DAMS AND SPILLWAYS

Definition: A dam is an impervious barrier built across a water course to store water for several purposes such as water supply, creating head, forming a lake etc.

Definition: A spillway is a component of a dam which serves to evacuate the flood wave from the reservoir without damaging the structure and environment.

Comparison of Weir and Dam

Weir	Dam
Σ Supply > Σ Demand	Σ Supply ≥ Σ Demand
Instantaneous Supply > Demand	S < D

Functions

to raise water	to store water
to divert water	to create head
to catch sediment	to form a lake

- Classifications of Dams:

Dams may be classified into a number of different categories, depending upon the purpose of the classification.

1) Classification according to use

a) Storage dams:

b) Diversion dams:

c) Detention dams:

d) Hydropower dams:

2) Classification according to structural type

a) Gravity (Ağırlık- dolgu) dams:

b) Arch (kemer) dams

c) Buttress (payandalı) dams

d) Fill (dolgu) dams

3) Classification according to materials of construction

a) Stone masonry

b) Concrete

c) Reinforced concrete

d) Earth

e) Rock

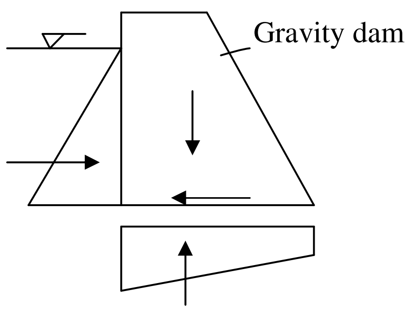
f) Steel

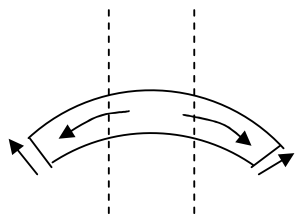
g) Timber

4) Classification according to hydraulic design

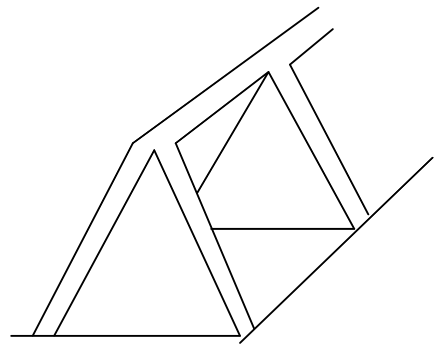
a) Overflow

b) Non-overflow

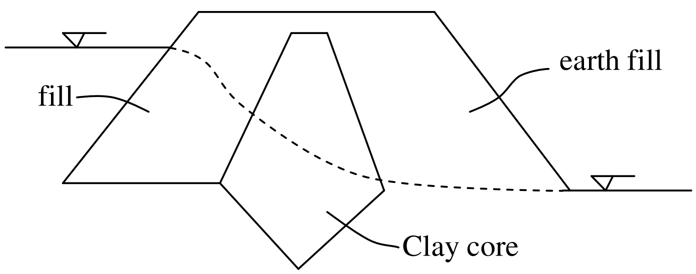




(kemer) arch dam



Buttress (payandalı) dam



- Parts of Dams:

a) Main body

b) Spillway (dolusavak): discharge the flood wave

c) Outlet: penstocks, bottom outlets, water intake structures

d) Other facilites: hydropower station, roads…

- Planning and Design of Dams

A) Reconnaissance Surveys (Keşif): At this stage the alternatives which seem unfeasible without performing intensive study are eliminated.

B) Feasibility Study:

a) Estimation of Water Demand:

b) Determination of Water Potential

c) Optimal plan selection

d) Dam site determination

1- Topography

2- Geology

3- Flood risk

4- Spillway location and possibilities

5- Climate

6- Diversion of the weir

7- Sediment problem

8- Water quality

9- Transportation

10- Right of way cost

e) Dam type determination

f) Project design

1) Hydrological design

- maximum lake elevation from design hydrograph
- spillway capacity
- crest elevation

2) Hydraulic design

- Loads acting (dynamic- static)
- Spillway design – energy dissipators
- Outlet design

3) Structural design

C) Planning Study

a) Topographic surveys

b) Foundation studies

c) Materials and construction details

d) Hydrologic study

e) Reservoir operation study

Construction Of Dams:

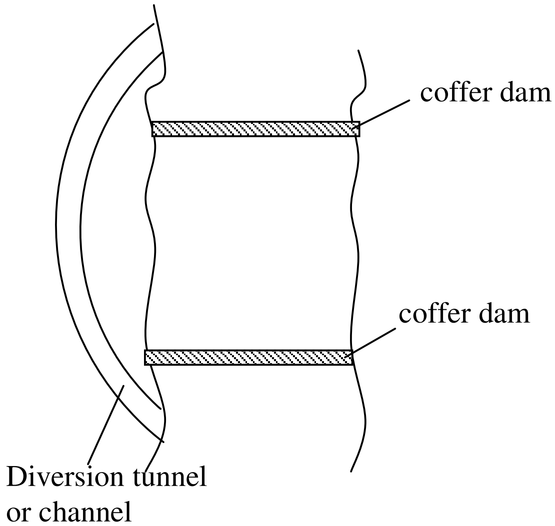
1) Work schedule & Required equipment

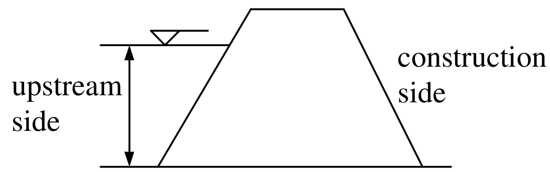
a) Dam location

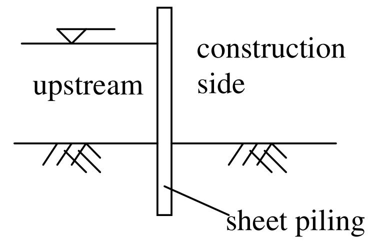
b) Quantities of work (excavation, grouting, explosions)

