KNOW YOUR DAM

Dam Types

1. Concrete dams

    Concrete gravity dam
    Arch dam
    Buttress dam

2. Embankment dams

    Homogeneous earthfill dam
    Zoned earthfill dam
    Rockfill dam

3. Composite dams – embankment + concrete dam

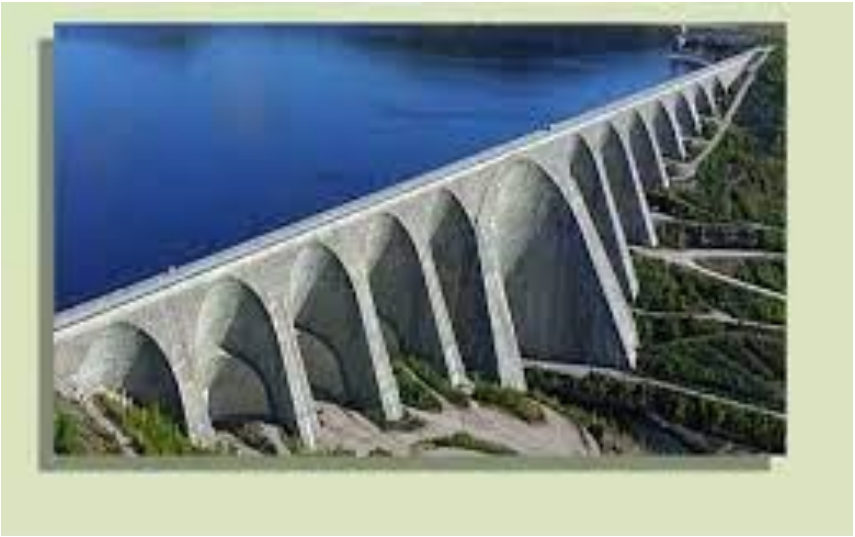
Concrete gravity dams

Gated

Ungated

Arch Dam

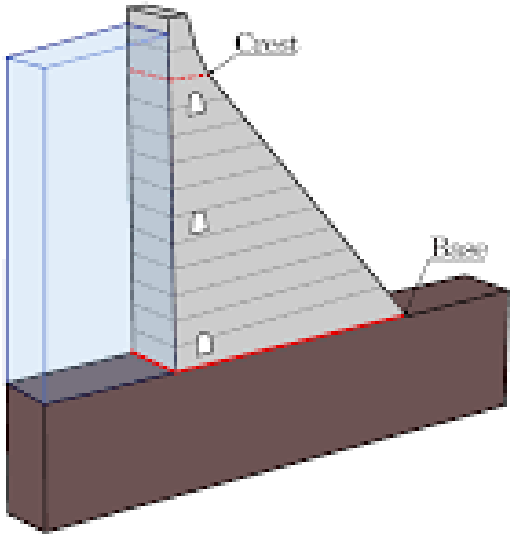
Buttress Dam

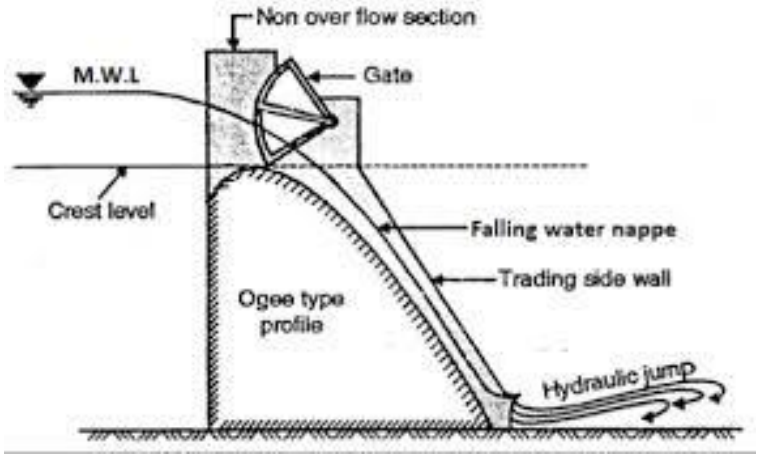


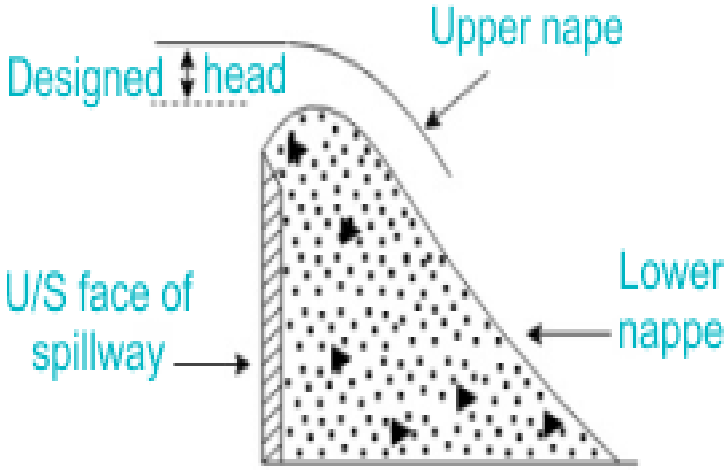
Embankment dam

Composite dam

Concrete gravity dams

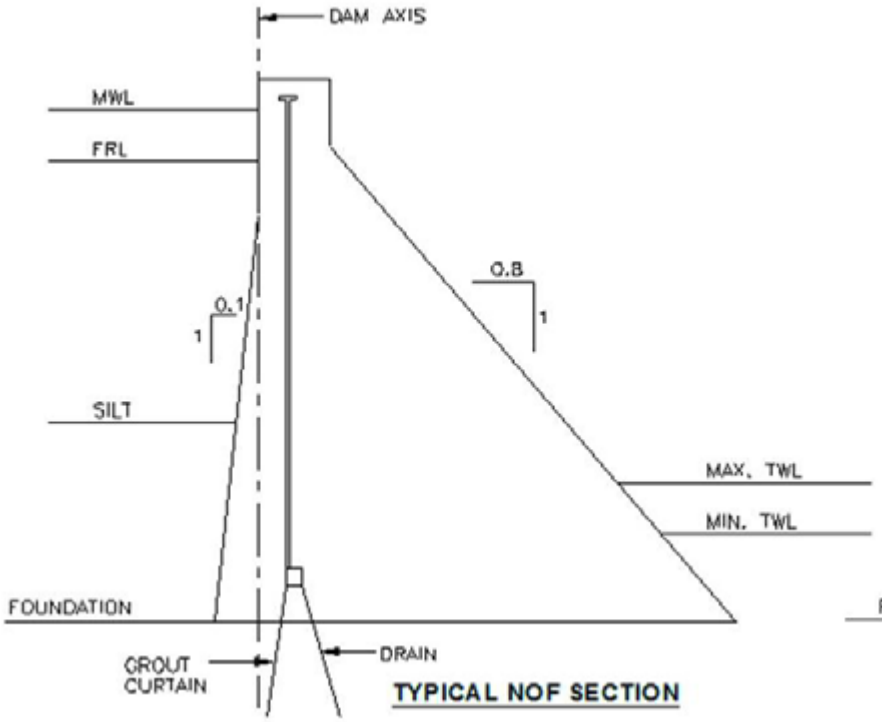


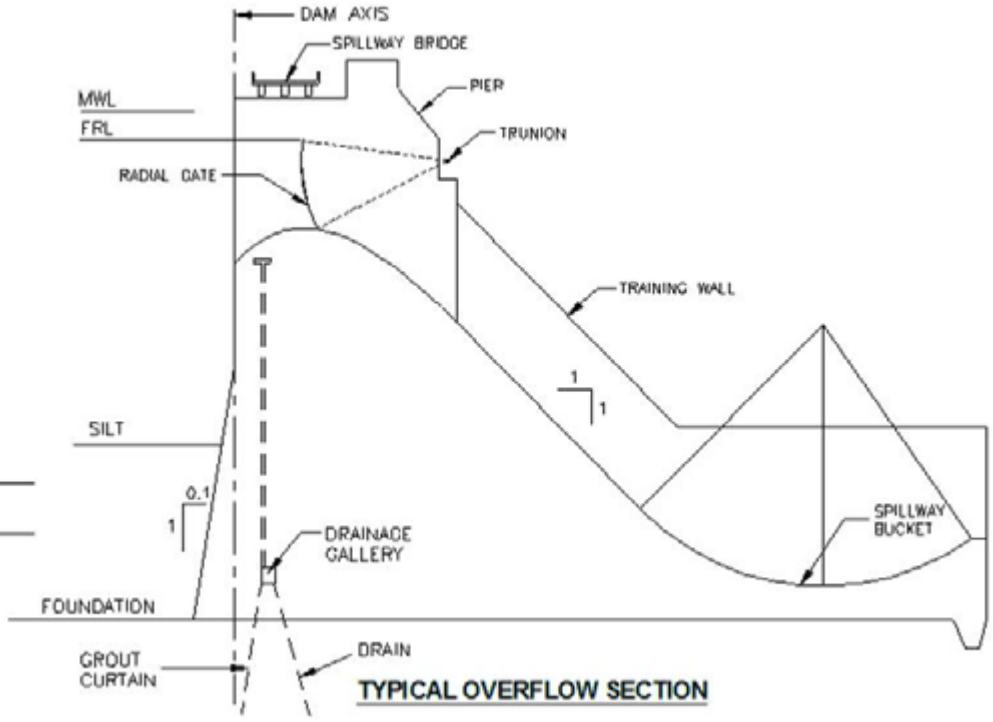




Ogee Spillway

Typical section of gravity dams





Design Criteria of Concrete Gravity Dam

Design Flood

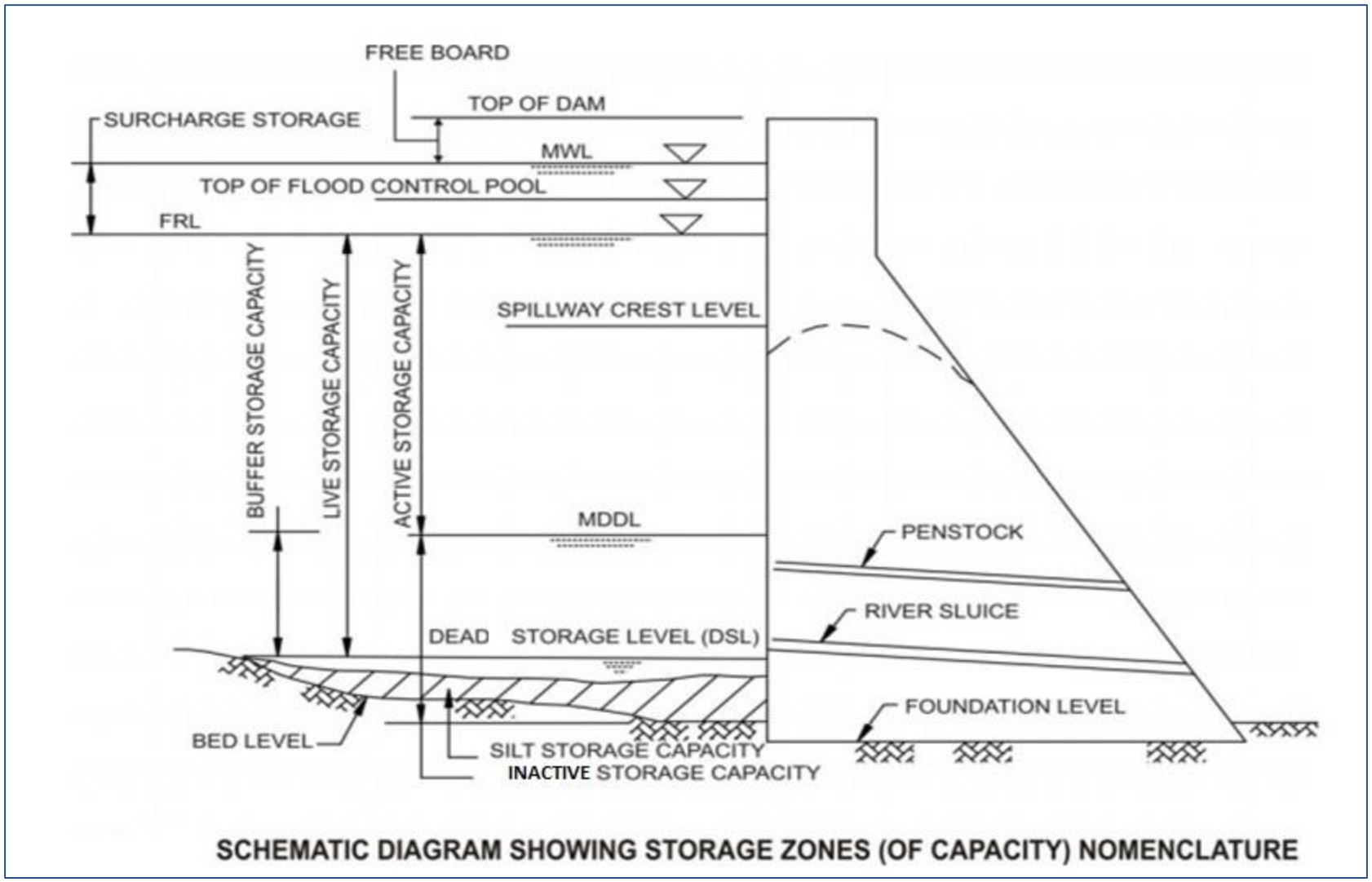
- Design Flood for a dam is decided as per IS:11223 .
- Dams are classified according to size by using Hydraulic head & the gross storage behind them.
- The overall size classification is greater of the two parameters

