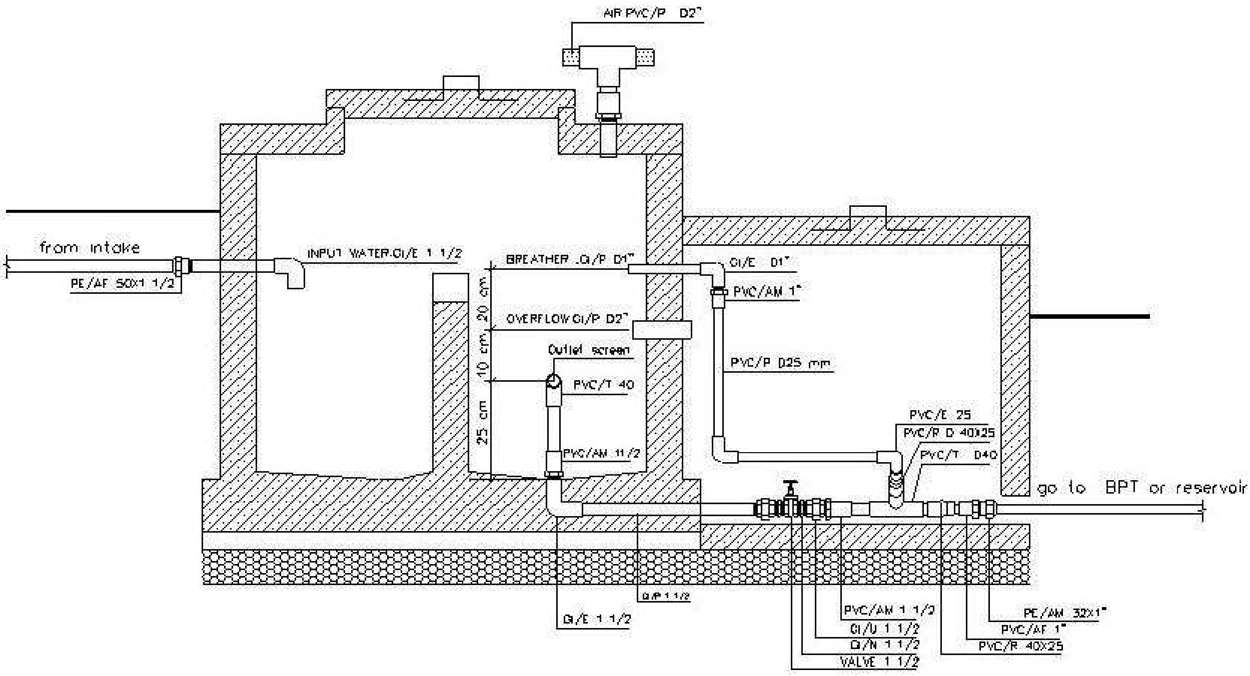


Figure 11 A Sedimentation tank (RC)

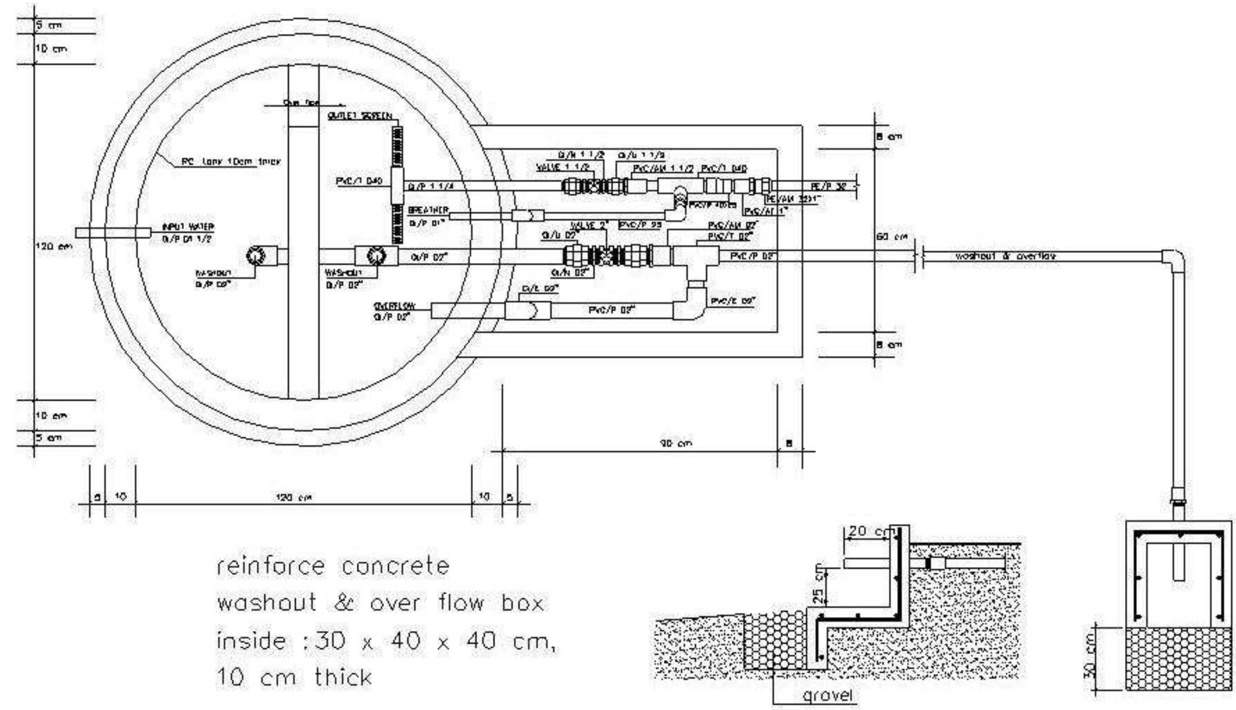


Figure 11 B Sedimentation tank (RC)

NOTE:

1. ALL THE REINFORCEMENT USE THE SIZE RB8 RS24 @15 CM BOTH SIDE
2. FOR THE CEMENT USE 350 kg PER 1 m3
3. IN SIDE AND OUT SIDE THE TANK MUST BE PLASTED BY THE MORTAR.
4. THE LEAN CONCRETE USED CEMENT 150 kg PER 1 m3.

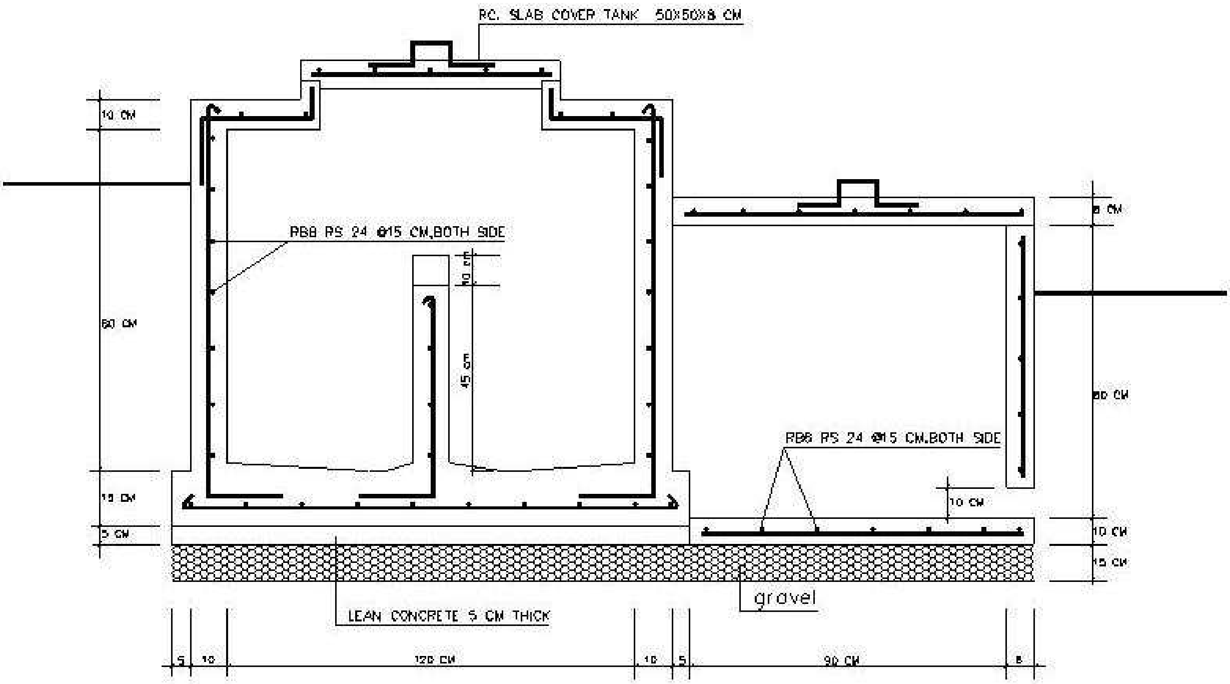


Figure 11 C Sedimentation tank (RC)