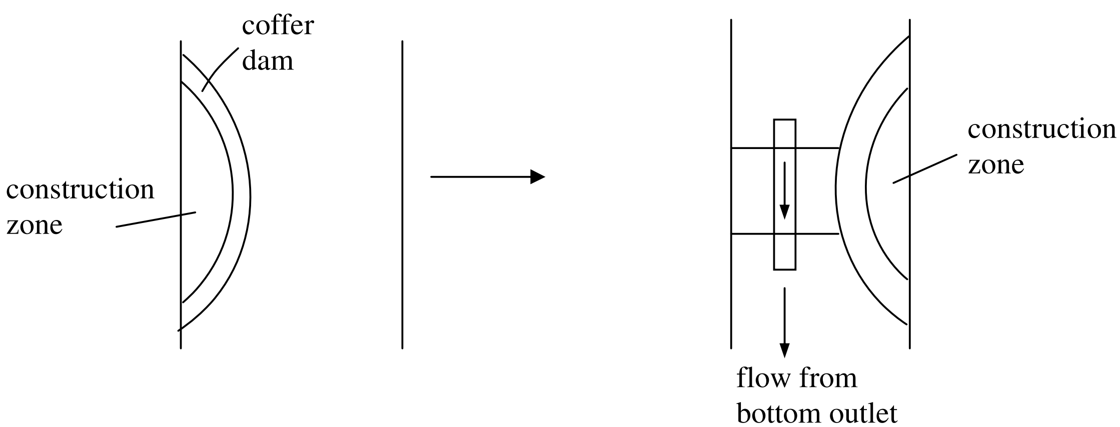
c) Diversion

2) Diversion of River Flow









3) Foundation treatment

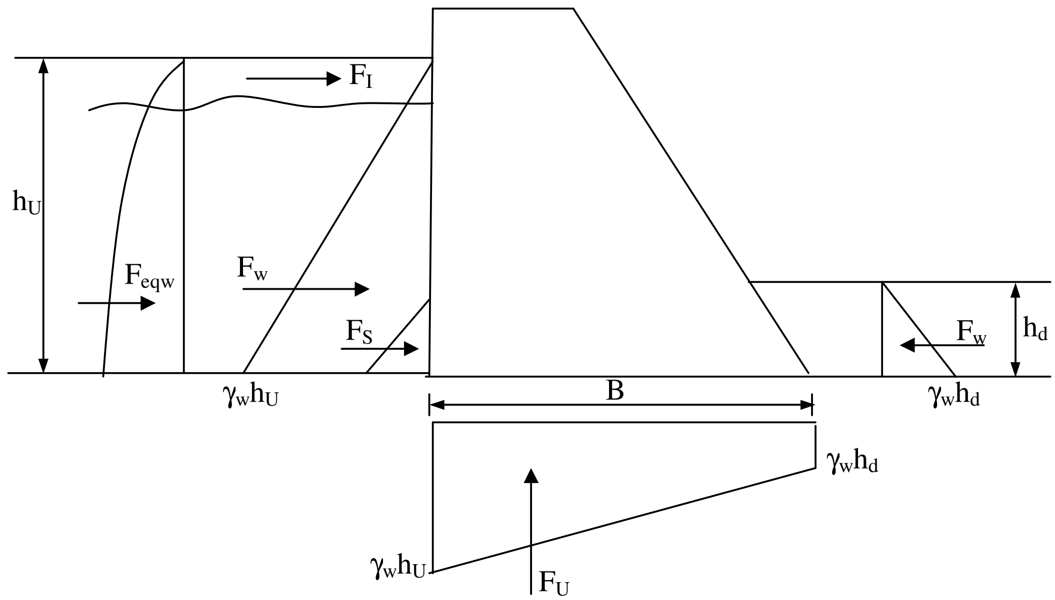
4) Formation of the dam body

Characteristics of Dam:

Dam Type	Foundation	Constr. Material	Construction Cond.	Critical Cond.
Earth Fill	Every type	Soil	Earth constr.equip. Average workmanship	- overtapping - siliding of slopes
Rock Fill	Hard sandy Gravel or rock	clay + rock	Earth constr.equip. Average workmanship	- overtapping - sliding of slopes - earthquake
Concrete Gravity	Rock Found.	Concrete	- concrete mixing plant - skilled worker	- sliding - settlement -overtapping -earthquake
Arch	Rock Found. Rock Abutment	R.C	- concrete mixing plant - skilled worker	- sliding - settlement -overtapping -earthquake -sliding on abutments
Buttress	Rock Found. Rock Abutment	R.C	- concrete mixing plant - skilled worker	- sliding - settlement -overtapping -earthquake -sliding on abutments

- Concrete Gravity Dams

Forces Acting on Dams



Hydrostatic Pressure

$$F_w = \frac{1}{2}\gamma_w h_u^2 \quad \text{(per unit length of the dam)}$$

Uplift force

$$F_u = \left[h_d + \frac{\phi}{2}\left(h_u - h_d\right)\right] B\gamma_w$$

B = bottom width of the dam

ϕ = uplift reduction coefficient

Silt Pressure

$$F_s = \frac{1}{2}\gamma_s h_s^2 \underbrace{\left(\frac{1-\sin\theta}{1+\sin\theta}\right)}_{K_a} \qquad \theta = \text{angle of internal friction (angle of repose)}$$

γ_s = submerged specific weight of soil

Ice Loads:

Example : Thickness of ice= 1 m , $\Delta t = 5°C/hr$ temp. inc.

$F_I = 14$ t/m

Assignment = Study Fig. 3.7 in your textbook

Earthquake Force:

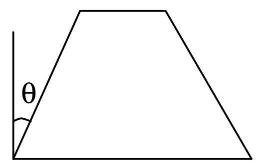
$F_{eq} = kW$ k= earthquake coefficient

W = weight of the dam

Earthquake wave force (Dynamic force):

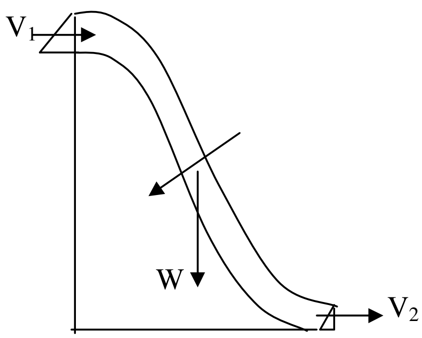
$$F_{eqw} = F_w = 0{,}726Ck\gamma_w h_u^2 \qquad \text{C: constant} = 0{,}7\left(1-\frac{\theta}{90}\right)$$

$F_{eqw} = F_w$ acts at a distance $\frac{4}{3\pi}h_u = 0{,}412h_u$ from the bottom



for vertical
face slope C = 0,7

Hydrodynamic Force:



If the spillway is running

$$\sum \vec{F} = \rho Q \Delta \vec{V}$$

$$\sum F_x = \rho Q(V_{2x} - V_{1x})$$

$$\sum F_y = \rho Q(V_{2y} - V_{1y})$$

Wave Forces are considered if reservoirs are large such that considerable fetch distance arises.