Classification	*Gross Storage*	*Hydraulic Head*
Small	Between 0·5 and 10 million m^3	Between 7·5 m and 12 m.
Intermediate	Between 10 and 60 million m^3	Between 12 m and 30 m.
Large	Greater than 60 million m^3	Greater than 30 m.

The inflow design flood for safety of the dam is given by

Size of Dam	**Inflow Design Flood for Safety of Dam**
Small	100 year flood
Intermediate	SPF
Large	PMF

Important Levels in Concrete Dams



SCHEMATIC DIAGRAM SHOWING STORAGE ZONES (OF CAPACITY) NOMENCLATURE

These specific levels and parts are generally defined as follows:

Full Reservoir Level (FRL)	It is the level corresponding to the highest reservoir level that can be maintained with or without spillway discharge.
Minimum Drawdown Level (MDDL)	It is the level below which the reservoir will not be drawn down so as to maintain a minimum head required in power projects.
Dead Storage Level (DSL):	Below the level, there are no outlets to drain the water in the reservoir by gravity.
Maximum Water Level (MWL)	This level is also called sometimes as the Highest Reservoir Level or the Highest Flood Level.
Live storage	The volume of water actually available at any time between the Dead Storage Level and the lower of the actual water level and Full Reservoir Level.

Free Board

- **Free Board is the vertical distance between the top of the dam and the still water level**
- **It shall be equal to wind set up plus *4/3* times the wave height above FRL or above MWL (corresponding to design flood) whichever gives higher dam top level**
- **Not less than 1m above MWL corresponding to design flood**
- **If design flood is not equal to PMF then the top of dam should be at least equal to MWL corresponding to PMF.**
- **At least 1m high solid parapet to be provided, not withstanding the above requirements.**

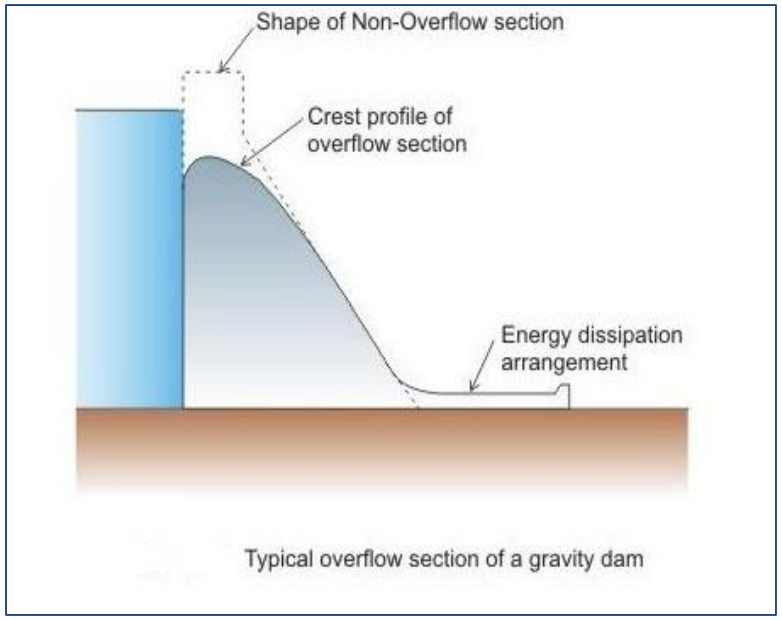
For Free Board IS: 11223 specifies the following

