Abdelhafid University Center Bousouf - Mila
2024-2025 Semester 1

Hydraulic works

– Course 3 –

Chapter 03 : Determination of the height of the dam and sizing of the reservoir .

Teaching staff			
Name	**Grade**	**Institute**	**E-mail address**
Boumessenegh Amel	MCB	Science and Technology	a.boumessenegh@centre-univ-mila.dz

Students concerned			
Institute	**Department**	**Year**	**Speciality**
Science and Technology	GC and hydraulics	Year 3 license	Urban hydraulics

Course Objectives 3

- Explain the parameters influencing the height of a dam.
- Calculate the useful height of a dam based on characteristic levels (minimum, normal, maximum level).
- Identify the components of a reservoir: useful volume, dead volume, flood volume.
- Evaluate storage needs according to uses (drinking water, irrigation, energy, regulation).
- Size a reservoir by integrating hydrological inputs, losses and safety constraints.

Introduction

The height of a dam and the sizing of its reservoir are essential elements in the design of a hydraulic structure. These parameters determine the storage capacity, the stability of the structure, and the efficiency of water resource management. Determining the height is based on analyzing the characteristic levels of the water body, while sizing the reservoir requires a precise assessment of inputs, losses, uses, and safety margins. This course aims to provide the methodological foundations for designing a reservoir adapted to the hydraulic and environmental objectives of the project.

Feasibility of a dam

Stages of the feasibility study:

III-1. Topographic and geomorphological study

- Geographical location, - Choice of the dike axis, - Geomorphological characteristics of the watershed, - Shape characteristics, Gravellius compactness index , Equivalent rectangle. – Hypsometry,

- Hydrography, -Morphometry.

<u>III-2- Geological and geotechnical study</u>

<u>III. 2- 1- Geological and Hydrogeological Study</u>

- Geology of the site and the basin, - Overview of hydrogeology, - Seismicity of the site, - Construction materials, - Foundation of the dike.

III. 2- 2- Geotechnical study

- Reconnaissance works: - Dam site, Borrowing areas, Site for supplying soil for the dike and rock quarry, Study of the characteristics of the foundation and backfill soil (Laboratory).

III-3- Hydrological study

The hydrological study of a dam project aims to estimate all the hydrological parameters necessary for the sizing of the structures.

It is therefore necessary to be concerned with the conditions for filling the reserve on the one hand and to ensure that the dam does not become an obstacle to the passage of floods which could submerge it.

To this end, it is necessary to study:

Monthly and annual contributions.

Instantaneous flow rates to define the maximum floods that can enter the reservoir.

For this study it is necessary to have all the data:

- Climatic (Temperatures, Precipitation).
- Fluid Intake (Estimate of Fluid Intake).
- Flow studies (Pj_{max} , Short-term rainfall, Determination of flood flows, Flood volumes and hydrographs).
- Studies of solid contributions.
- Study of regularization .
- Flood rolling.

III-4- Technical Study

It is the performance of calculations and necessary measurements during the development of the project while respecting economic conditions (minimizing the cost).

This study consists of the design of the dam and studying the following problems:

- Avoid all danger of submersion.
- The saturation line must not exceed the level of the drainage mass (Case of embankment dam).
- and downstream embankments must ensure the stability of the dam.
- The absence in the body or in the base of any preferential passage allowing water to flow from upstream to downstream.
- Sealing against leaks and water that manages to pass through the body of the dam or the bedding ground must come out downstream with as low speeds as possible in order to prevent fine materials from being carried away.
- The upstream facing must be protected against the action of waves and floating bodies

, and the downstream facing against erosion caused by rainwater and wind.

III-4-1. Dam design

The type and design of the dam (general profile of the dam) is chosen according to local site conditions.