- Stability of Dams:

a) Safety Against Overturning

$$F.S_o \leq \frac{\sum M_r}{\sum M_o}$$

According to various loading conditions factor of safety values are given in Table 3.3 of the textbook.

For example: For usual loading $F.S_o = 2$

b) Safety Against Sliding

$$F.S_c \leq \frac{f\sum V}{\sum H}$$

f = friction factor between planes. Given in Table 3.4

c) Combined Shear and Sliding

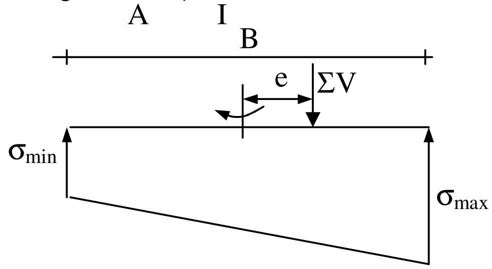
$$F.S_{ss} \leq \frac{f\sum V + 0,5A\tau_s}{\sum H}$$

A= Area of shear plane

τ_s = allowable shear stress in concrete

d) Foundation Stresses

$$\sigma = \frac{\sum V}{A} \mp \frac{Mc}{I}$$



σ = vertical normal base pressure

M = the net moment about the centerline of the base

$$M = \sum Ve$$

c = B/2, I = B^3/12 (moment of inertia)

First term in σ eqn. is the normal stress, second term is the flexural or bending stress.

$\sigma_{min} \geq 0$, $\sigma_{max} \leq \sigma_{all.}$

$$e \leq \frac{B}{6}$$

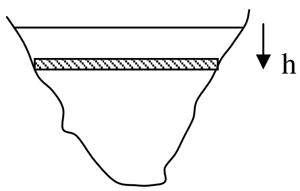
ARCH DAMS

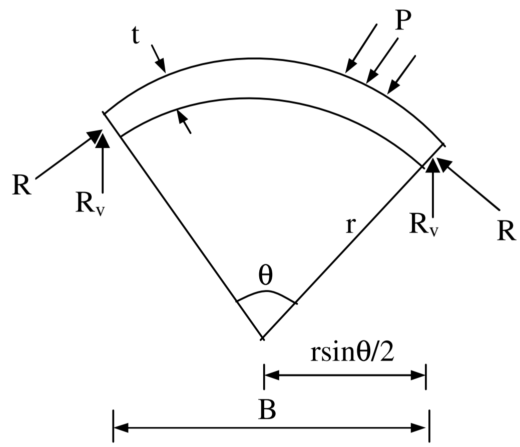
a) Constant center – variable radius arch dam

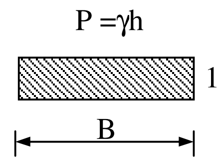
b) Variable center – constant angle arch dam

c) Variable center variable angle arch dam

ELASTIC ARCH METHOD







Force Balance

$$R_v = R\sin\frac{\theta}{2}$$

$$2R_v = PB$$

$$2R\sin\frac{\theta}{2} = PB = \gamma h 2r\sin\frac{\theta}{2}$$

$$R = \gamma hr$$

For a single arch rib = $\underbrace{1\times t\times\sigma_{all}}_{\text{concrete}} = R$

Volume of concrete required = $t = \dfrac{R}{\sigma_{all}} = \dfrac{Pr}{\sigma_{all}}$

$\forall$ = Lt (for a unit height)

L = is the length of the arch (rθ)

$$\forall = r\theta\frac{P}{\sigma_{all}}r = \frac{P}{\sigma_{all}}\theta r^2 = \frac{P}{\sigma_{all}}\theta\left(\frac{B}{2\sin\frac{\theta}{2}}\right)^2$$

$\dfrac{d\forall}{d\theta} = 0$: to find minimum volume : θ = 133°

HYDROELECTRIC POWER

1) General

Electrical energy can be generated by

1) Hydraulic Energy (falling water)
2) Thermal Energy (coal, oil, natural gas)
3) Solar, wind energy

Power is measured by 2 parameters

Watt (W), kilowatt (kW) and kilowatt-hour (kWh)

2) Terminology

Base load = demand exists 100% of the time

Firm (primary) power = is the power which can be produced by a plant with no risk

Surplus (Secondary) power = is all the power available in excess of firm power.