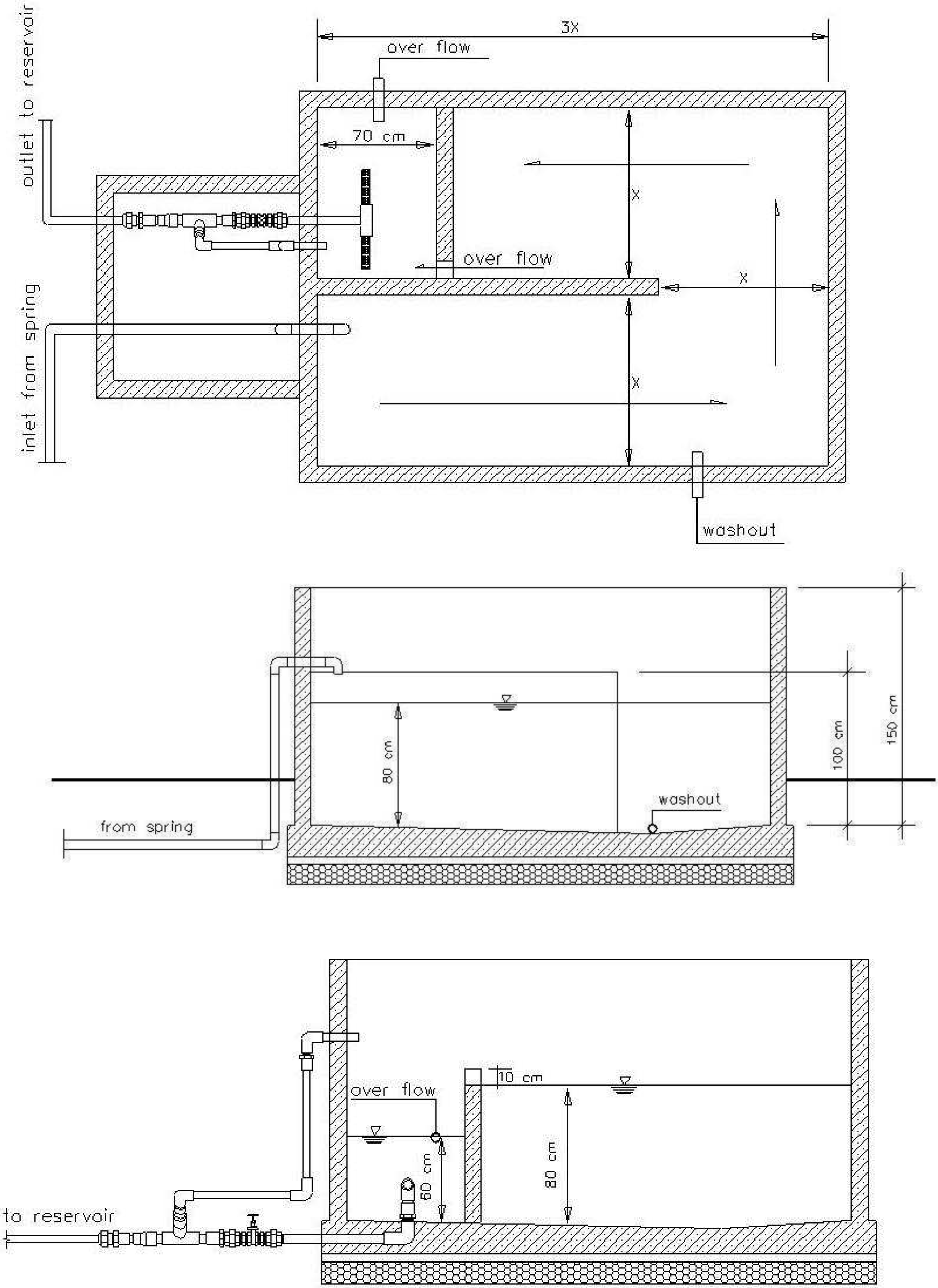


Figure 12 Sedimentation tank (RC) 2

III.4. TAPSTAND

All the tapstands must be equipped with regulation valve (stop cock valves). This device allows regulating the pressure available at the tap, and thus to ensure an optimal operation of the network. If regulations valves are installed, an open/close valve must be also installed, to isolate the tapstand in case of work (pressure regulator does not allow closing completely the water flow)

Tapstands are generally constructed in reinforced concrete:

- 10cm depth excavation
- Use of galvanized pipes with tap (s) and valve (see figure 13C and 14C),
- Construction of a toe (underground concrete foundation wall preventing the infiltration of water below the slab) and small protection wall (10cm of thickness and 30cm height); a drainage ditch as long as necessary; it is also important to built a 20 to 30 cm toe at the end of drainage ditch, to prevent water infiltration under the ditch.
- Lay down the dry stones for foundation (leave a 5cm depth hole for the tapstand body),
- Construction of tapstand body, use of 6mm steel bar (horizontal) and 8mm (vertical), use wooden planck for the formwork,
- Slab construction, it is important to have a good slope in the direction of the drainage ditch (approximately 2% slope); use 8mm or 6mm (mesh of 15cm) steel bar. To prevent the concrete from eroding too quickly, install a flat stone below the tap where the water hit the slab, or use a flat piece of wood like on the figure of fig.15,
- Valve box construction,
- Construction of a fence to prevent animals from accessing to the tapstand. The fence can be made out of wood, bamboo or even with shrubs.

The details of a 1 tap tapstand construction with are given in figure 13 and those of 2 taps tapstand in figure 14.