III-4-2. Dam sizing

❖ General profile of the dam :

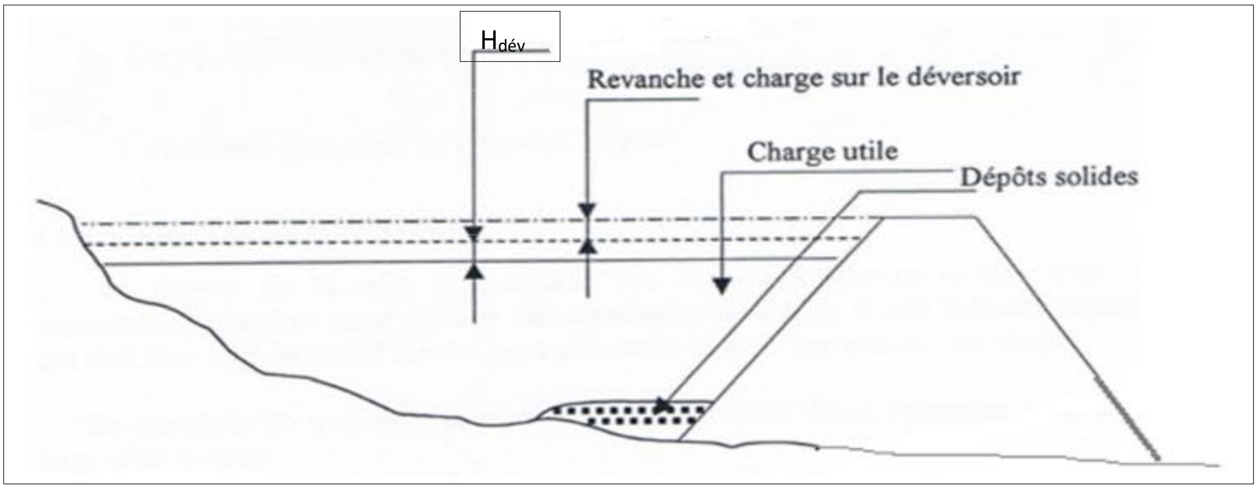


Figure 3.1. General profile of a dam

The type of earth dam being considered is chosen according to the local conditions of the site and the importance of the structure. The next stage of the studies consists of defining the general profile of the dam.

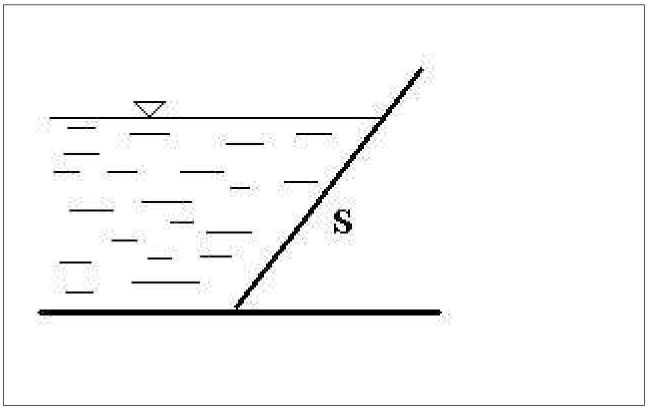
a) Dam height

The height of the dam is equal to the normal height of the reservoir (*NNR*), increased by the maximum load above the threshold of the flood spillway (*hd*) and the freeboard (*R*).

$$H = H_{NNR} + H_{dev} + R$$

b) Normal reservoir level (NNR)

The retention height is calculated taking into account the useful capacity to be stored, the dead section, possibly provided at the bottom of the reservoir to store deposits, and the section corresponding to losses by evaporation and infiltration.



c) Highest water level:

The maximum load above the flood reservoir depends on the characteristics of the flood spillway defined according to the hydrology of the reservoir catchment area and flood lamination.

It is determined by the study of the flood spillway.

The highest water level is called the normal level of the reservoir plus the load on the flood spillway.

$$\textbf{NPHE} = \textbf{NNR} + \textbf{H}_{\textbf{dev}}$$

d) Revenge:

It is a section between the highest water level (NPHE) and the crest of the dam. To determine it, we must take into account the height of the waves that form on the body of water and the projection of the water towards the top of the dam, which is due to the speed of propagation of the waves when they are against the dike.