- The freeboard as specified in IS: 6512 shall be available at FRL and MWL corresponding to all bays operative condition.
- For gated spillways a contingency of 10% of gates (min. one gate) being inoperative is considered as an emergency.
- A reduced freeboard may be acceptable under the emergency condition.
- The dam shall not be allowed to be overtopped in any case.

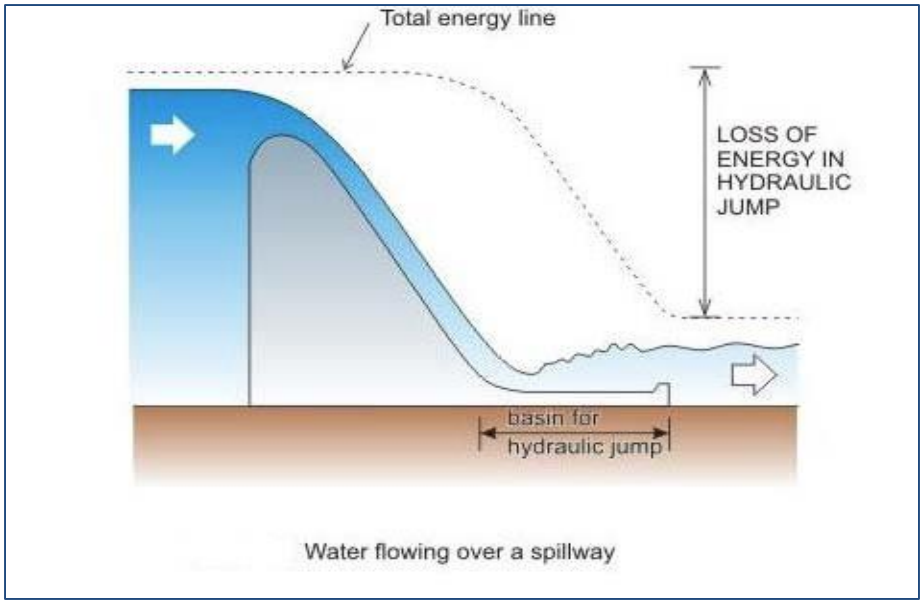
Energy dissipation

- A gravity dam should also have an appropriate spillway for releasing excess flood water of the river during monsoon months.

- The flood water glides over the crest and downstream face of the spillway and meets an energy dissipating structure that helps to kill the energy of the flowing water, which otherwise would have caused erosion of the river bed on the downstream.



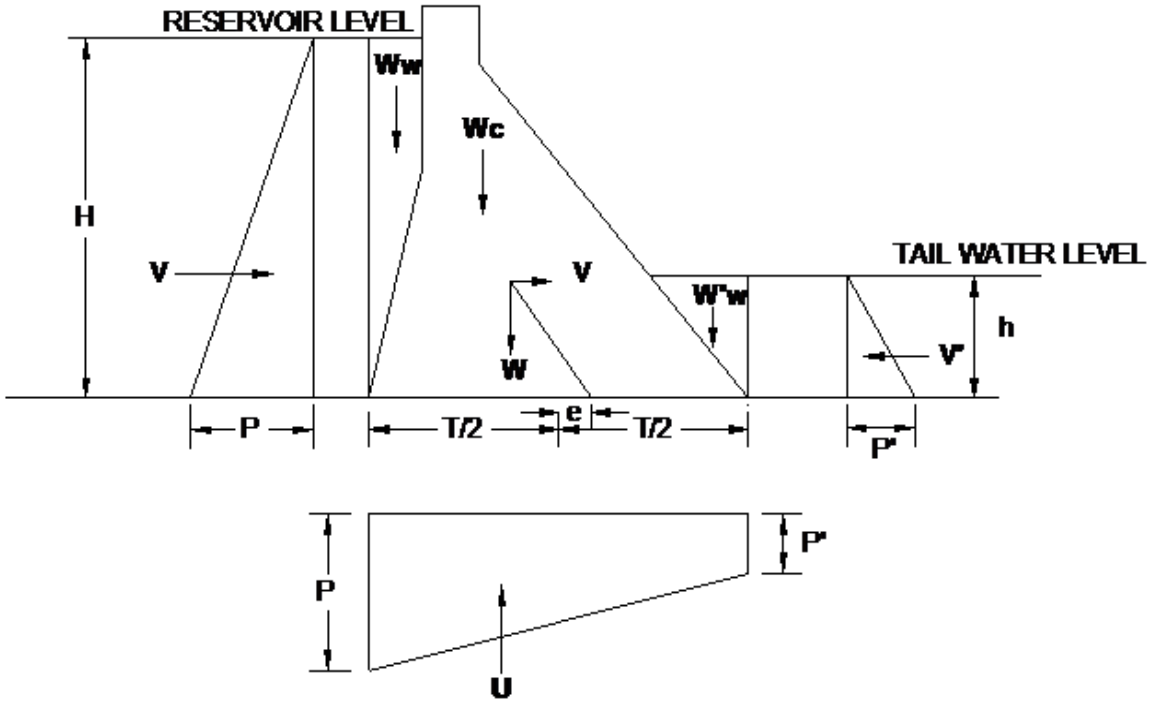
Typical overflow section of a gravity dam



