# Design of a reservoir hydropower scheme

**Arthur Guillot - Le Goff**

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**Design of a reservoir hydropower scheme**
- Task 1: Determine the design of a gravity dam, height H to satisfy safety factors against sliding and overturning.
    - Finding measurement
    - Stability analysis
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# Task 1: Determine the design of a gravity dam, height H to satisfy safety factors against sliding and overturning.

## Finding measurement

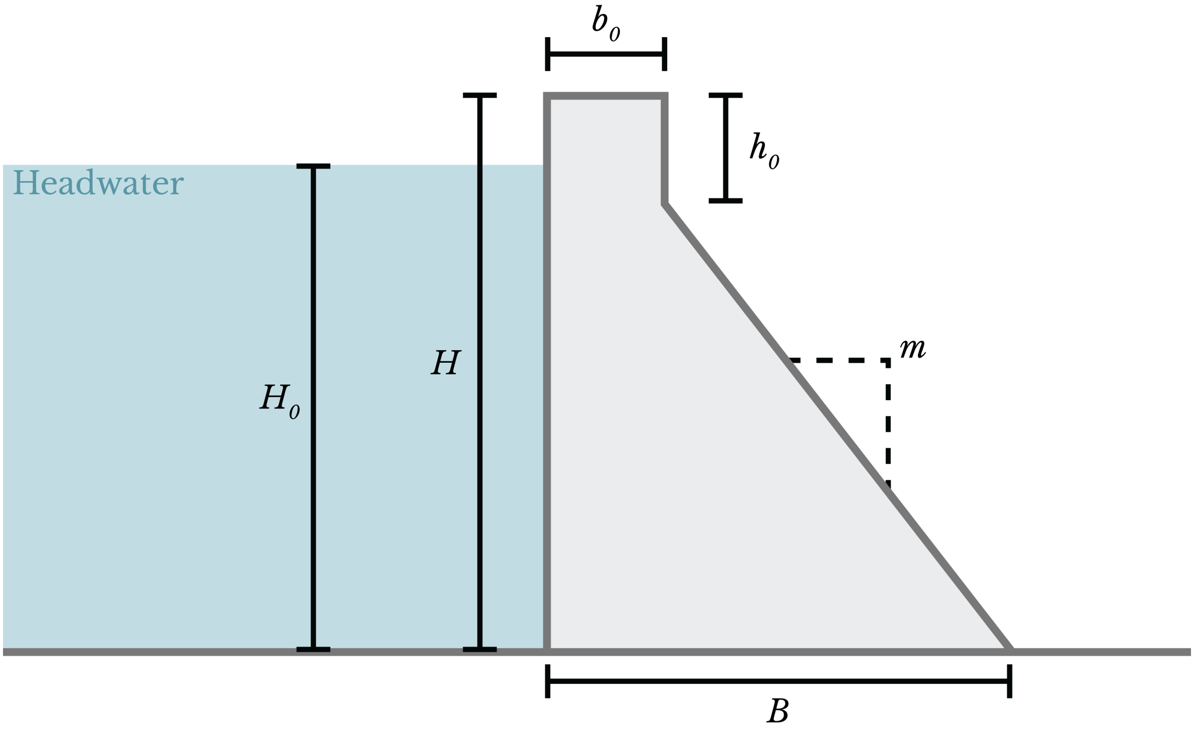


*Figure 1 : Introduction to notations for the gravity dam measurements*

According to the Bureau of Reclemamation of the USA departement of the intrior "Design of gravity dams" paper we can calculate the missing dimensions according to the current standards.

$$m = \frac{B}{H} = \frac{b_0}{h_0} \simeq 0,8$$

$$b_0 = \frac{H}{10} \geq 8m$$

We can therefore calculate :

- $B = m.H = 0,8 \times 71 = 56,8$m
- $b_0 = \frac{H}{10} = \frac{71}{10} = 7,1m \leq 8$, so we choose $b_0 = 8m$
- $h_0 = \frac{b_0}{m} = \frac{8}{8,0} = 10m$

## Stability analysis

Now we have to figure out the weakpoints ans the critical failure modes. We can identify three of them:

- **Sliding** : too much pressure causes the dam to move in the horizontal plane. The following safety factor is then considered: $n_{SL} = \frac{\sum V}{\sum H}$. Where $\sum V$ represent the sum of the vertical efforts and $\sum H$ for the horizontal ones. To meet the safety requirements $n_{SL} > 3$ for the usual load case.
- **Overturning** : the dam rotates around a fixed point. In our case and as shown in the diagram the lower end on the right. The safety factor is described as, $n_{OV} = \frac{M_{stab}}{M_{dest}} > 2$.
- **Crushing :** in this case we are looking at compression and tension failure.