Revenge$\mathbf{R} = \mathbf{0,75} h_v + \frac{V_v^2}{2g}$

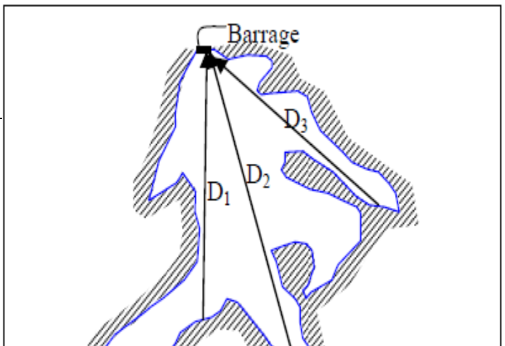
With :

R : revenge (in m).

g= 9.81 m ^{2} /s

Vv : wave speed (in m/s). **Evaluate using the Gaillard formula $V=1.5+2h_v$**

hv : wave height (in m)



Si F< 30km $h = 0.76 + 0.032\,.\sqrt{V.F} - 0.26.\sqrt[4]{F}$

Si F>30km $h = 0.032\,.\sqrt{V.F}$

V – average wind speed (in km/hour)

F : Fetch or length of the water body in (km)

Or by the simplified formula: $\mathbf{R=1+0.3\sqrt{F}}$

Figure .3.2 : Fetch definition .

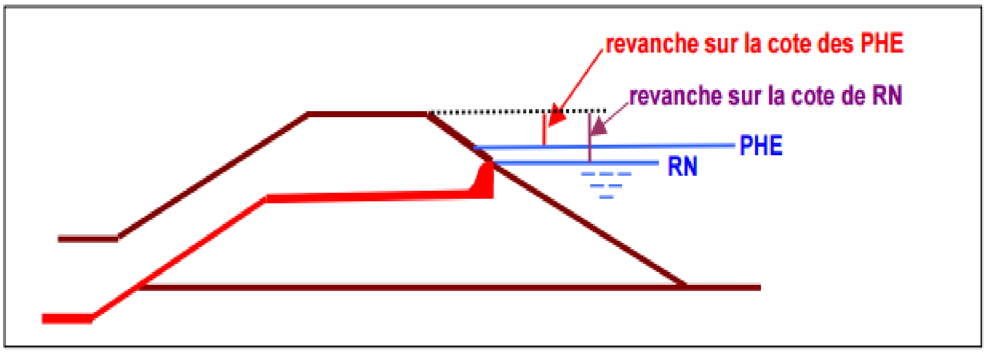


Figure 4.3 – Revanche sur les PHE ou sur la RN pour un barrage non équipé d'un mur pare-vagues

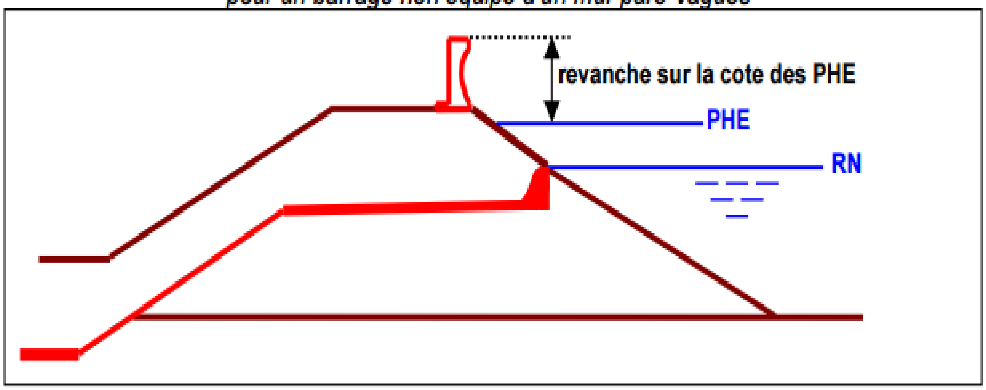


Figure 4.4 – Revanche sur les PHE pour un barrage équipé d'un mur pare-vagues

e) Width at dam crest:

The crest width "L" is generally determined by one of the following formulas where "H" is the height of the dam in m .