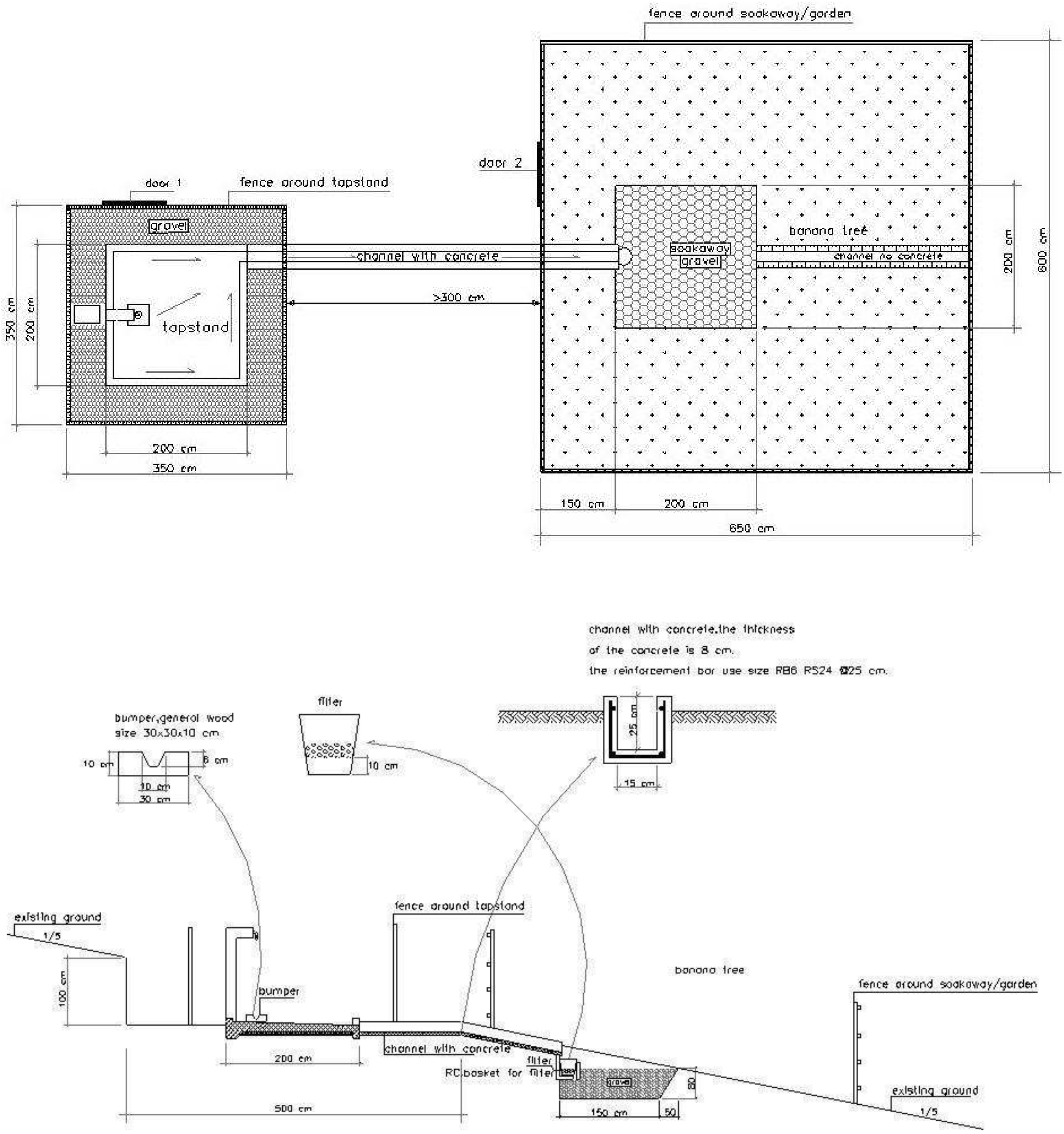


Figure 13 A Tapstand 1

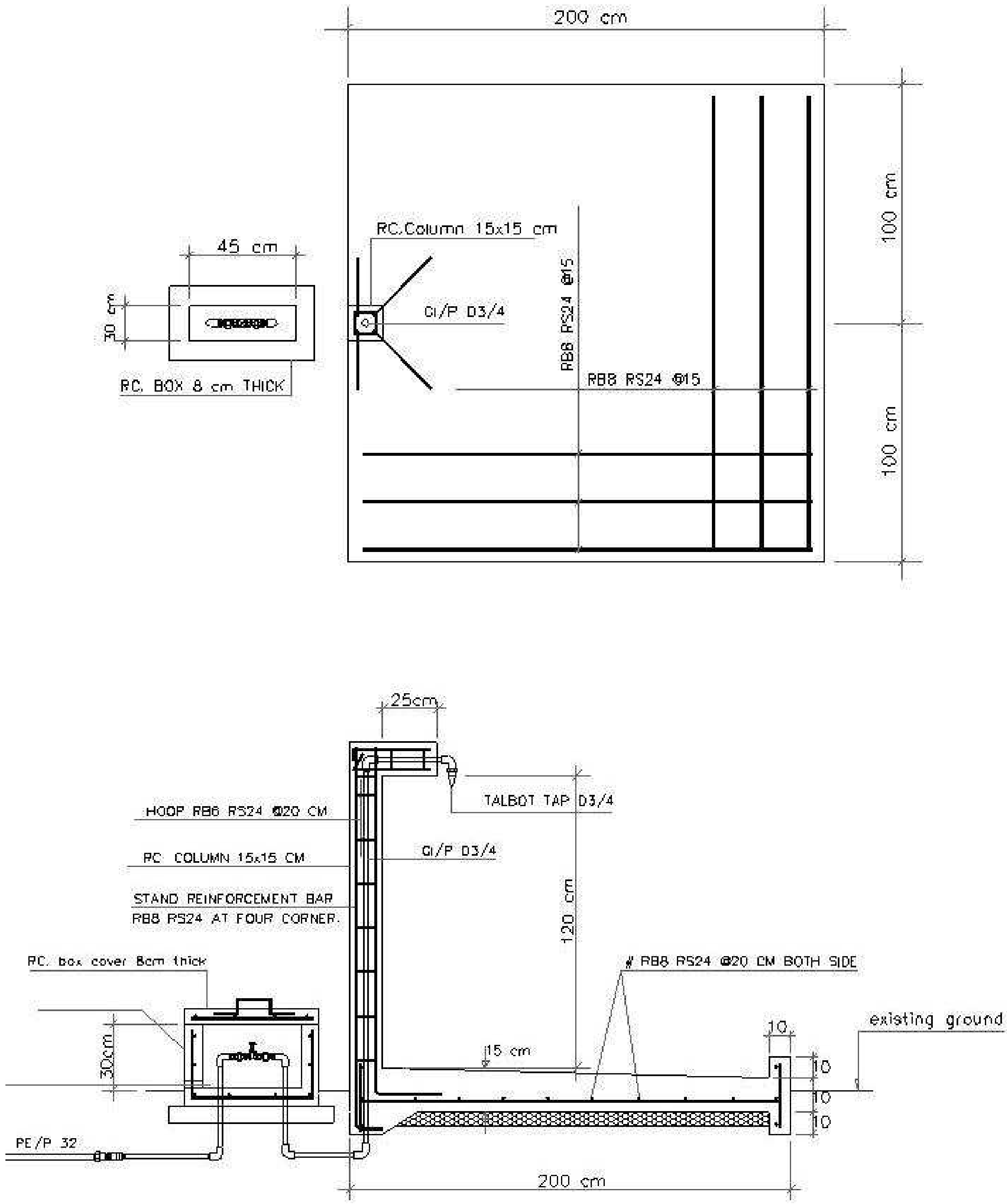


Figure 13 B Tapstand

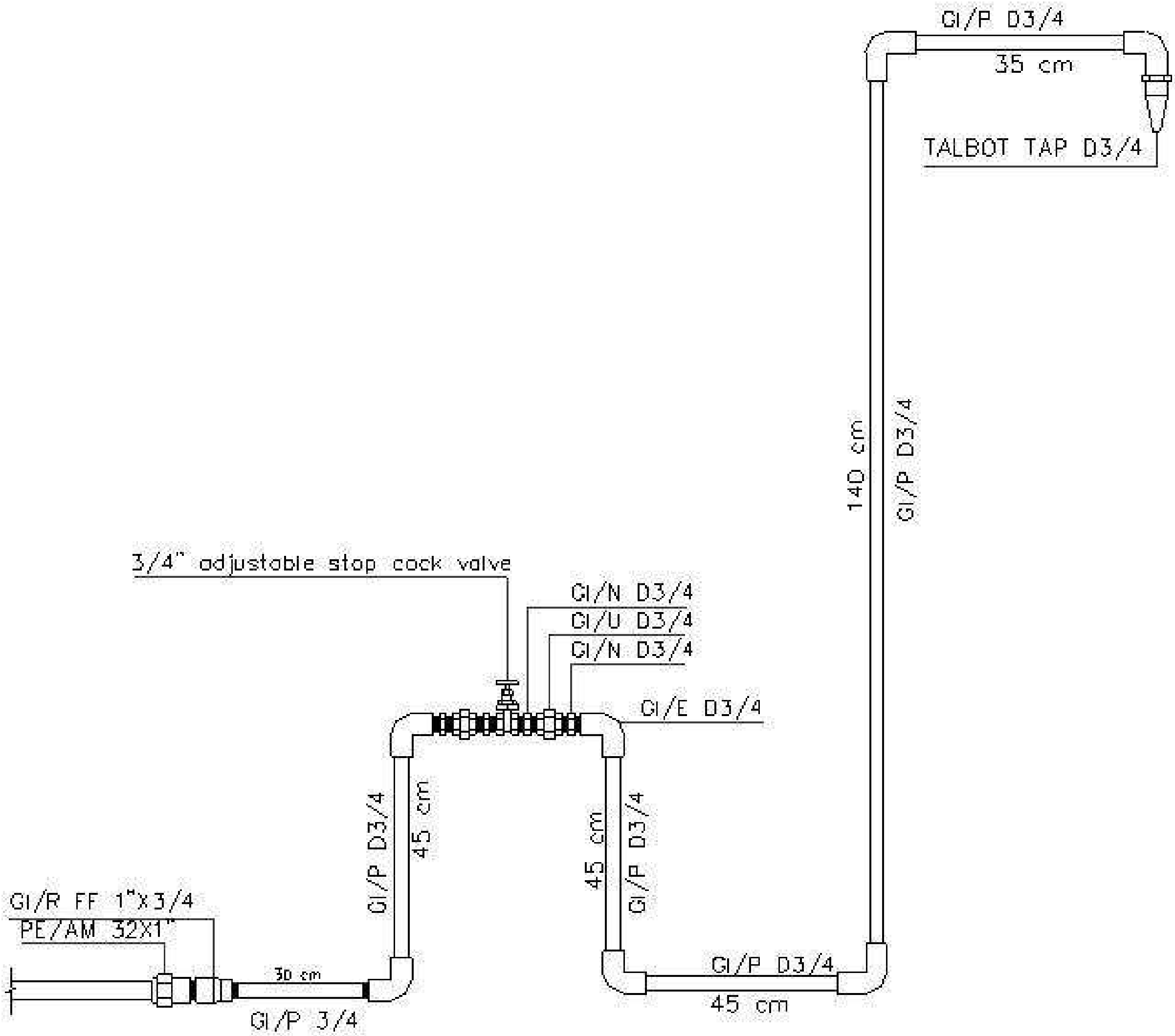


Figure 13C Tapstand

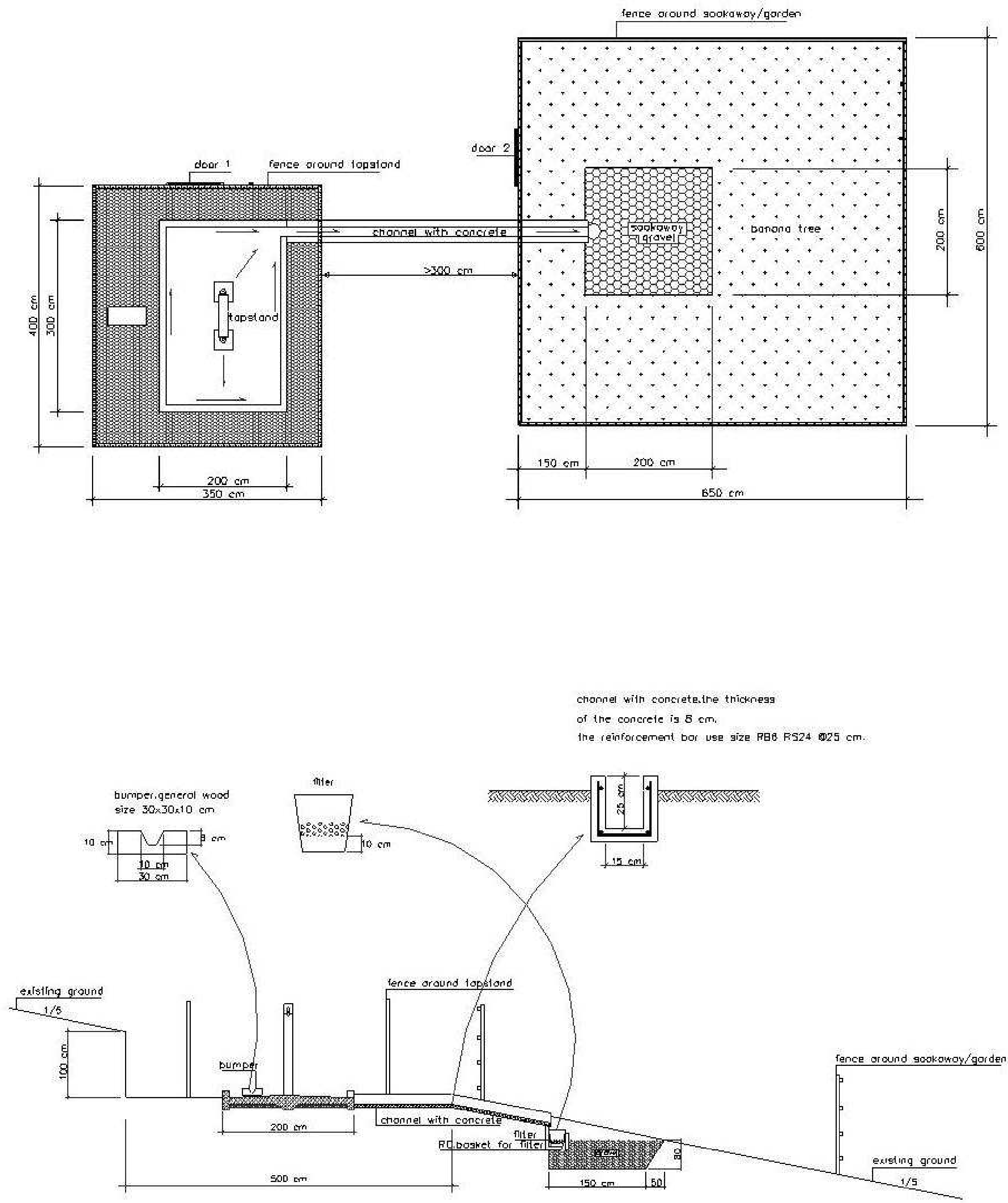


Figure 14A Tapstand 2

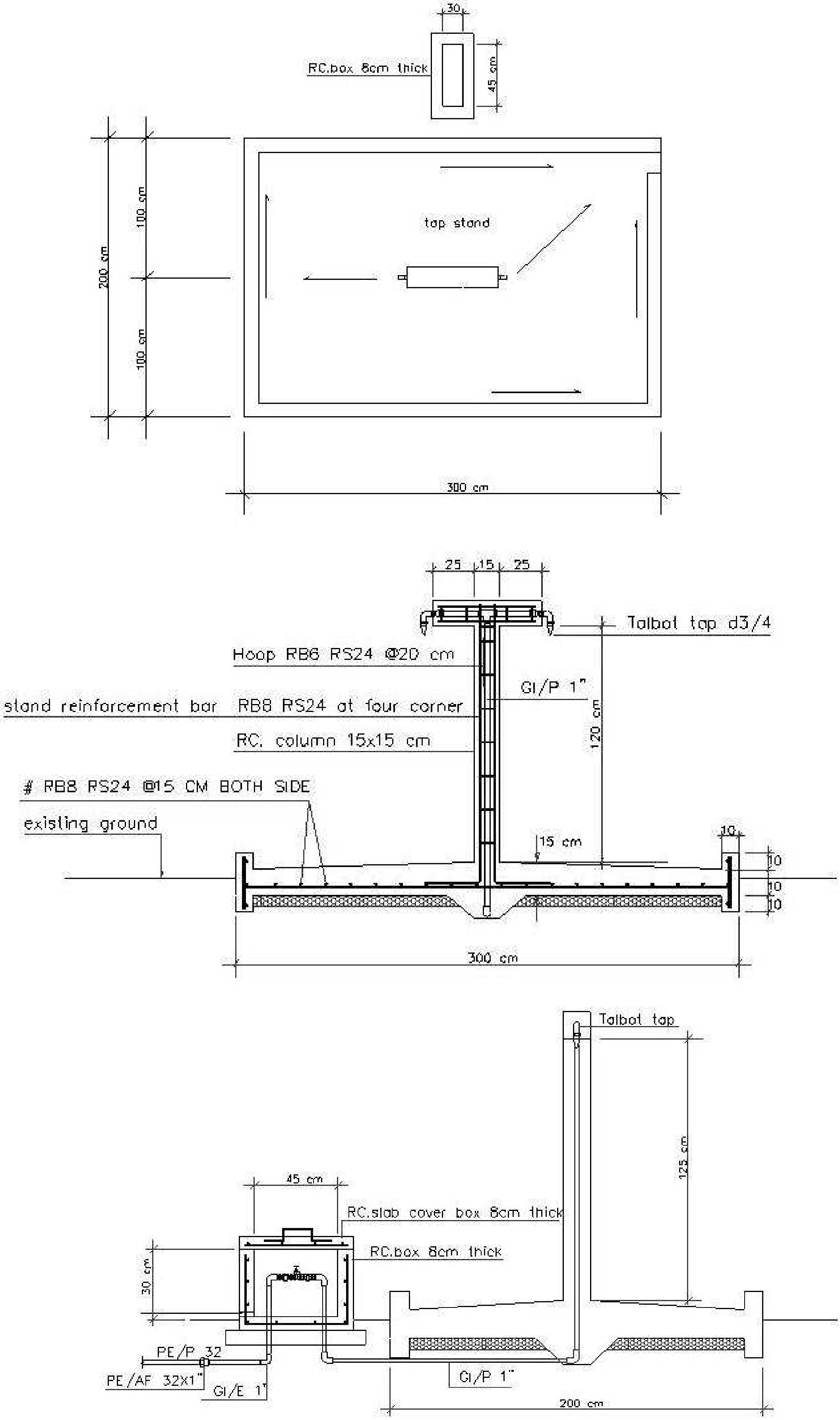


Figure 14 B Tapstand 2

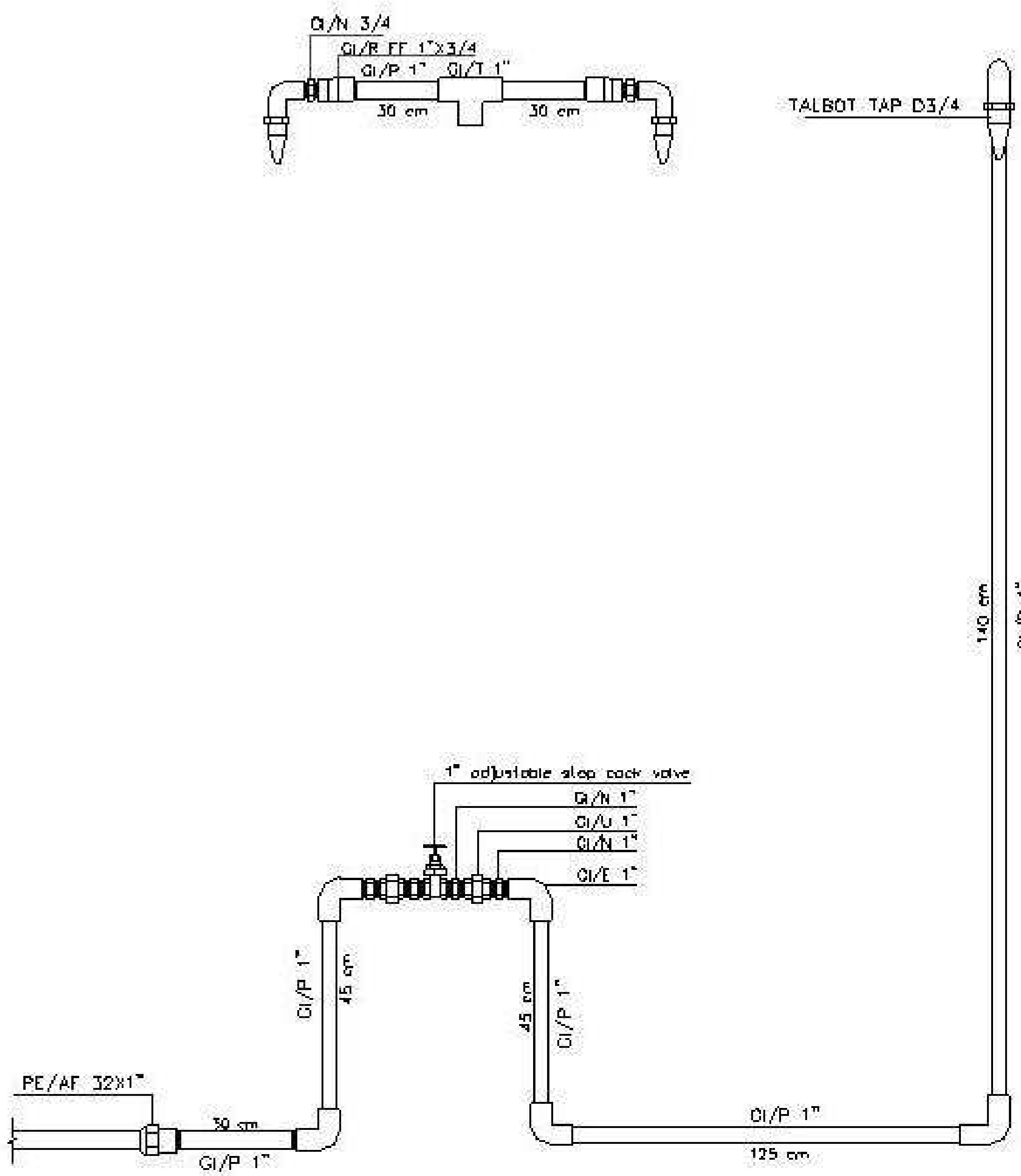


Figure 14C Tapstand 2

Fig.15: Example of tapstand . A piece of wood is used to avoid erosion of concrete and splashes of water

III.5. PIPELINES

III.5.1. Pipes and pipes fittings

→ **Choice of pipe**

As we saw in the Module II, plastic pipe (PE or PVC) are preferred to GI pipes for the construction of GFS in rural area. When PE pipe and fitting are locally available, then PE is preferred to PVC. If not, PVC pipes will be used. for some parts of the network, GI pipes are used:

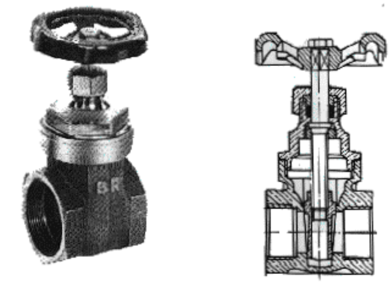
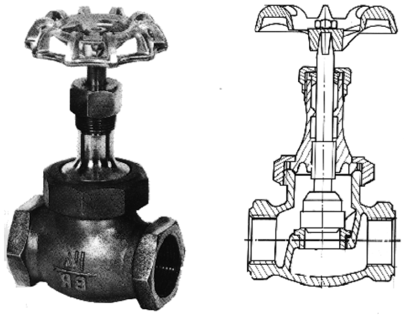
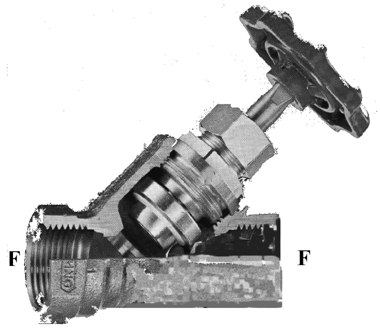
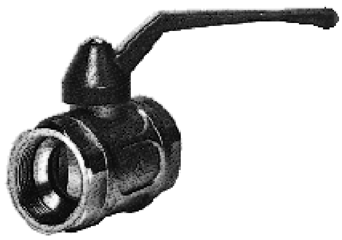
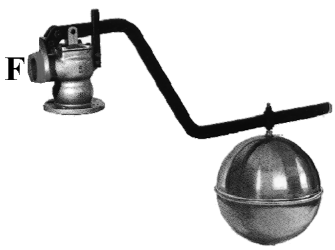
- Plastic pipe must be imperatively buried, because they are very sensitive to shock and sunlight. When (and only when) it is completely impossible to burry the pipe (rocks, or when the pipeline cross a guley, or a river), then GI pipes should be used. Platic pipes can either be put inside GI pipe of larger diameter, or connected to GI pipe of same diameter using GI/PE or GI/PVC adaptor