Water flowing over a spillway

Forces

- Dead loads
- Reservoir and Tail water loads
- Uplift pressures
- Earthquake forces
- Silt pressures
- Ice pressure
- Wave pressure
- Thermal loads, if applicable



VERTICAL CROSS SECTION SHOWING FORCES ACTING ON A GRAVITY DAM

TERMINOLOGY :EMBANKMENT DAMS

- **BORROW AREA** – Source of construction materials for earth & rock fill dam.
- **CASING** – Zones except core in a zoned earthen dam, also called shell or shoulder.
- **CORE** – A zone of impervious earth within a zoned earth or rock fill dam.
- **CUT-OFF** – A barrier to reduce seepage of water through foundation and abutments.
- **POSITIVE CUT-OFF** – A cut-off taken to an impervious stratum. A full cut-off in the form of an open excavated trench and back filled with compacted impervious material, also provided in the form of sheet piles, plastic diaphragm, concrete diaphragm, grouted cut-off, cut-off wall, etc.
- **PARTIAL CUT-OFF** – A cut-off, which does not go down to impervious stratum.
- **FULL RESERVOIR LEVEL (FRL)** – The highest reservoir level that can be maintained without spillway discharge or without passing water through sluiceways. It dose not include any depth of surcharge.

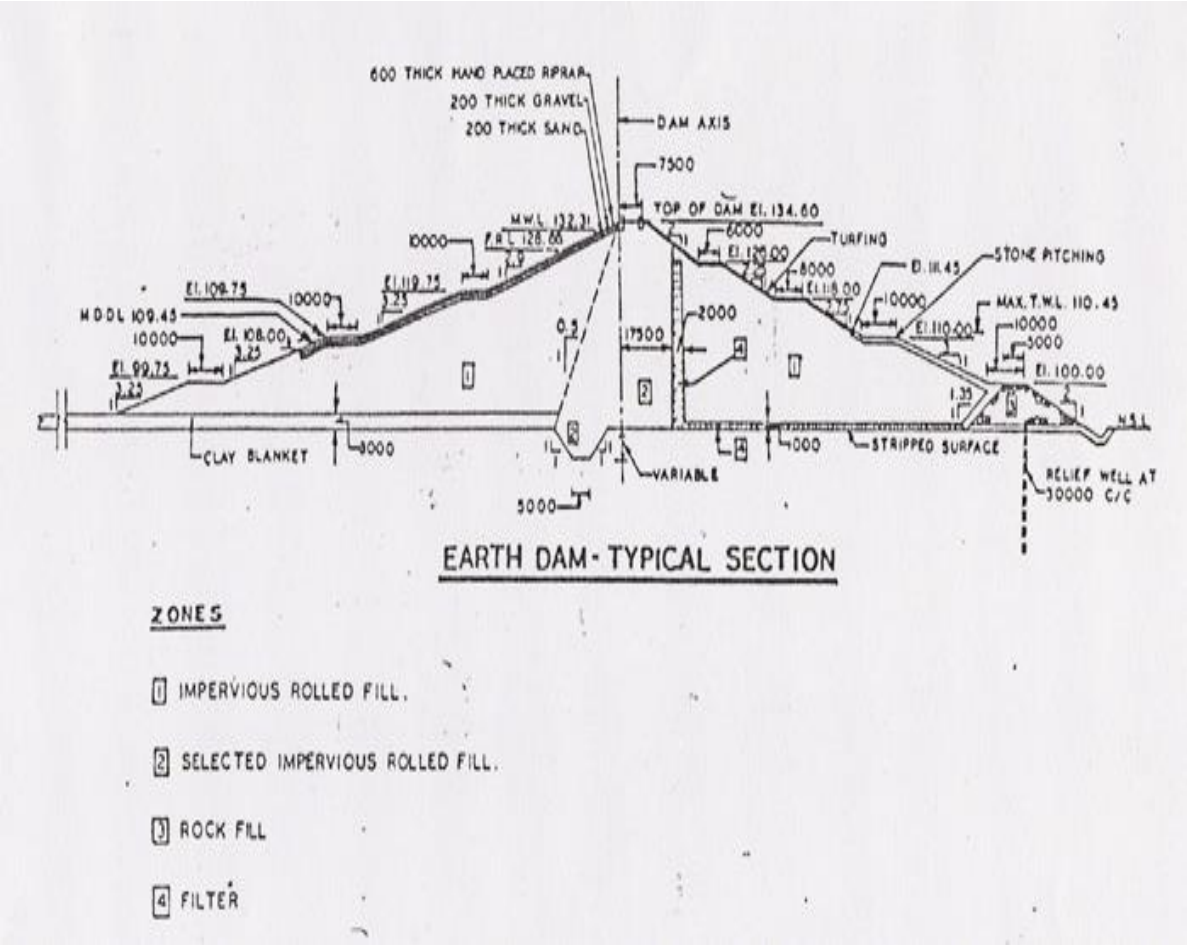
Contd…….

- **MINIMUM DRAW DOWN LEVEL (MDDL)** – The lowest level to which a reservoir may be lowered keeping in view the requirements for hydro-power generation or irrigation and other requirements.
- **FREEBOARD** – The vertical distance between the crest of the embankment (without camber) and the maximum reservoir water level.
- **HORIZONTAL FILTER** – A layer of uniform or graded previous materials placed horizontally.
- **INCLINED/VERTICAL FILTER** – A layer of uniform or graded pervious materials, placed inclined or vertical.
- **IMPERVIOUS BLANKET** – An upstream impervious soil layer laid over a relatively pervious stratum and connected to the core.
- **RELIEF WELL** – Relief Wells are generally provided downstream of partial cut-off to relieve excess hydrostatic pressure.

