Abdelhafid University Center Bousouf - Mila
2024-2025 Semester 1

Hydraulic works

– Course 2 –

Chapter 02 : *Different types of dams and choice of typical profile*

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Course Objectives 2

- Identify the main categories of dams (gravity, arch, buttress, embankment, etc.).

- Understand the structural and functional characteristics of each type of dam.

- Analyze the advantages and limitations of different dams depending on site conditions.

- Determine the most suitable type of dam taking into account topography, geology, hydrology and intended use.

- Develop a critical mind on the choice of the typical profile based on technical and security criteria.

Introduction

Dams are essential hydraulic structures designed to store, regulate, or divert water. Depending on the site configuration, geological conditions, hydrological constraints, and operational objectives, several types of dams can be considered. Each type has specific design, material, and structural characteristics. The aim of this course is to present the different types of dams and the criteria for choosing the most appropriate profile for a given situation.

II.1 Choice of the retention site, the dam and its type

The study of a dam requires the intervention of several scientific disciplines that complement each other because of its complex and delicate nature (environmental data of the site: topographical, geological, geotechnical and in particular the choice of materials for its body, the foundation and specific safety measures).

The choice of the type of dam is obvious, without the need for extensive investigations.

On the other hand, the choice of the type of dam will be a compromise (agreement) between the following different aspects: nature of the foundation, availability of materials nearby, hydrology, to arrive at the best economic choice. But it will always be in your interest to choose as quickly as possible, generally at the end of the feasibility studies.

II.1.1- choice of the retention site

After setting the objectives for constructing a dam in a given area, the feasibility study begins by searching for a site capable of meeting these previously set objectives. This research is carried out on existing documents (general map, aerial photos; geological maps, etc.). In general, at this stage of the study, several sites are chosen. The final choice must take into account several factors, including water use, but above all, the site that provides the most economical m3 of water mobilized must be sought .

The final choice of the site is made after visiting the site(s) in order to decide on the following points:

- Access to the site.
- Watershed vegetation cover.
- Morphology of the watercourse and its watershed.
- Water retention area.

The choice of the retention site must be made according to the following conditions:

- **Topographic conditions** (watershed boundaries, river valley topography, reservoir site topography to estimate reservoir volumes based on water levels). The topographic study covers the watershed, the river valley upstream and downstream of the dam, the dam site, the reservoir and possibly borrow areas.
- **Geological conditions** (stability of supports and foundations, watertightness of the basin, stability of slopes, state of fracturing, existence of borrow areas)
- **Hydrological conditions** (watershed of the reservoir, rainfall, flow rates of watercourses, floods, solid input, etc.)
- The geotechnical study must focus on determining the mechanical and hydraulic characteristics of the foundation soils of the structure and the soils that can be used as construction materials for a dike.

II.1.2- choice of dam site

The best location is where the valley narrows. Upstream of the narrowing, the valley must be wider and have a low slope to allow the greatest volume to be stored. The dike is the smallest and therefore the least expensive.