- It is not recommended to use plastic pipe when pipes are cast in concrete. For exemple, for tapstand's pipes, GI pipe must be used.

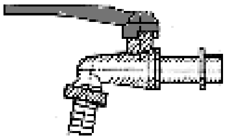
Please refer to Module II for more details on how to choose the type and diameter of pipe

→ **Valves and taps**

Various types of valves and taps presented in table 9

Table 9: Valves and taps

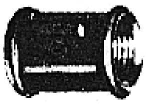
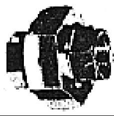
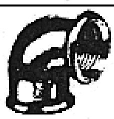
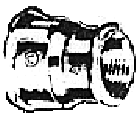
DRAWING	*ENGLISH NAME* **INDONESIAN NAME**	USE
	*Gate valve*	Open/close Can be used for flow regulation but prefer stop cock valve
	*Stop cock valve*	Flow regulation Possible to use also for open/close, but prefer gatevalve or ball valve
	*Adjustable stop cock valve*	Flow regulation with adjustable maximum opening position Possible to use for open/close, but prefer the gatevalve or ball valve
	*Ball valve*	Open/close Not possible to use for flow regulation
	*Float valve*	Automatic open/close according to water level (tank, break pressure tank…) water level control

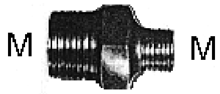
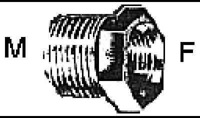
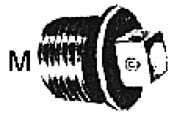
	*Self closing tap "Talbot"*	Public water distribution Open/close (no adjustable opening)
	*(hose) Ball tap*	Public distribution if TALBOT not available Short life duration

→ **GI pipes and GI fittings**