## Load Combination

### 1 - Usual load combination

For this example we have chosen to consider the usual load case. It is then a question of determining the set of forces wich have a reasonable probability of simultaneous occurence. The problem will be solved with the following assumptions :

- The reservoir is at his operational level ($H_0$),
- we are considering the dead load of the dam,
- the uplift pressure is at his full drainage capacity,
- there is a presence of silt that affect the dam.

We can report on the following efforts :

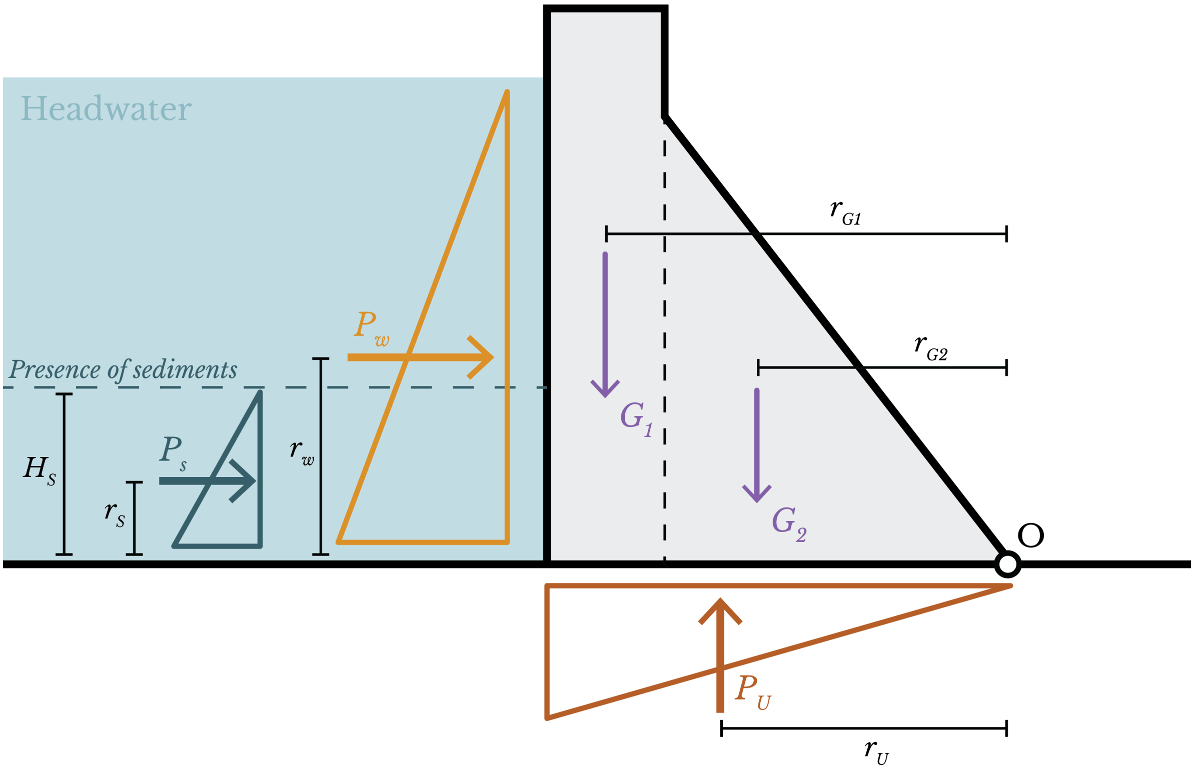


*Figure 2 : Efforts on the dam*

Where :