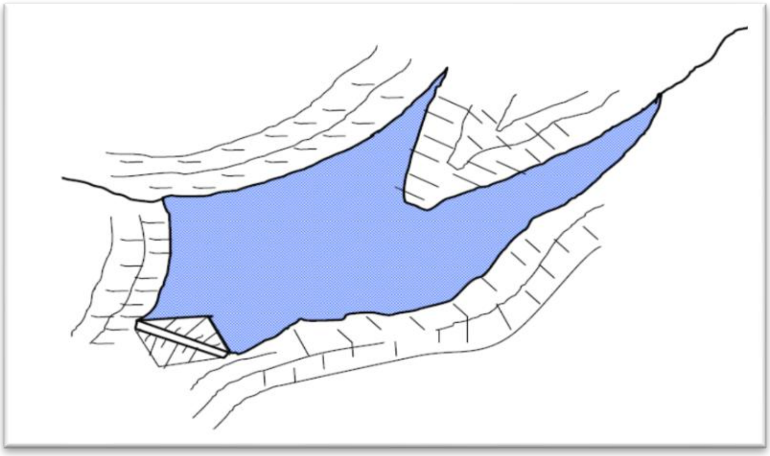


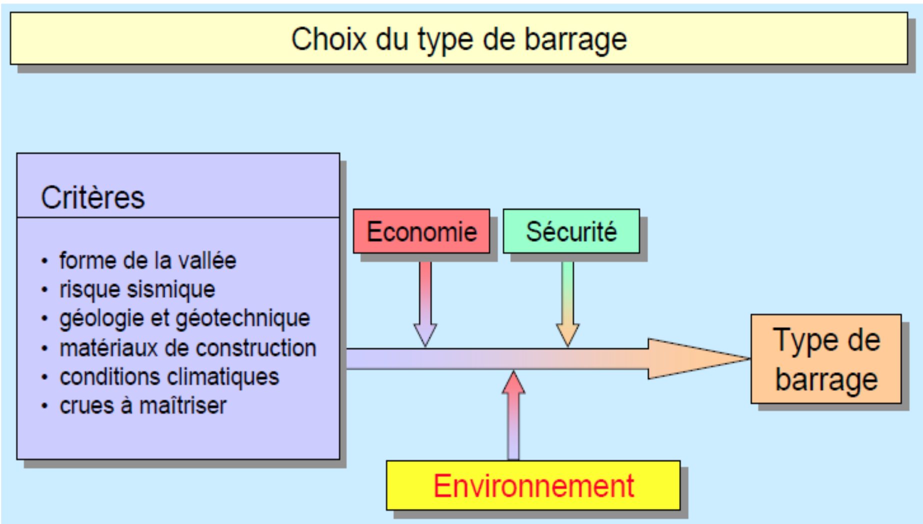
Fig.2.1. Area suitable for the construction of a dam

II.1.3- The choice of dam type

The choice of the type of dam is made based on local conditions:

- Geotechnical qualities of the support
- Resources in building materials (in quality and quantity)

The final decision is made taking into account the expected benefits (energy production, site protection, etc.), costs (acquisitions, works, etc.) and the impact on the environment (natural and human).



II.2 Classification of dams according to the type of materials and the mode of resistance to water pressure

Dams are often classified based on the type of construction materials or the method of resisting water pressure. The main types of dams are:

- ❖ Rigid dams (made of assembled materials)
  - Gravity dams

- Buttress dams
- Arch dams
- Multiple arch dams
- Roller compacted concrete (RCC) dam

❖ Embankment dams (made of unassembled materials)

- Earth dams
- Rockfill dams

Dams with a height of less than 100 m are called ordinary dams, the others are called high dams.

II.2.1-Rigid dams (made of assembled materials) or concrete

Concrete dams are divided into three groups (Figure 2.2).