Contd…

- **RIPRAP** – It is the protection to the embankment material against erosion due to wave action, velocity of flow, rain-wash, wind action, etc. provided by placing a protection layer of rock fragments or manufactured material.
- **TURFING** – It is a cover of grass grown over an area to prevent erosion of soil particles by rain wash.
- **TOE DRAIN** – A trench filled with filter material along the down-stream toe of an earthen dam to collect seepage from horizontal filter and lead it to natural drain.
- **PARAPET WALL**– A wall provided along the edge of the embankment.
- **PORE PRESSURE** – The pressure developed in the fluid within the voids of the soil under external force when drainage is prevented.
- **ROCK TOE** – A zone of free draining material provided at the toe of the dam.

EMBANKMENT DAM: TYPICAL SECTION



TYPES OF EMBANKMENT DAMS

- Homogeneous Embankment
- Zoned Embankment
- Rock-fill Dams with Clay Cores
- Rock-fill Dams with u/s Face Membranes

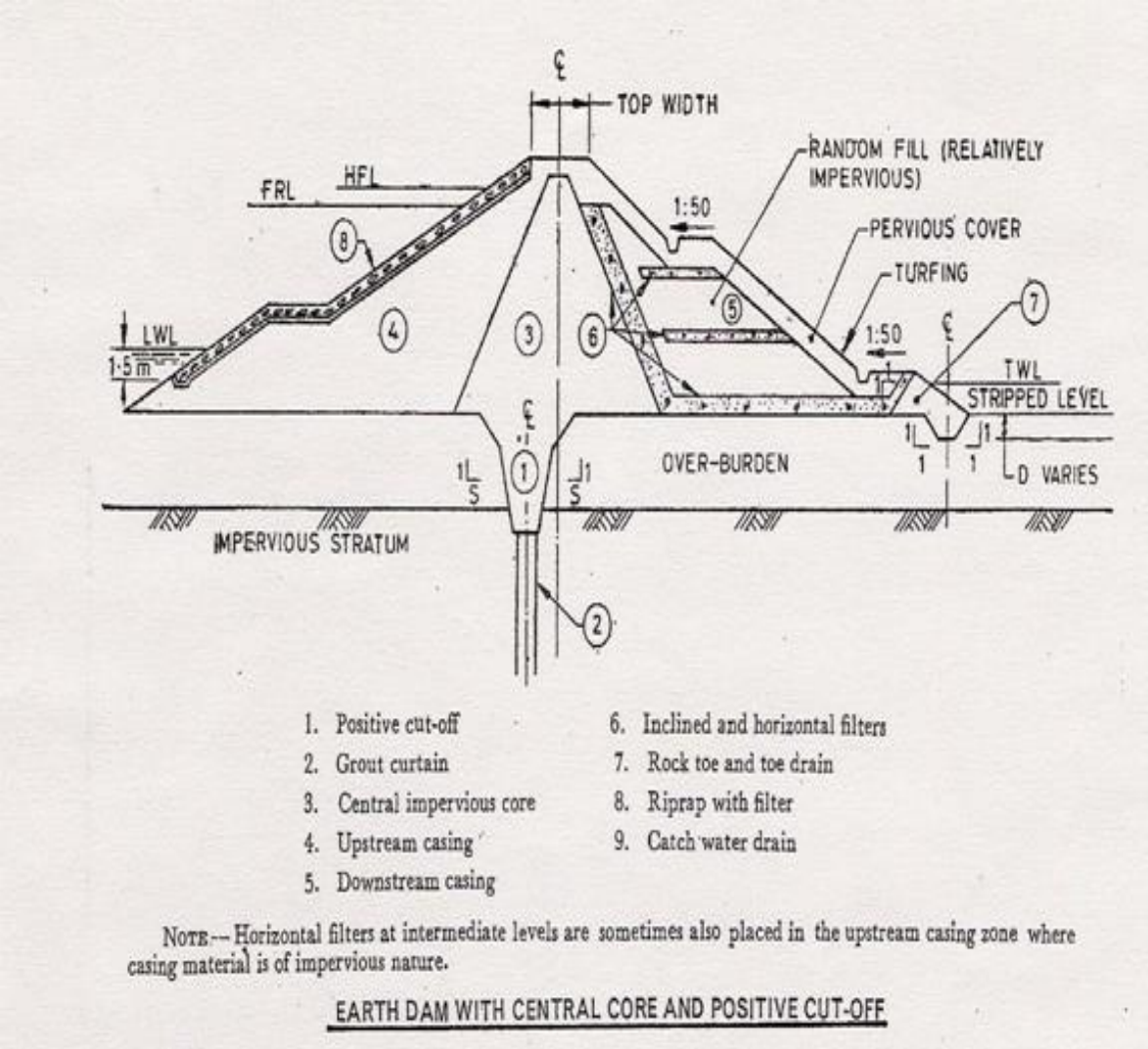
HOMOGENEOUS EMBANKMENT:

- ✓ In this type of embankment, the dam section entirely consists of almost one type of material.
- ✓ It is adopted due to compulsions of material availability within a reasonable distance.
- ✓ A zoned section is always preferable, if materials in the two broad categories of 'impervious or semi-pervious' and 'pervious' are available.
- ✓ Usually this type of section is made of low permeability material and requires flatter slopes than a zoned section.