GI pipes and fittings are usually used only when pipes cannot be buried, or when they are cast in the concrete. The various GI fitting are presented at table 10.

Table 10: GI fitting

DESSIN	*ENGLISH NAME* INDONESIAN NAME	USE
F  F	Socket	Joining of 2 pipes
M  M	Nipple	Joining of two female fittings
F  F	Union	Joining of two pipes with possible disassembling
 F F	elbow 90°	Joining of two pipes close with 90° angle
 F F	elbow 45°	Joining of two pipes with a 45° angle
F  F F	Tee 90°	Joining of 3 pipes of same diameters
F  F	Reducer	Joining of 2 pipes of different diameters

	Reducer M-M	Reducer Male-Male
	Reducer M-F	Reducer Male-Female
	Cap M	Male cap
	Cap F	Female cap

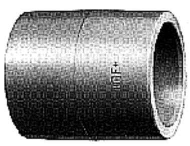
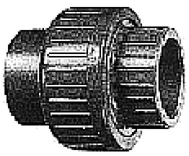
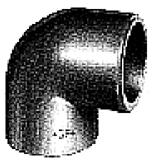
GI pipes are connected using GI sockets. Each pipe is threaded on the two ends and in theory, purchased with a socket.
The water tightness is ensured using Teflon tape.
To use these pipes, it is necessary to have special tools:

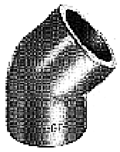
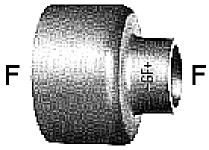
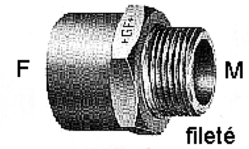
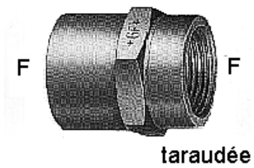
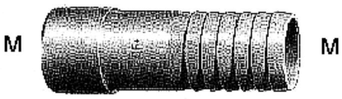
- A pipe threader, which allows threading pipes (the standard pipe threader tool allows working on pipe from ½" to 2" ½ with three sets of threads size)
- Pipe cutter
- Pipe vice

→ **PVC pipes and fittings**

The accessories for PVC pipes are presented in table 11.

Table 11: Fittings for PVC pipes.