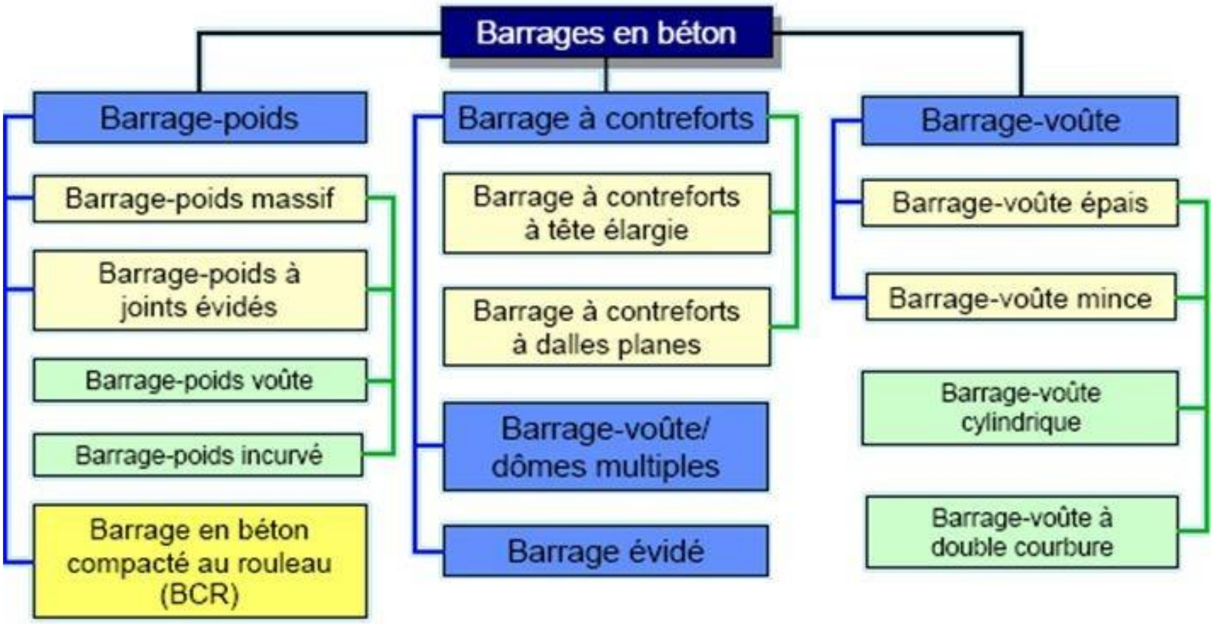
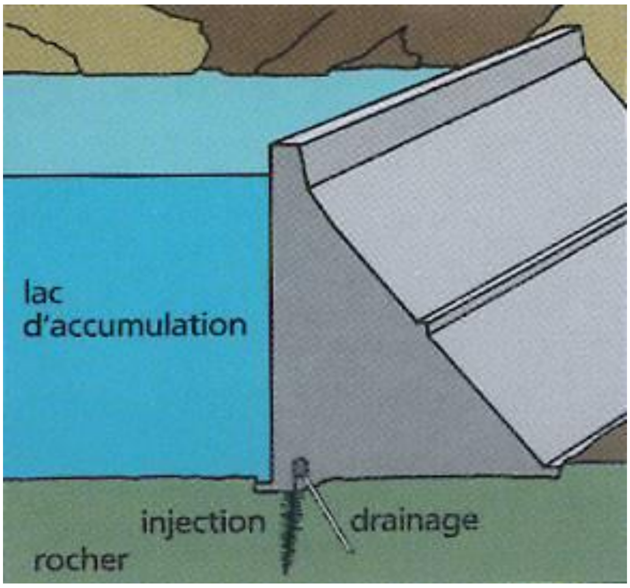


Figure 2.2: The different types of concrete dam

II.2.1.1 Gravity dams: (or gravity dam)

Due to their weight and trapezoidal section, they resist the pressure of water. Just like masonry dams, concrete dams are rigid structures and therefore their design will also be determined by the quality of the foundations.



A. Simplified diagram of a gravity dam B. Photo of a gravity dam (Colombia).

- **Advantages and disadvantages**

Benefits :

- Simple shape, easily adapts to the topography
- Low stresses in concrete.
- Low stresses transmitted by the foundation to the rock.
- Temperature variations produce only small variations in stress.
- The spillway can easily be combined with the dam (directing floods directly underneath).

Disadvantages:

- There are significant pressures in the foundation.
- Medium risk of subsidence.
- The volume of concrete is important (for the hollow gravity dam it is lower).
- Fragility to earthquakes (if the joints between the blocks are not made by injections).

II.2.1.2 Buttress dam

Buttress dams are concrete dams made of:

- Walls, usually triangular in shape, built in the valley parallel to the axis of the river. These walls are the buttresses.
- Gates between the buttresses to hold the water in the reservoir. These gates rest on the buttresses to which they transmit the water's thrust.

Definition : Dams Movable element of a dam whose operation allows the upstream level of the watercourse to be regulated.

The buttresses are very often inclined downstream so that the water pressure is directed downwards in order to improve the stability of the buttresses. In the transverse direction, particularly with regard to seismic effects from bank to bank, the buttresses can be fitted with struts.

Figure 2-3) Curved slab buttress dam; multiple arch.