ZONED EMBANKMENT:

- ✓ This type of embankment uses two or more types of materials, depending on their availability, utility and costs.
- ✓ There is an impervious zone called the 'core' inside the dam section.
- ✓ The outer zones on both sides, called 'shells', should preferably be of pervious materials.
- ✓ If different grades of pervious material are available, the coarser or more pervious materials are placed on the outer faces.
- ✓ The different zones are separated by filters and even if the

EARTHEN DAM
WITH CENTRAL CORE & POSITIVE CUTOFF

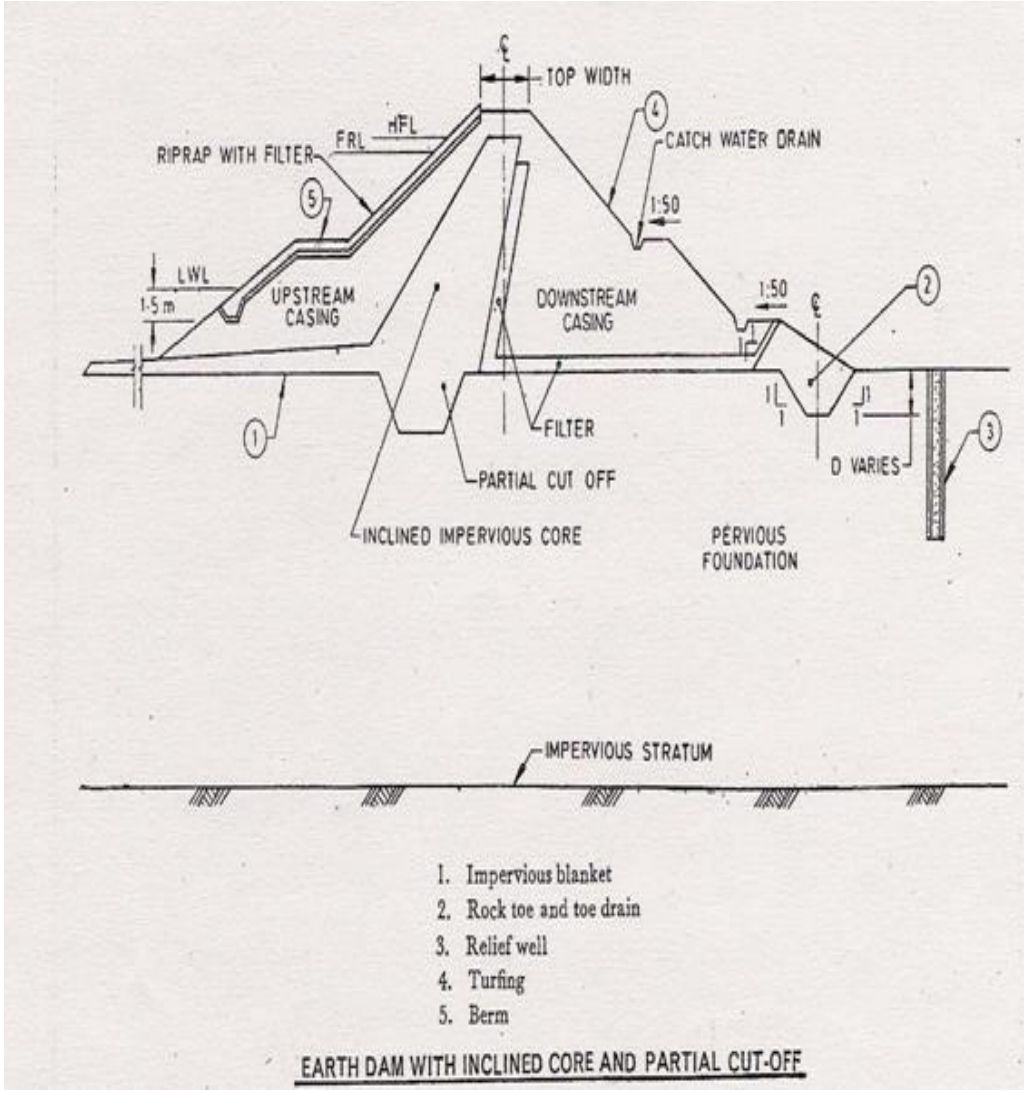


1. Positive cut-off
2. Grout curtain
3. Central impervious core
4. Upstream casing
5. Downstream casing
6. Inclined and horizontal filters
7. Rock toe and toe drain
8. Riprap with filter
9. Catch water drain

NOTE—Horizontal filters at intermediate levels are sometimes also placed in the upstream casing zone where casing material is of impervious nature.

EARTH DAM WITH CENTRAL CORE AND POSITIVE CUT-OFF

EARTHEN DAM
WITH CENTRAL CORE & PARTIAL CUTOFF



1. Impervious blanket
2. Rock toe and toe drain
3. Relief well
4. Turfing
5. Berm

EARTH DAM WITH INCLINED CORE AND PARTIAL CUT-OFF

ROCK FILL DAMS WITH EARTH CORES

- Any dam which relies on fragmented rock material, either obtained by blasting or available as natural boulder deposits, as a major structural element is called a rock fill dam.
- Rock fill dams with earth cores usually have substantial rock fill zones on both sides, with an impervious zone in the middle, and transition zones and /or filters in-between.
- There may be further zoning by material type gradation or degrees of compaction within each category also.
- Good quality rock fill provides free drainage and high shear strength and most of the highest embankment dams are of this type.
- This type is basically similar to zoned earth embankment.

ROCK FILLED EARTHEN DAMS (Contd..)