DESSIN	***ENGLISH NAME*** **INDONESIAN NAME**	**UTILISATION**
	Socket	Joining two pipes
	Union	Joining two pipes with possible disassembling
	elbow 90°	Joining two pipes with 90° angle

	elbow 45°	Joining two pipes with 45° angle
	Tee 90°	Joining three pipes with the same diameter with 90° angle
	reducer	Joining two pipes of differents diameter
	male adaptator	Joining PVC-GI pipe female, or PVC-GI valve etc...
	female adaptator	Joining PVC-GI male, or PVC-GI nipples etc.
	Flexible pipe adaptator	Allows joining PVC to flexible pipe. A clamp should be used
	cap	Close a PVC pipe

The PVC pipes are joined using PVC socket and special PVC glue (see figure 16).

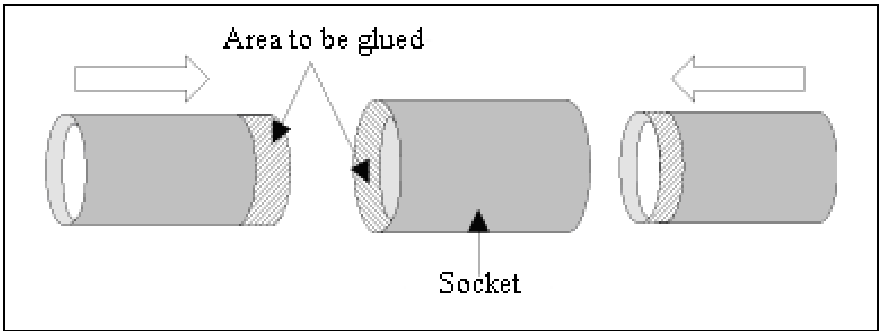
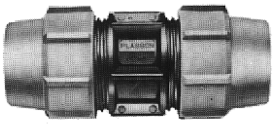
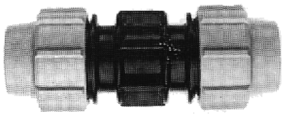
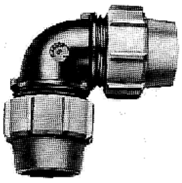
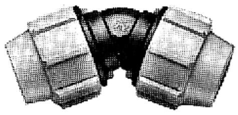
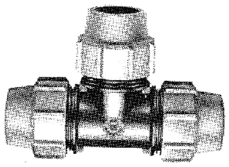
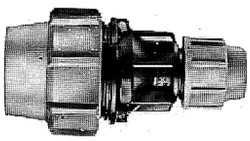
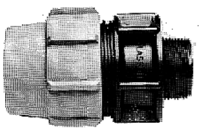
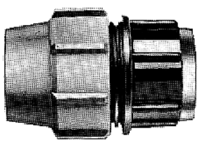
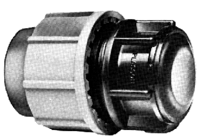


Fig.16: Joining of PVC pipes with glue.

→ **PE pipes and fitting**

PE pipes and PE accessories are often used for GFS, provided that there are some spare parts available. The PE pipe accessories are given in table 12.

Table 12: PE pipe fitting

DESSIN	*ENGLISH NAME* INDONESIAN NAME	UTILISATION
	socket	Joining two pipes
	Union	Joining two pipes with possible disassembling
	elbow 90°	Joining two pipes with 90° angle
	elbow 45°	Joining two pipes with 45° angle
	Tee 90°	Joining three pipes of the same diameters with 90° angle
	reducer	Joining two pipes of different diameters
	male adaptator	Joining PE-GI pipe female, PE-valve etc…
	female adaptator	Joining PE-GI pipe male, PE- GI nipples etc.
	cap	Close the PE pipe

For the joining of PE pipes, we use compression joint until the diameter of 2" ½ (see figures 17 and 18). For the higher diameters, it is preferable to use heat welding joints.

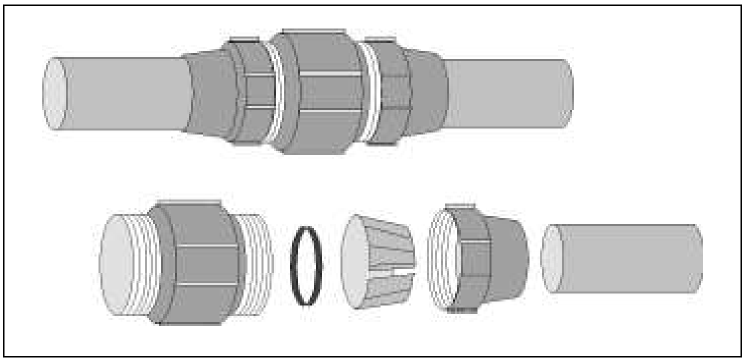


Fig.17: PE compression joints.

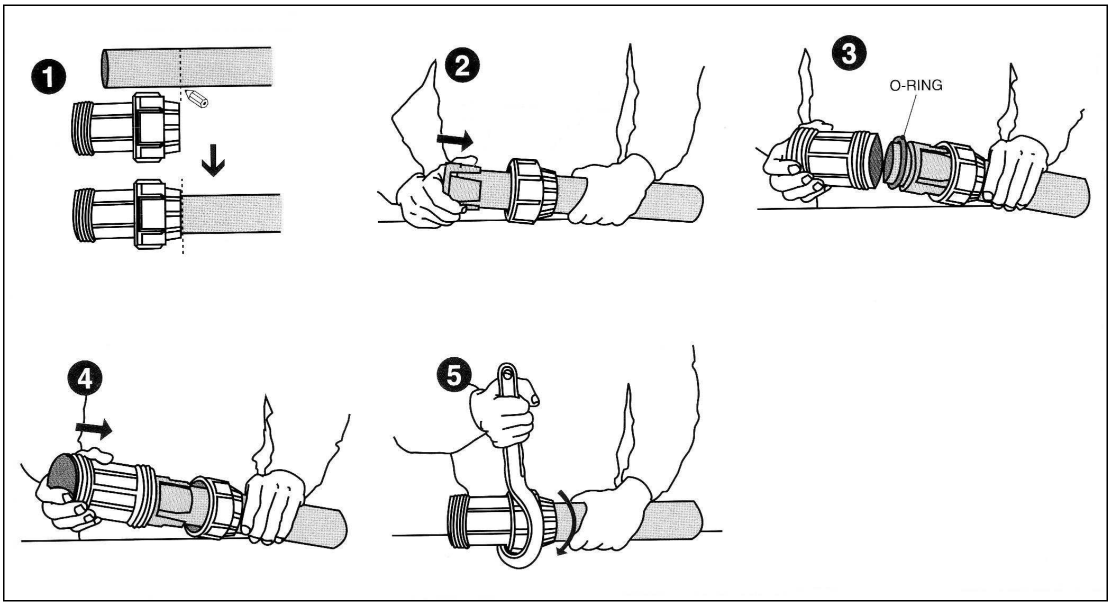


Fig.18: Assembling of PE compression joints.

III.5.2. Pipes installation

- Trenches

Minimum depth: 0,8m and width of 14 to 40cm.
Remove all stones and roots, which can damage the pipe.
The trench should be dug at the last moment, to avoid it to collapse, or to be washed away in case of raining.
If for planning constraint the trench has to be dug long before the pipe installation, build small dams inside the trench as often as required by the slope, so the water will not run inside the trench and destroy it.

- Pipe laying

If the bottom of the trench is not flat or if there is a risk that the ground can damage the pipes (weathered rocks), a layer of sand must be installed in the bottom of the trench. If there is no sand, sieved soil can be used.
Lay the pipes and assemble them with care. Be careful to the pipe expansion phenomenum, particularly during the installation of important length PE pipes in a hot weather. Once covered with ground, concraction will occur. It is thus important to let some slack to the PE pipes during its installation in order to avoid problem during backfilling (see figure 19).
The PE pipes are generally bought in rolls of 100 meters that are unrolled as shown on figure 20. Pipes are joint with sockets or unions.

Before joining the pipes permanently, it is necessary to wait until water flows out to prevent the formation of air plug during the first time water is flowing in the pipes. Another method to avoid the formation of air plug during the network commisioning is to start running water in the pipes after the completion of each section: for example, build the header tank – storage tank pipeline, then run water. Then build the storage tank – break pressure tank pipeline, run water etc…running the water progressively can also be useful to make water available for the construction works downstream.