❖ **Advantages and disadvantages**

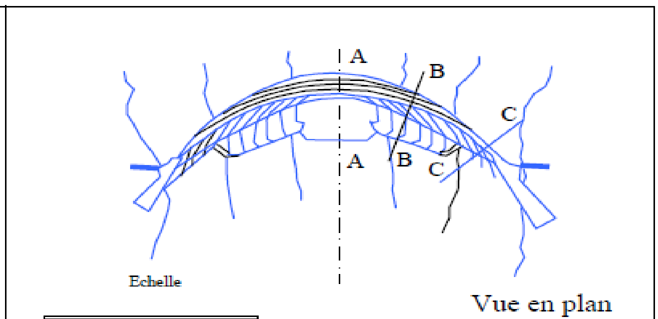
Benefits :

- ✓ Buttress dams are suitable for all types of valley, even fairly wide valleys.
- ✓ Typically require less than half the volume of concrete required by gravity dams
- ✓ They have an optimal inclination towards the upstream and ensure dissipation of underpressures
- ✓ Allow for differential settlement between the buttresses as well as easy inspection of the facing
- ✓ Creager type spillways are easily adapted to these structures.

Disadvantages:

- ✓ Buttress dams require extensive and complicated formwork and are not necessarily less expensive than gravity dams.
- ✓ Significant formwork work and quantities of steel
- ✓ Large numbers of sealing gaskets
- ✓ The rapid increase in labor costs in recent decades has caused buttress dams to lose much of their popularity.

II.2.1.3 Arch dams



a. Simple vault

The arch dam is generally a concrete dam

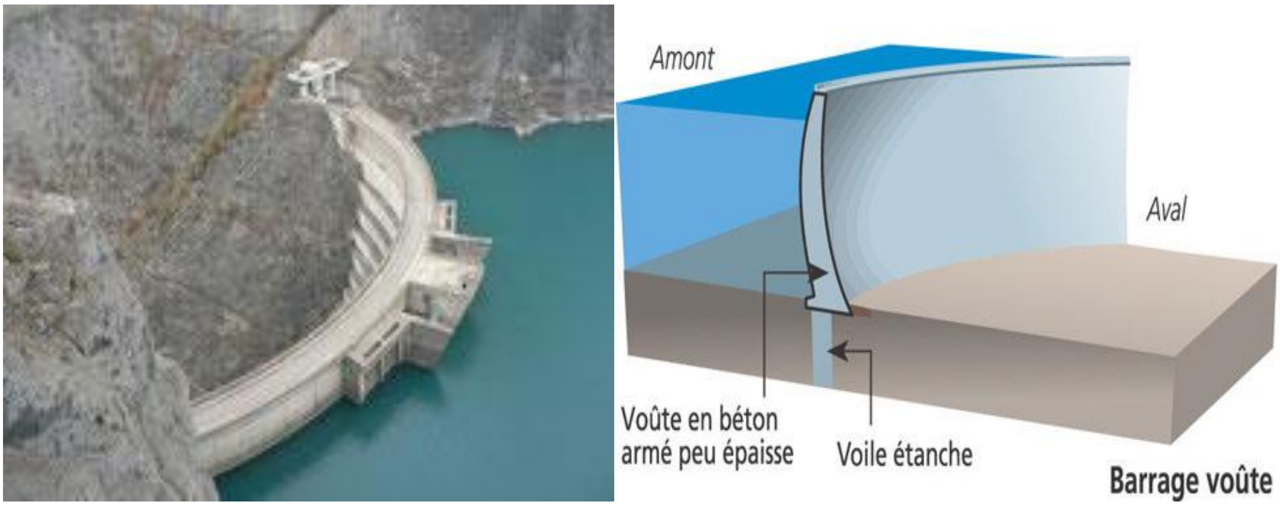
whose curved shape allows for the transfer of forces

water thrust on the rocky banks of the valley.

- ***Benefits :***

✓ The volume of concrete is small.
✓ Earthquake resistance is high.
✓ Underpressures at the foundation level
foundation surface is small).

Figure 2.4: arch dam (Ginocchio , 1959).