- $G_1$ and $G_2$represent the **dead load** of the dam. The following formulas describing the effort are then considered :
    - $\gamma_{conc} = 24$ kN/m³
    - $G_1 = b_0 . H . \gamma_{conc} . e = 13632$ kN
      where $e$ is the thickness of the study section ($e = 1$ m), so we won't consider it in the next equations
    - $G_2 = \frac{1}{2}(B - b_0)(H - H_0)\gamma_{conc} = 35721$ kN
    - $r_{G1} = B - \frac{b_0}{2} = 52,8$ m
    - $r_{G2} = \frac{2}{3}(B - b_0) = 32,5$ m
- $P_w$ the **hydrostatic pressure** on the dam :
    - $\gamma_w = 10$ kN/m³
    - $P_w = \gamma_w . \frac{H_0^2}{2} = 21125$ kN
    - $r_w = \frac{1}{3} . H_0 = 21,7$ m
- $P_u$ the **uplift pressure** on the dam :

- To reduce the effect of uplift, draingaes to the ground are installed in the dam. This reduction is associated with the coefficient $\lambda = 0,85$
    - $P_u = \lambda . H_0 . \gamma_w . \frac{B}{2} = 15691$ kN
    - $r_u = \frac{2}{3} . B = 37,8$ m
- $P_s$the **silt pressure** on the dam :
    - $\gamma_S = 18$ kN/m³
    - $H_S = \frac{H_0}{3} = 21,6$ m
    - $P_S = \gamma_S . \frac{H_s^2}{2} = 4225$ kN
    - $r_S = \frac{H_s}{3} = 7,2$ m

<u>We can therefore calculate our safety factors :</u>

$$n_{SL} = \frac{G_1 + G_2 - P_u}{P_w - P_S} = 1,99$$
$$n_{OV} = \frac{G_1 . r_{G1} + G_2 . r_{G2}}{P_w . r_w + P_S . r_S + P_u . r_u} = 1,74$$

We can now conclude that the current design of the dam does not satisfy the safety criteria because $n_{SL} < 3$ and $n_{OV} < 2$.

## 2 - Flood load case

In this second case, we are considerating the same problem as the previous case, whereas the reservoir is at his flood level : $H_0 = H$

For this case the safety factors we have to check have different values : $n_{SL} > 2$ and $n_{OV} > 1,5$.

<u>By doing the same calculation we can calculate our new safety factors :</u>

$$n_{SL} = 1,6$$
$$n_{OV} = 1,5$$

For this second case we can conclude that a flood scenario could be critical for the dam can the safety critria are not respected.

## 3 - Extreme case : earthquake

For this last case, we are considering the following load combination :

- the dead weight of the dam,
- the reservoir at its operational level,
- the silt presence,
- the uplift pressure,
- the seismic failure,

For the modelisation of the seismic forces we are using the Chopra method and for our calculus we are looking at the worst scenario possible.