For this we use formulas; the most applied among them are:

a) T. KNAPPEN formula

$$b = 1{,}65\sqrt{Hb}$$

b) EF PREECE formula

$$b = 1{,}10\sqrt{Hb} + 1$$

Rolley formula , R

$$b = 3{,}60\sqrt[3]{Hb} - 3$$

By being:

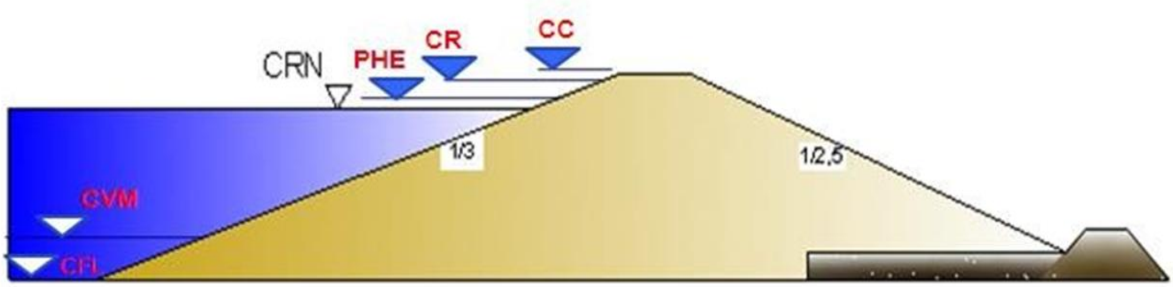
b the width of the crest and *Hb* the height of the dam.

For dikes with heights less than 10 m, the crest width should not be less than 3 m. For dikes with a height greater than 10 m, the crest width will be equal to 1/3 of the height of the dike, but in general it is recommended that the width be 4 to 6 m.

f) Crest Coast (CCB)

The coast of the dam crest is leveled to the corresponding coast at the level of the highest water (PHE), increased by the freeboard (R).

CCB = PHE + R



CFL : Côte fond du lit

CVM : côte du volumemort

CRN : Côte retenue normale

PHE : Côte des plus hautes eaux

CR : Côterevanche

CC: Côte crête dubarrage

CVM –CFL: Volumemort

CRN -CVM : Volume utile de laretenue

CRN : Charge sur le déversoir

CR –CPHE: Revanche

CC–CR: Sécurité +tassements

Hauteur totale du barrage hors fondations = CC – CFL

II.5- slopes of the embankments of the dike:

The slope of the earth dam embankments is determined by the stability conditions of the massif and its foundations.

To determine the slope of the facings, we generally give ourselves slopes which appear optimal, taking into account the nature of the materials, and we verify by a stability study that the dam presents sufficient safety with these slopes.

(Table I) gives some values which will have to be confirmed by a stability study:

Table 3.1 - slope values of slopes

Height of the Dam (m)	Dam type	Slopes of the facings	
		Upstream	Downstream
3 to 5	-Homogeneous -A zones	1/2.5 1/2	1/2 1/2
5 to 10	-Homogeneous, wide grain size - Homogeneous, with a high percentage of clay -A zones	1/2 1/2.5 1/2	1/2 1/2.5 1/2.5
10 to 20	-Homogeneous, wide grain size - Homogeneous, with a high percentage of clay -A zones	1/2.5 1/3 1/2	1/2.5 1/2.5 1/3
20 and over	Homogeneous, wide grain size - Homogeneous, with a high percentage of clay -A zones	1/3 1/3.5 1/3	1/2.5 1/2.5 1/3

The foundation of the structure must also be mechanically stable. Therefore, it is not only the dam mass that must be considered, but the entire mass and foundation. When the foundations are of poor quality, for example clayey, the slope of the embankments must be reduced by widening the entire structure.

- ❖ **Risberme**

Definition: Protective embankment built at the base of a bridge, dam or hydraulic structure.

When Hb > 10m , build the dam with variation in the slope of the embankments to ensure stability.

The change in slope is 10 to 15m, it is 0.5 upstream and 0.25 downstream, this change in slope can be carried out with or without a berm.

The minimum width is 3.5 and 4 m.

The berm aims to:

- Monitoring the condition of the slope covering and possibly its protection.
- Increased base width to extend streamlines.
- Introduction of the cofferdam into the body of the dam planned during construction.
- Allowing for changes in slopes of embankments.
- Allow trucks to pass

The width of the berms is 2 to 3m if no traffic lanes are provided.