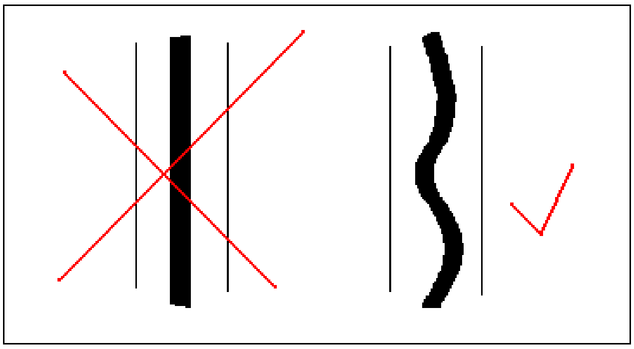


Fig.19: PE pipes laying in the trench

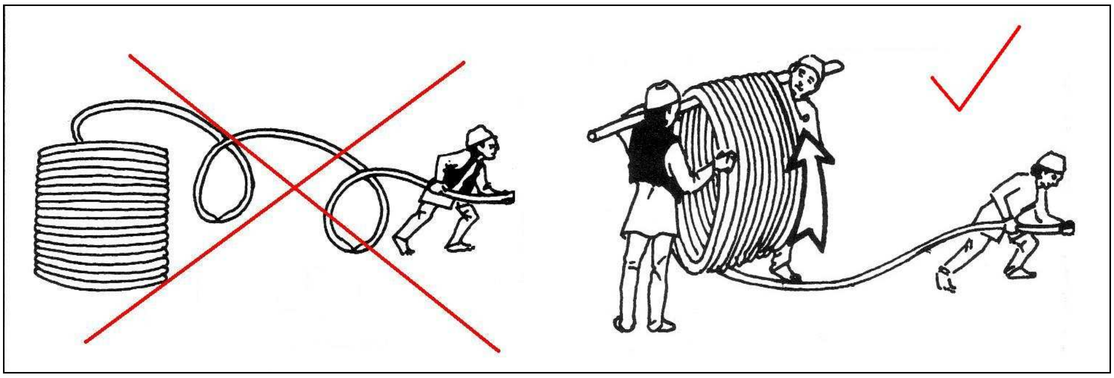


Fig.20: Unrolling PE pipes

- Backfilling

Use the same ruble to backfill, after having removed all the elements that could damage the pipe (roots, stones etc…).
After the pipe installation, backfill on 30cm depth except at joints level, and tamp down. If possible then run water in the network and search for possible leakages. If water runs in a regular way and there is no leakage, finish the backfilling and tamp down.

- Above-the-ground pipe section

* Pipe laying through a rocky section:

When it is not possible to bury the pipe with more than 30cm because of difficulty or impossibility to dig (rocky ground or rocks), you have to install pipe above the ground. In this case it is necessary to protect the plastic pipes by putting them inside a GI pipe. The GI pipe must be anchored using reinforced-concrete blocks as illustrated in figure 21.

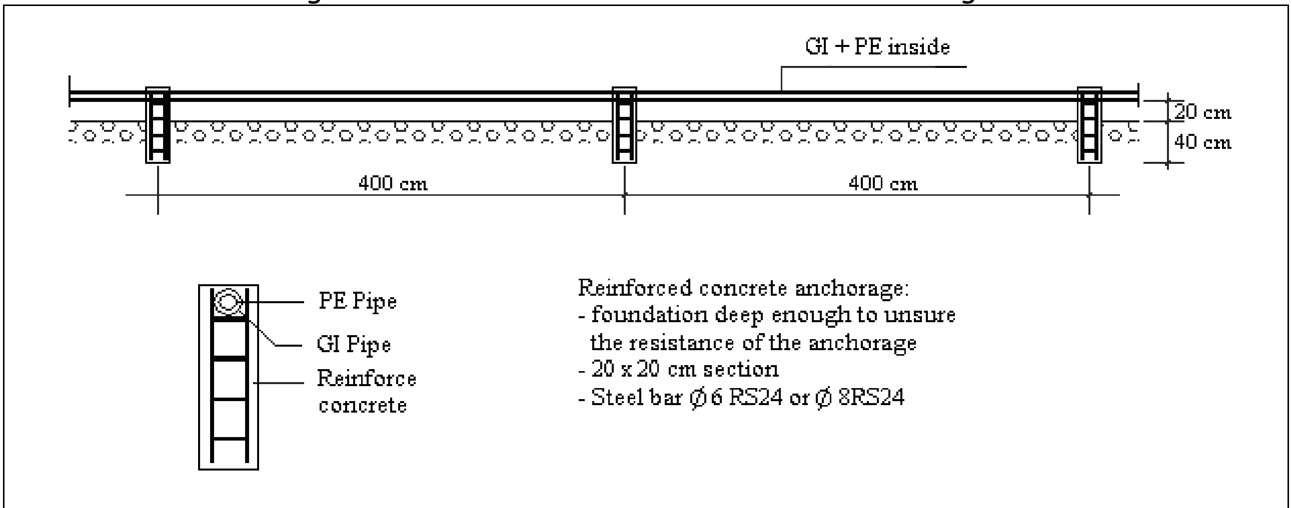


Fig.21: Above-the-ground pipe laying

* Pipe paying over a gully or a river:

In the case pipe have to be installed over a gully or a river, several solutions are possible according to the length to cross:

- If the length is less than 5m, the use of GI pipe is recommended. GI pipe are indeed self-supporting over a length of 5m. In the case of a plastic pipeline, GI pipe can be used as sleeve. In this case it is important to anchor the ends of galvanized-pipe in concrete blocks as illustrated in the figure 22.
- If the length is 5 to 10m, the use of two GI pipes is recommended. It is indeed necessary to support the pipes using vertical GI pipes filled with concrete and anchored at their base in reinforced concrete block as illustrated in figure 23. The location of the pipe used as posts depends on the type of soil and/or the quantity of water in the river.

- If the range is higher than 10m, it is essential to support the galvanized pipe with a cable. It is important to anchor the cable on the two banks of the gully or river (see figure 24). The pipes must be attached to the cable every 70cm. The cable diameter is selected according to the length and the pipe diameter (see table 13).

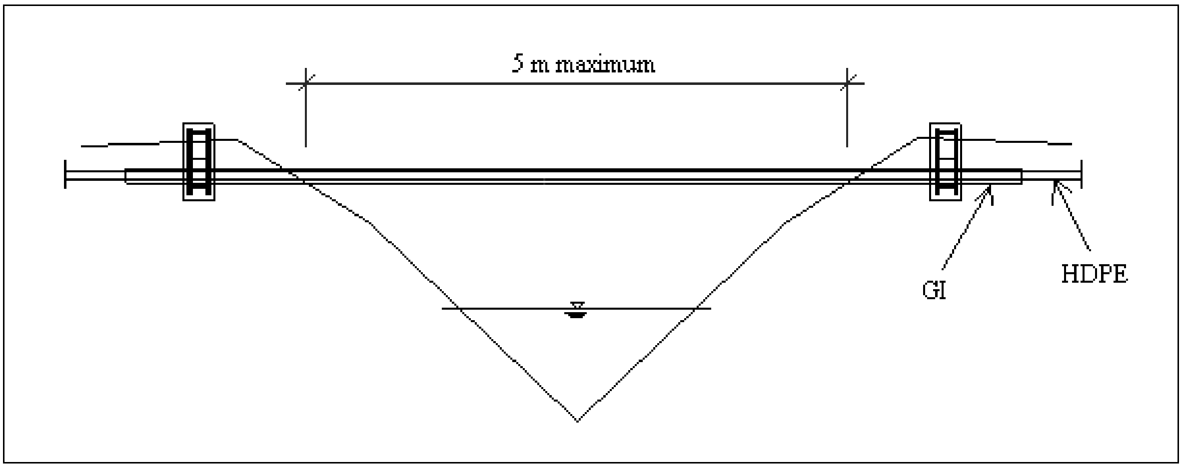


Fig.22: Crossing a gully or a river with a length lower than 5m

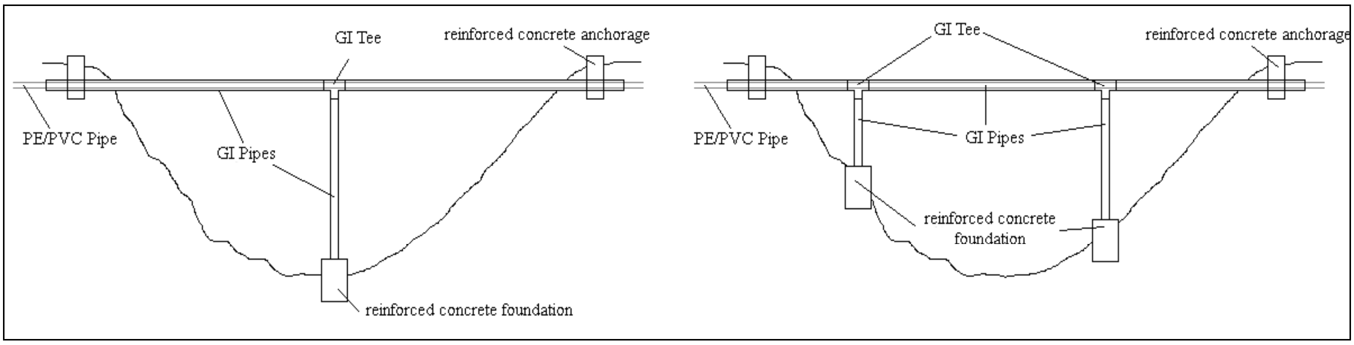


Fig.23: Crossing a gully or a river on a length of 5 to 10 m.