- ***Disadvantages:***

✓ The constraints are significant in concrete and in rock.
✓ The forces are transmitted obliquely in the supports.
✓ Medium risk of subsidence.
✓ The integration of the flood spillway (large flows) into the dam is difficult.
✓ The gradient of the uplift pressures at the foundation level is very large.
✓ Underpressure in rock cracks can cause support slippage.

b. multiple vault

A multiple-arch dam comprises two distinct parts, each playing a specific role:

✓ A waterproofing mask consisting of a number of thin concrete or reinforced concrete vaults

- ✓ Concrete buttresses on which the vaults rest and which transfer the thrust exerted by them to the ground.

Roselend Dam (photo h. Barthélémy).

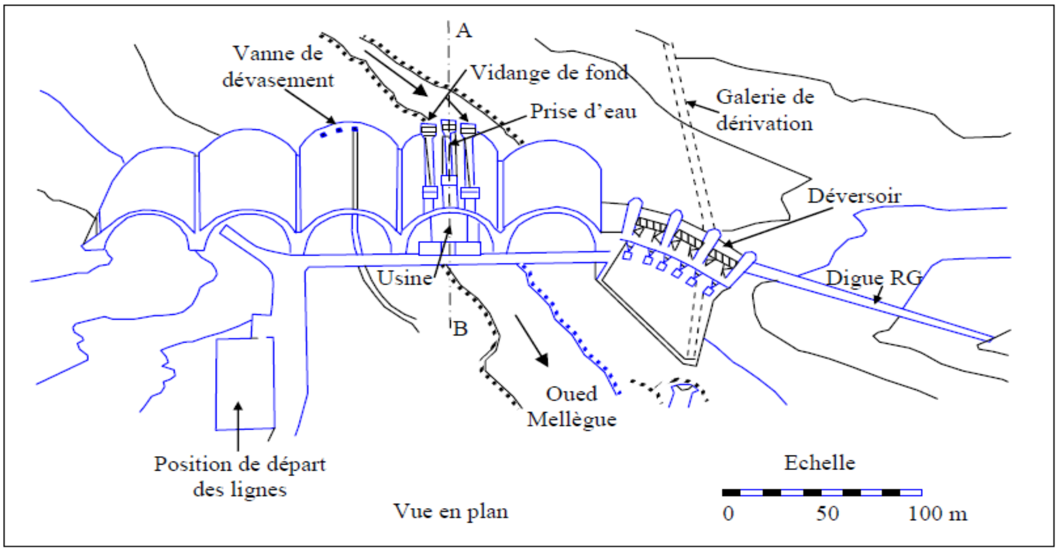


Figure 2.5: Mellègue Dam , Tunisia

❖ Advantages and disadvantages

Advantage :

- ✓ The volume of concrete is small.
- ✓ The excavation is quite small.
- ✓ The underpressures at the foundation level are low.
- ✓ Concrete heating is very low during construction.

Disadvantages

- ✓ The constraints are significant in the vaults.
- ✓ High risk of settlement. Temperature constraints can be very high.

- ✓ Very susceptible to earthquakes.
- ✓ Combining the dam with the spillway is difficult.
- ✓ Underpressure in rock cracks can cause support slippage.

II.2.1.4 Roller-compacted concrete dams (RCC)

Since the late 1970s, a new technology has been developed to optimize gravity dam construction: roller-compacted concrete (RCC). The placement of RCC concrete allows the use of very dry concrete with a low cement content. The resulting particularly low strengths are compatible with the requirements of gravity dams, which oppose the thrust of the water by their own weight. The properties of concrete are best exploited by implementing placement and compaction techniques derived from embankment dams.

Photo of a roller-compacted concrete dam BCR

❖ **Advantages and disadvantages**

- ***Advantage :***
- ✓ The low volume of cementitious materials compared to that of aggregates, which constitute approximately 85% of the volume of RCC;
- ✓ Low production, installation and compaction costs (little or no formwork)
- ✓ Fast construction pace (high placement rate)
- ***Disadvantages***

The main disadvantage of RCCs is the production rate that can be achieved with conventional production equipment. In most projects carried out to date, conventional concrete mixers used for RCC production do not necessarily seem to be designed to mix RCCs, which have a much drier consistency.

Therefore, to obtain a homogeneous mixture, the volumes of BCR to be mixed must be smaller, which lengthens the mixing time and reduces the production rate.