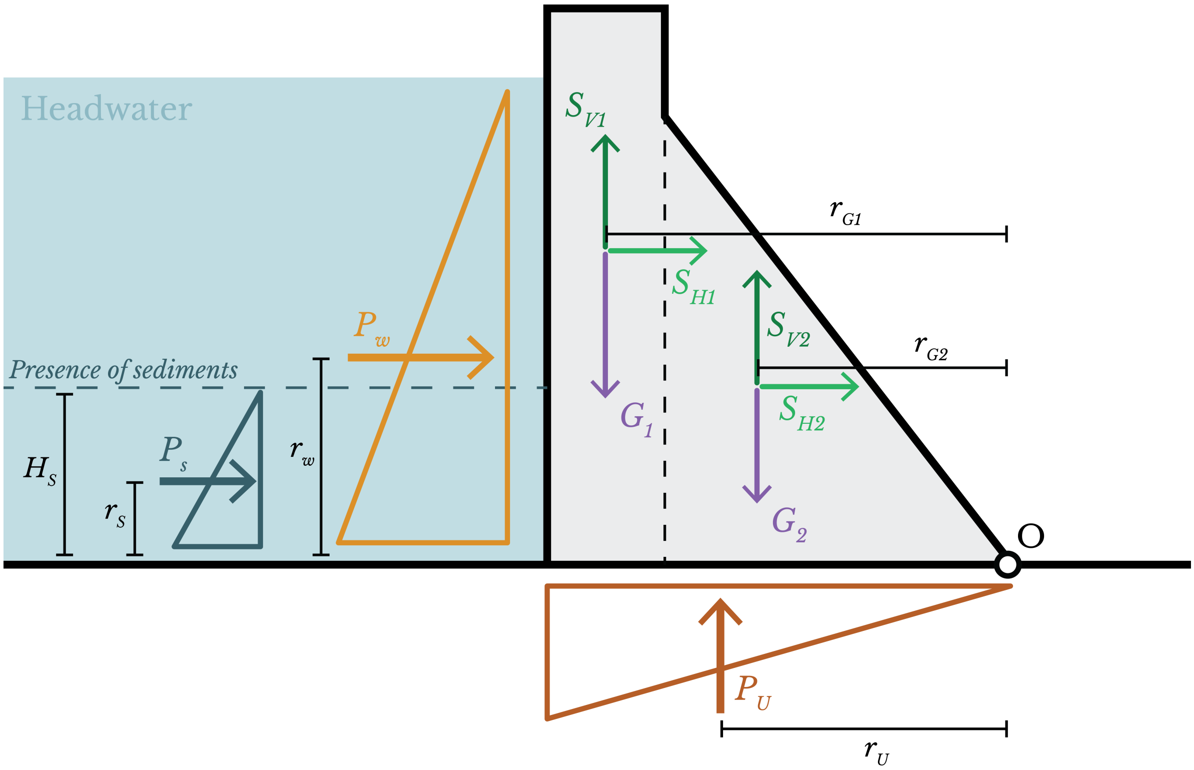


*Figure 3 : Efforts on the dam for the earthquake case*

As for dead loads, we devide our calculation in two parts :

- $S_V$ represent the vertical **effort of an earthquake** and $S_H$ the horizontal ones :
  - $\alpha = 0,1g$ the sismic cofficient
  - $S_{V1} = \alpha . G_1 = 13372$ kN
  - $S_{H1} = \frac{2}{3}\alpha . G_1 = 8915$ kN
  - $S_{V2} = \alpha . G_2 = 35042$ kN
  - $S_{H2} = \frac{2}{3}\alpha . G_2 = 23361$ kN

Our safety facors are : $n_{SL} > 1,3$ and $n_{OV} > 1,2$.

<u>We can calculate them :</u>

$$n_{SL} = \frac{G_1 + G_2 - P_u - S_{V1} - S_{V2}}{P_w - P_S - S_{H1} - S_{H2}} = 0,95$$

$$n_{OV} = \frac{(G_1 + S_{V1}).r_{G1} + (G_2 S_{V2}).r_{G2}}{P_w.r_w + P_S.r_S + P_u.r_u + S_{H1}.r_{G1} + S_{H2}.r_{G2}} = 1,6$$

As expected this case do not satisfy every safety criteria . Even though the overturning possibility respect its safety factor.

# Annex: calculation code

```
'''Finding measurement'''
H=71
m=0.8
B=m*H
b0=H/10
if b0<=8:
    b0=8
h0=b0/m
'''Load combination'''
#dead load
gconc=24
H0=H-6
G1=b0*H*gconc
G2=0.5*(B-b0)*(H-h0)*gconc
rG1=B-(b0/2)
rG2=(2/3)*(B-b0)
#hydrostatic pressure
gw=10
Pw=gw*0.5*H0*H0
rw=(1/3)*H0
#uplift pressure
gamma=0.85
Pu=gamma*H0*gw*B/2
ru=(2/3)*B
#silt pressure
gs=18
Hs=H0/3
Ps=gs*0.5*Hs*Hs
rs=Hs/3
#earthquake forces
a=9.81*0.1
Sv1=a*G1
Sv2=a*G2
Sh1=(2/3)*a*G1
Sh2=(2/3)*a*G2

'''security factors check'''
nsl=(G1+G2-Pu-Sv1-Sv2)/(Pw-Ps-Sh1-Sh2)
print("nsl=",nsl)
nov=((G1+Sv1)*rG1+(G2+Sv2)*rG2)/(Pw*rw+Ps*rs+Pu*ru+Sh1*rG1+Sh2*rG2)
print("nov=",nov)
```