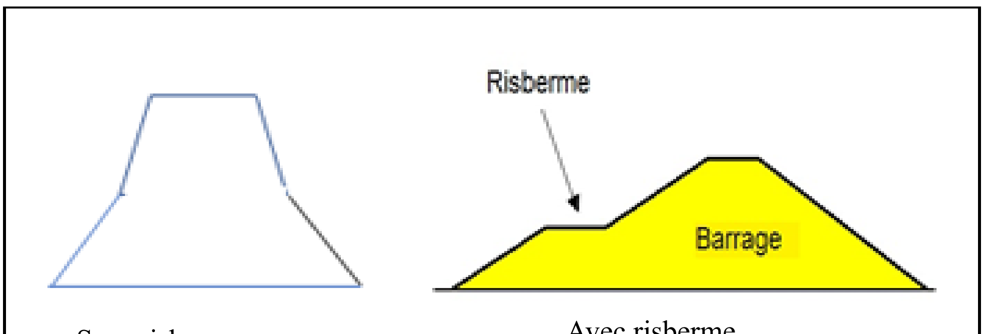


Fig.3.3 Berms

III-6- Protection of the dike

Introduction

Slope stability problems are frequently encountered in the construction of roads, canals, dikes, and dams. In addition, some natural slopes are or can become unstable. A slope failure can be catastrophic, causing loss of life and considerable natural hazards.

The following study is general and can be applied to all of these structures that we will call "slopes".

III-6-1- Protection of slopes

When constructing an earth dam, the upstream and downstream slopes must be protected against erosion caused by wind and rain.

It is also imperative to protect the dam against the phenomenon **of foxing** and resurgence (return) which is harmful to the stability of the dam.

A **hydraulic fox is a very dangerous internal** erosion phenomenon that occurs in a hydraulic structure from downstream to upstream . It is the second most common cause of failure for dikes , and one of the main causes of failure of earth dams, responsible for about half of the failures of embankment dams .

Photo shows the fox phenomenon.

III-6-1-1The downstream slope

The most economical protection is to sow the grass on the slopes, directly after the completion of the earthworks, covered the slope with a layer of topsoil varying from 10 to 15 cm.

In the case of relatively high dams subject to heavy rainfall, small berms or ditches parallel to the crest line can be provided, which will intercept the runoff water before it reaches the foot of the slope at too high a speed.

However, infiltration water can also be considered a danger to the stability of the structure, hence the need to have a drain at the foot of the dike.

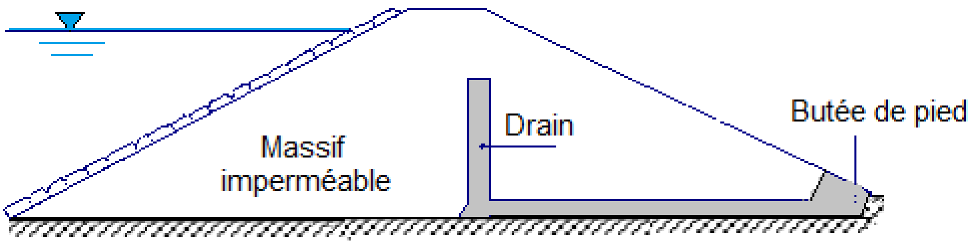


Figure 3.4: Homogeneous earth dam with drain

III-6-1-2 The upstream slope

This slope is protected against the effect of waves by a layer of rockfill (stone protection) or by a waterproof coating (bituminous concrete). Therefore, for protection, loose rockfill of the rip-rap type is provided; before laying the stones, a draining layer of gravel and sand of approximately 30 cm must be placed, forming a filter .

In the case of permeable ground or high hydraulic heterogeneity (dam or foundation soil), the screen can be placed on the facing of the upstream slope, and possibly extended vertically through the foundation to the center of the dike.