II .2.2- Embankment dams (made of unassembled materials)

Embankment dams are all dams built with earth materials. This category of dams includes several categories that differ in terms of the types of materials used and the method used to ensure waterproofing. Thus, construction materials can have a wide range of grain sizes, from very fine to coarse.

The use of generally cheap local materials and their availability close to the site makes the solution: embankment dam intuitively chosen compared to other types of dams.

Photo of a general view of an embankment dam.

II.2.2.1- Earth dam:

Compacted earth dams can be divided into three main types: homogeneous earth structures, those with watertight cores and those with upstream masks.

Photo of a general view of an earth dam.

a) Homogeneous earth dams

They are entirely constructed with a single material
Which is most often clayey filling
Simultaneously both screen and ground functions.
This material must have characteristics
Ensure sufficient sealing
And stability of the embankment (Fig.2.6).

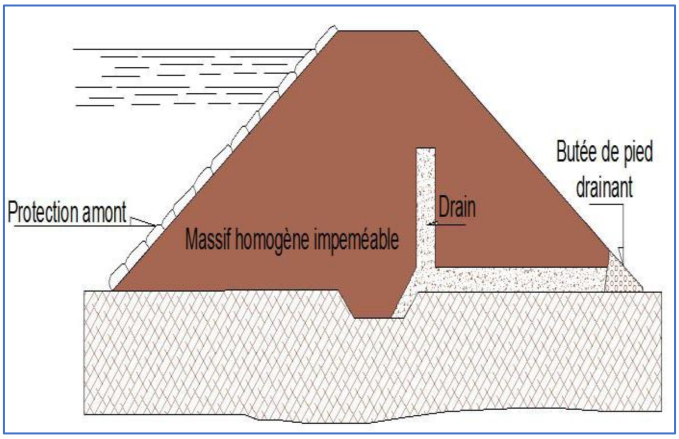


Fig.2.6. Homogeneous earth dam

b) Earth dams with a watertight core

In the event that the quantity of materials

Raincoats available on site are insufficient

To make the entire body of the dam, we opted

Most often for a work with zones with

A clay core ensuring waterproofing.

The watertight core can be vertical or inclined

Figure 2.7.

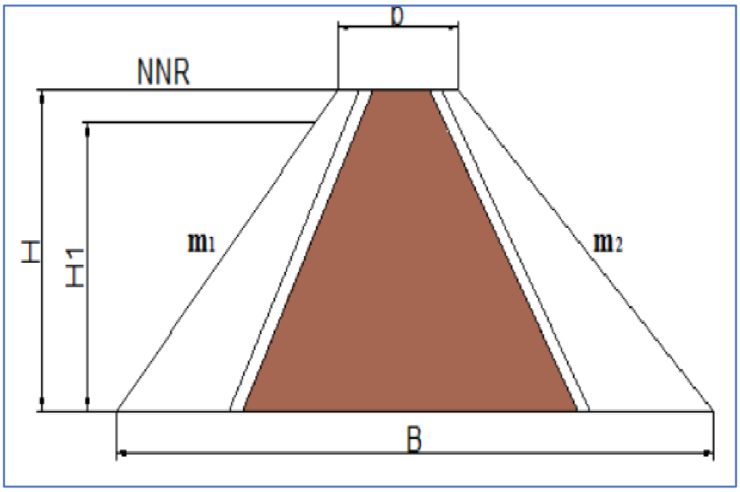


Fig.2.7. Earth dam with watertight core

- ***Benefits :***
- ✓ The dam body is very flexible and adaptable to ground conditions.
- ✓ Use of local materials for the construction of the dam body
- ✓ Small to medium excavation. The dike is not necessarily founded on sound rock.
- ✓ The soil compression is low.
- ✓ The gradient of the uplift pressures at the foundation or core level is low.
- ***Disadvantages:***
- ✓ Installation of large volumes of materials.
- ✓ The clay core embankment is influenced by atmospheric conditions (climate rain).