Capacity (installed capacity) = is the maximum power which can be developed by the generators

Gross Head (H_g) = is the vertical difference between upstream and downstream water levels.

Net (effective) head (H_n) = head available for energy production

Hydraulic efficiency (e_h) = is the ratio of net head to gross head

Overall efficiency (e) = $e = e_h e_g e_t$ (60-70%)

where e_g = efficiency of generator

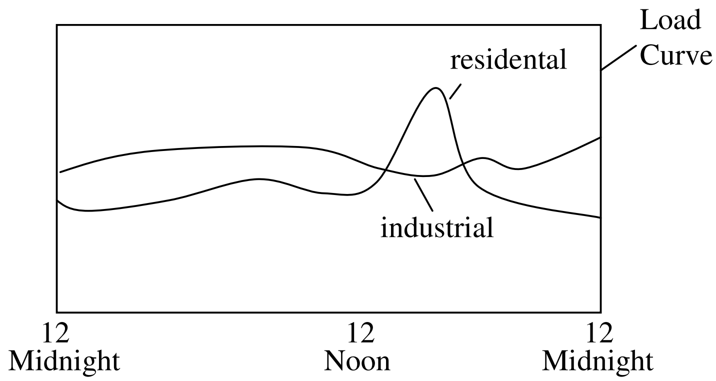
e_t = efficiency of turbine

Load factor:

$$\text{Load factor} = \frac{\text{average load}}{\text{peak load}}$$

L.F = 0.6 residential

L.F = 0.8 industrial



3) Hydroelectric Power Plants

1) Run-of-river plant = limited storage and dependent on river discharge

2) Storage plant = with considerable storage. Capacity of firm power is much greater than minimum river discharge due to storage

3) Pumped storage plant = generates power for peak load, but at off peak water is pumped from the tail water to the upstream reservoir.

Penstock (cebri boru) = used to withdraw water from reservoir

Trashrack (ızgara) = used to eliminate large particles entering into penstock and therefore turbines.

Surge tank = A storage tank that eliminates water hammer pressures in the penstock.

Tailrace (kuyruk suyu kanalı) = is a channel which receives water from turbines.

4) Turbines

Power of a turbine $P = \gamma Q H_g e$

P: kW, γ: kN/m^3, Q: m^3/s , H_g : gross head (m), e : overall efficiency (%)

$$E = \frac{V_w H_g \gamma_e}{3600}$$

E: kwh, V_w: volume of water (m^3)

A turbine is a machine which converts hydraulic energy into mechanical energy. A generator converts this mechanical energy into electrical energy.

Turbines: a) Impulse turbines

b) Reaction turbines

For Impulse turbines atmospheric pressure is existing

For Reaction turbines pressurized flow is running in the turbine.

Cavitation is critical for reaction turbines

5) Similarity Laws for Turbomachinary

Similarity laws enable us to predict the performance of a turbine under different operating conditions. They enable us to predict the performance of a series of homologous machines of different sizes from the known performance of any one of the series.

a) Discharge is required

$$Q_2 = Q_1 \left(\frac{N_2}{N_1}\right)\left(\frac{D_2}{D_1}\right)^3$$

Indices 1, 2 are homologous turbines 1 and 2

N = rotative speed of (rpm)

D = diameter of runner (m)

Q = discharge (m^3/s)

b) Power is required

$$P_2 = P_1\left(\frac{N_2}{N_1}\right)^3\left(\frac{D_2}{D_1}\right)^5 \qquad P = \text{power (hp)}$$

c) Head is required

$$H_2 = H_1\left(\frac{N_2}{N_1}\right)^2\left(\frac{D_2}{D_1}\right)^2$$

The specific speed n_s of a turbine can be used as an indicator of a selection in turbine type.

$$n_s = \frac{N\sqrt{P} \rightarrow h_p}{H_n^{5/4}} \qquad (h_p \longrightarrow kw)$$

(1 kW = 1,34 H_p)

Specific speed = özgül dönme sayısı = En yüksek verimde 1 m düşü altında 1 beygirlik gücü sağlayacak devir sayısıdır.