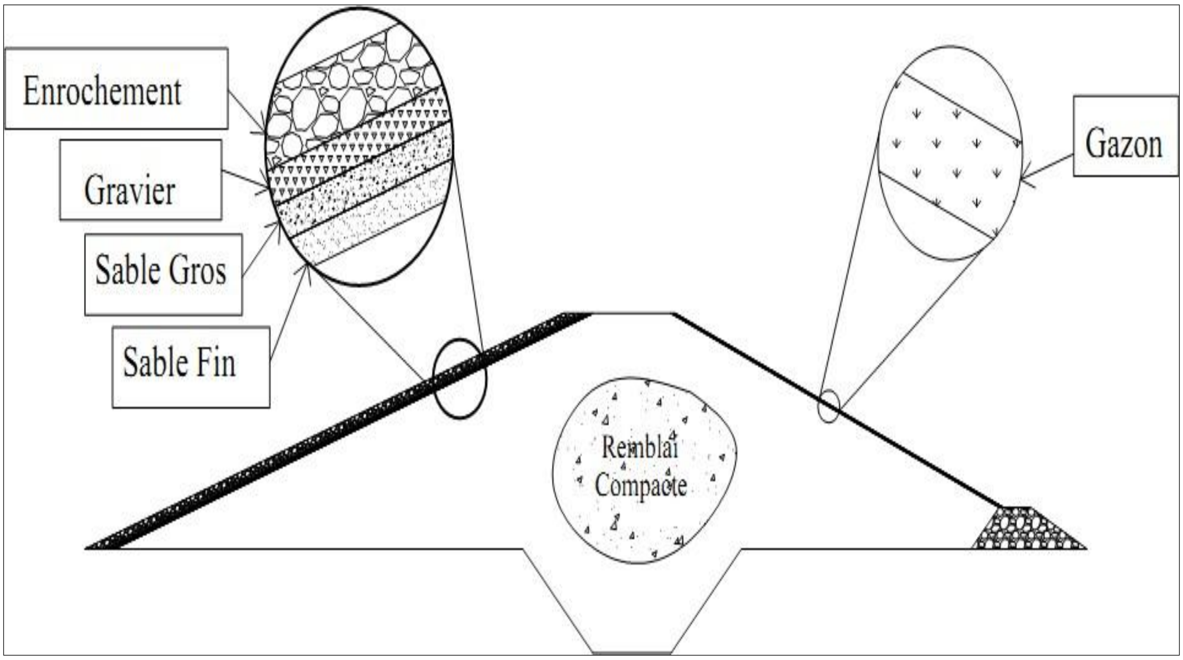


Figure No. (3.5): Protection of upstream slopes by rip-rap rockfill.

The dimensions of the rockfill can be determined theoretically as a function of the wave height H_V and their speed V, by the following formula:

- **Loose rockfill:**

It is the most used material for the protection of the upstream slope.

The dimensions of the rockfill can be determined theoretically by the following formula:

$$e = C.V^2$$

e : Thickness of the rockfill in m

V : Wave propagation speed in m/s

C : Coefficient in the value of C is given by (table 2)

Table 3.2- value of C

Slope of embankment	Value of C for different specific weights		
	γ =2.5	γ =2.65	γ =2.8
1/4	0.027	0.024	0.022
1/3	0.028	0.025	0.023
1/2	0.031	0.028	0.026
1/1.5	0.036	0.032	0.030
1/1	0.047	0.041	0.038

Half of the rockfill must consist of elements of a unit weight w such that $\mathbf{w \geq 0.52.\ C.\ e^{3}}$

III-6-1-3 **Ridge protection:**

To protect the dike crest from possible cracking caused by atmospheric agents, it should be protected by using a 0.15m bituminous layer.

In particular, it helps prevent the formation of ruts caused by the passage of vehicles, and the drying out of the last compacted clay layers.

III-6-1-4 **<u>Determination of the different transition layers</u>**

Granulometric study (from a granulometric analysis in the laboratory - curves) of:

- Embankment materials from the dike.
- Filter and drain materials.
- Calculation of filters and transition layers (Zones).
- Checking for the absence of the fox phenomenon.

Useful links

- https://youtu.be/65Ee-4RC_bY
- https://youtu.be/tIno0da06Pc

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