Earth dams with upstream mask

Earth mask dams are embankments
Permeable with an impermeable screen called
Mask placed on the upstream facing. Figure 2.8.
The body of the dam is constructed with a material
any as long as it is not very deformable

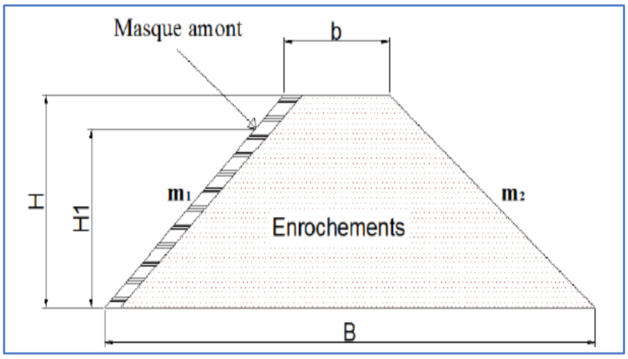


Fig.2.8 Upstream mask dam

And able to ensure the sliding stability of the entire structure.
The mask that ensures the seal can be made of concrete,

In bituminous products or geomembrane.

- ***Benefits :***
- ✓ The dam body is very flexible and adaptable to ground conditions.
- ✓ Limited settlements are tolerable.
- ✓ Not very susceptible to earthquakes. Below the mask, an efficient drainage system is necessary due to cracking.
- ✓ The volume of debris is average.
- ✓ The mask must be connected to the rock (directly or by a cut-off device).
- ✓ The soil compression is low.

- ***Disadvantages:***
- ✓ Installation of large volumes of materials.
- ✓ Inability to discharge flood flow above the dam crest
- ✓ Presence of water flow in the body of the dam (possibility of deformation).
- ✓ Large water losses through the dam and its foundations.

II.2.2.2- Rockfill dams

In general, this type of dam is composed of rockfill with a volume of between 0.1 and 10 m3 (0.25 to 25 tonnes). The rockfill is implemented in two different ways. It can be arranged by hand or by crane, or it can be deposited in bulk. The disadvantage of the latter method is that the structure is subject to significant settlement after completion (of the order of 5% of the height). This can be reduced by spraying with high-pressure water during construction. This spraying will allow the fine elements to be driven out between the contact points of the rockfill and consequently to fill the spaces between large stones with fine elements.
Figure II-2.8 shows a typical cross-section of a trapezoidal rockfill dam.
Rockfill dams are widely used in remote areas where cement is expensive and the materials for an earth dam are not available.

Photo of rockfill dam

These structures can be built on a non-rocky foundation soil, provided that it is sufficiently strong not to cause the waterproofing mask to rupture due to settlement.

The slope of the embankments is of the order of 1:1. Low rockfill dams can have steeper embankments, 1:2. In general, the downstream embankment has a slope of 1:1 to 1:3, corresponding to the internal friction angle of the rockfill. For dams higher than 60 m, the upstream embankments generally have slopes of 1:1 to 1:3.