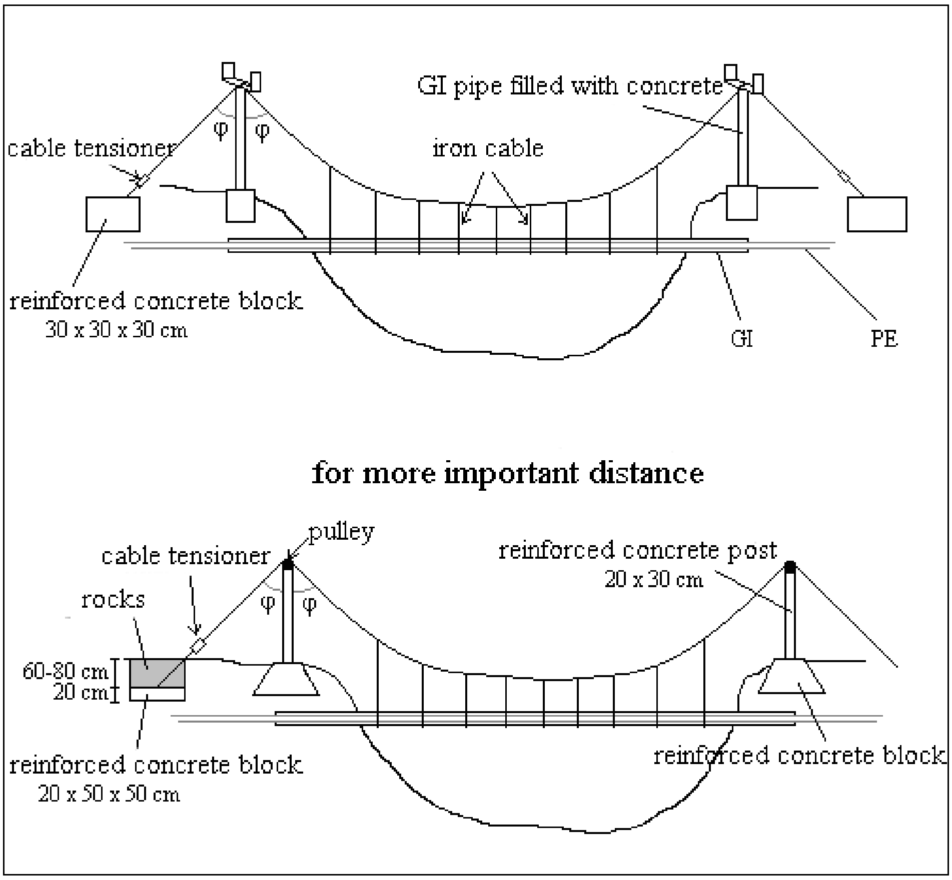


Fig.24: Crossing a gully or a river using suspended pipe (length above 10 m).

Table 13: Pipe diameter and maximum length with a cable of 8mm diameter.

Diameter of PE/PVC pipe	20 mm	32 mm	40 mm	50 mm	63 mm
Diameter of GI pipe	1"	1" ½	2"	2" ½	3"
Maximum length	170 m	100 m	70 m	50 m	40 m

*Crossing a shallow river:

When the river is not very deep, the pipe can pass below the river. In this case, we install the PE/PVC pipe inside a GI pipe located in the riverbed as illustrated in figure 25. To prevent the pipe to be washed away by the water stream, you must build a low but large wall of stone at a distance of 1-2m downstream of the pipe, to decrease the water speed at this place.

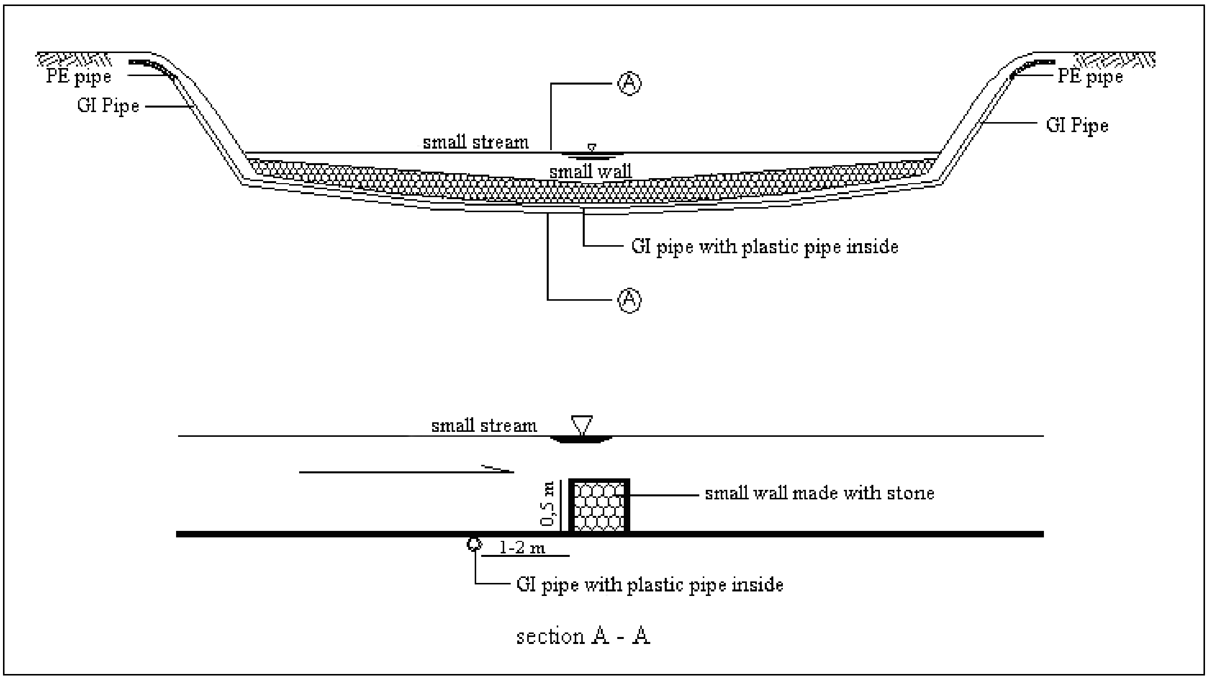


Fig.25: Crossing a shallow river.

- Crossing a road

The pipe must be buried at a minimum depth of 1m.
Use only GI pipe, a GI sleeve or concrete culvert.

- Marking blocks

To mark the pipe laying, concrete or masonry marking blocks must be installed every 100m, especially at the joints level, and at each sensitive point (junctions, change of direction, etc). Ideally, you must indicate on the blocks the pipe type and diameter, the direction of the flow direction and a block registration number.

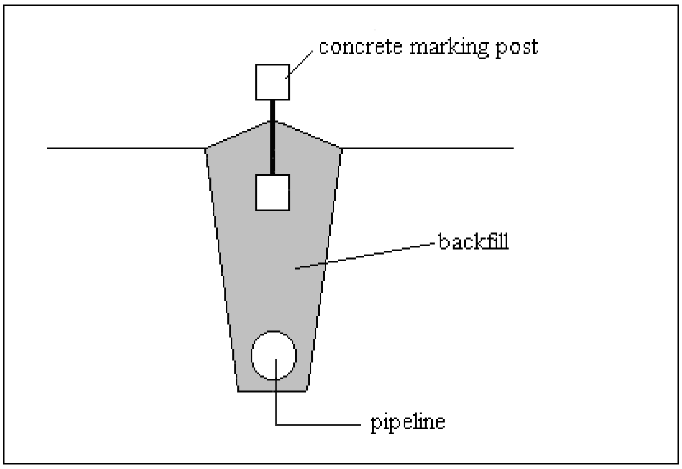


Fig.26: Marking block.

III.6. WORK DURATION AND MANPOWER

The time necessary to construct a GFS depends on many factors such as length and complexity of the network, participation and motivation of the beneficiaries, weather, etc.
The work requiring specialized workers during the construction of GFS are the pipe laying and the civil work. This work requires the supervision of 1 or several experience technicians.
The villagers are generally involved in various works as follows:

- The clearing of the future pipeline layout and transportation of equipment,
- The trench and foundations digging
- The drainage of remaining water and external protection of the various infrastructure works (for example protection fence)

In table 14 are indicated the necessary manpower and average completion period of main works of a GFS construction.

Table 14: Work duration and manpower

Work / Activity	Construction period	Number of necessary specialized worker	Number of necessary villagers
Catchments	7 days	1	5 - 6
Plastic header tank	4 - 5 days	1	10
Concrete header tank	7 - 8 days	1	10
Plastic reservoir	5 - 6 days	1	10
Concrete reservoir	3 weeks	2	15
Tap stand	7 - 9 days	1	5 - 6
Trench	5 m/pers/d	-	all
Pipes laying	50 m/pers/d	1 – 2	5 - 6
Backfilling	8 m/pers/d	1	all
Material transportation	-	-	15 - 20