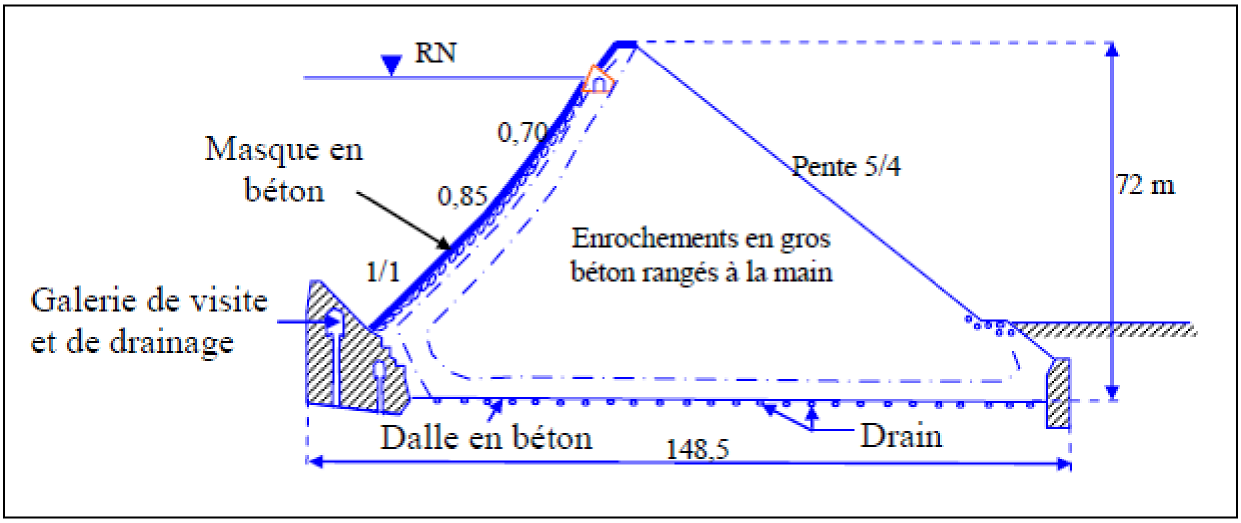


Figure II-7.7: Ghrib rockfill dam (Ginocchio , 1959).

- ***Benefits :***
- ✓ The dam body is very flexible and adaptable to ground conditions.
- ✓ Little susceptible to subsidence and earthquakes.
- ✓ Small to medium excavation. The dike is not necessarily founded on sound rock.
- ✓ The soil compression is low.
- ✓ The gradient of the uplift pressures at the foundation or core level is low.
- ***Disadvantages:***

- ✓ Installation of large volumes of materials.
- ✓ Leaks are frequent there
- ✓ Significant settlements at the time of the first filling after the end of construction
- ✓ Vertical and horizontal displacements greater than 5% were observed

II-3 Sealing elements

The waterproofing elements consist of two parts: one at elevation and the other at foundation.

a) Elevation mask

In elevation, the mask is made up of a layer of waterproof materials generally placed on **the upstream facing** . This layer is either:

1) a **reinforced concrete slab** with bituminous joints

2) a layer of **bituminous concrete** 10 to 15 cm thick resting on a concrete form and protected by a layer of reinforced concrete.

In both types, the masks are placed on a layer of stones arranged several meters thick between two filter layers (sand and gravel) which prevent the core materials from being carried into the body of the structure (downstream filter layer) or through the protective coating (upstream filter layer).

b) Foundation mask

When the foundation ground is permeable, the elevation mask is extended by a cut-off similar to that made for earth dikes.

c) Central core dam: the core is made of impermeable or partially permeable soil to ensure watertightness, but the stability of the massif will be ensured by permeable zones called recharges (CHERIF, et al., 2013).

d) Sloping core dam : in this case the core is moved upstream. The potential sliding surfaces cross the core and the slope of the upstream face is therefore gentler to ensure stability. The mass of the downstream support body also increases, which represents a certain advantage for the dam.

Classification of dams

Dams are classified according to different criteria:

a) The height
   - Small dams
   - Large dams

b) Elasticity
   - Rigid dams
   - Flexible dams

c) Materials used for construction
   - Concrete dams (BCR, BCV)
   - Masonry dams
   - Embankment dams
     - earth dams
     - rockfill dams
     - homogeneous

  - with internal screen
  - with upstream core
  - with central core
  - with inclined core
  - with cut-off

d) Shape
- Straight dams
- Curvilinear dams

e) Resistance to water thrust force
- Massive gravity dams
- Arch dams
  - multi-arch dams
- Buttress dams

Massive gravity dams have the characteristic of resisting the pressure of water due to their weight. Arch dams, on the other hand, distribute water pressure along the banks.

Conclusion on the choice of dam type

The choice of the type of dam is a natural one in many cases, without the need for extensive investigations.

Thus, when the bedrock is at a depth greater than approximately 5 metres, only an embankment dam is reasonably feasible, at least for structures less than 25 metres high.

In some regions, the geological context is such that the type of dam is almost always the same. In other cases, the choice of dam type will be a compromise between the following different aspects: nature of the foundation, availability of nearby materials, hydrology, to arrive at the most economical choice. But it will always be in your interest to choose as quickly as possible, generally after the feasibility studies have been completed.

Useful links

- https://youtu.be/wAY41zKhITU
- https://youtu.be/ggdLZ2_EmOo
- https://youtu.be/hngdM-ZPQy0

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