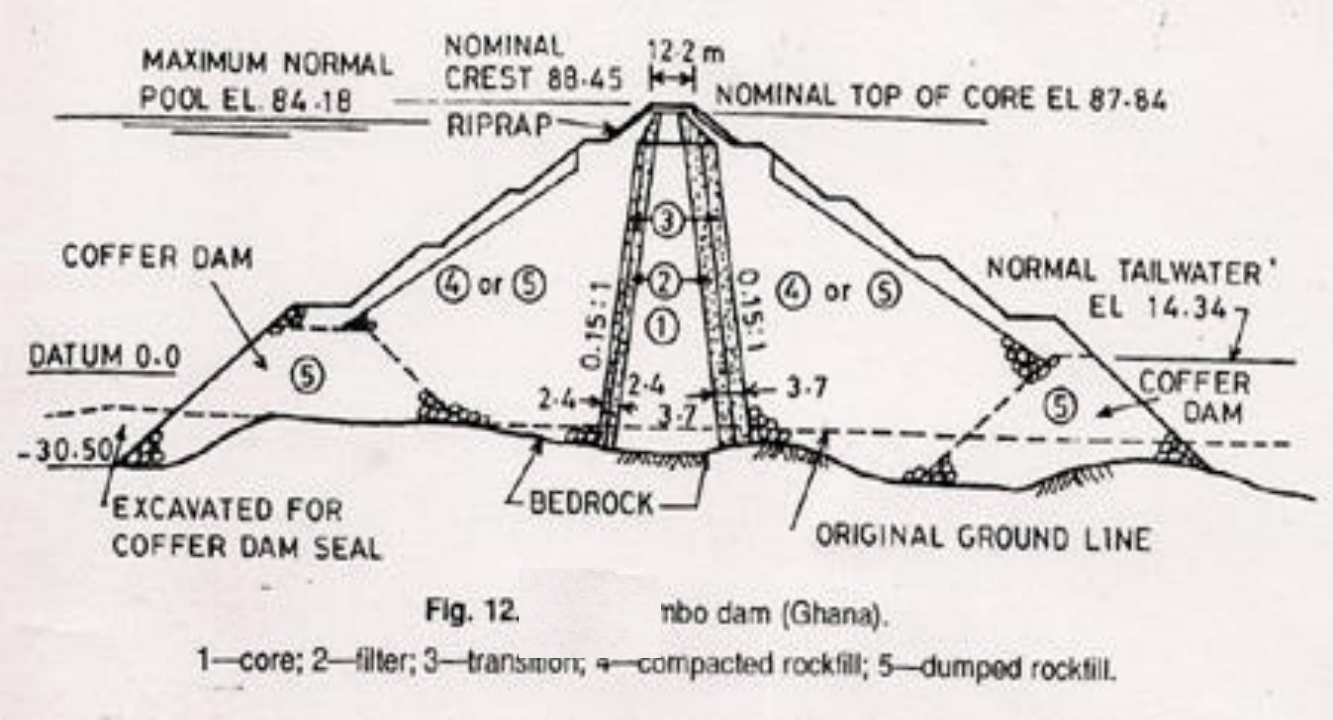


Fig. 12. nbo dam (Ghana).

1—core; 2—filter; 3—transition; 4—compacted rockfill; 5—dumped rockfill.

ROCK FILLED EARTHEN DAMS (Contd..)

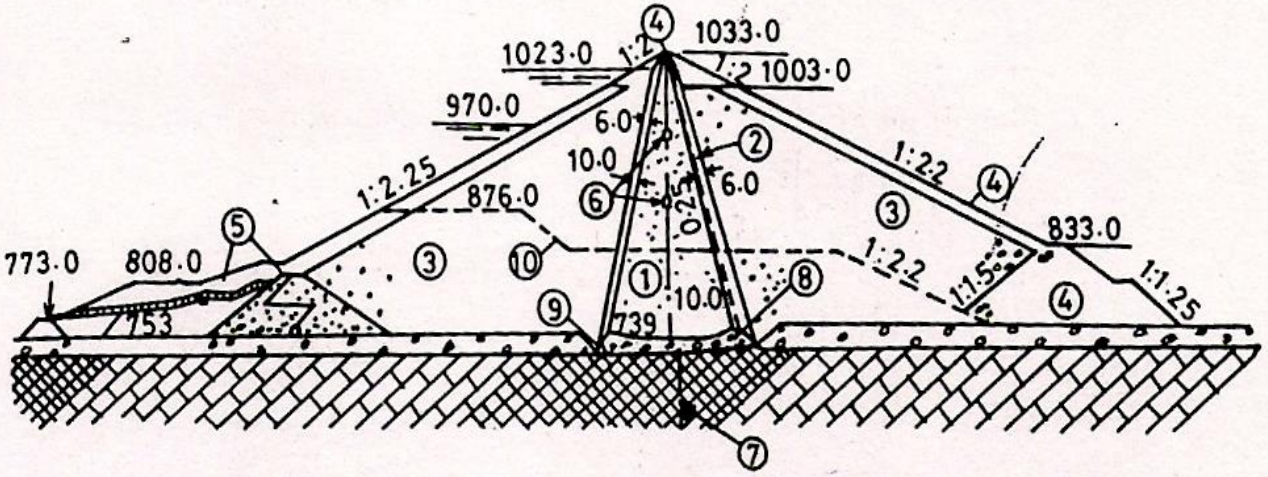


Fig. 12.4. Nurek dam, Russia.

1—rocky clay; 2—filter; 3—coarse gravel shells; 4—oversize rock surcharge on slopes; 5—upstream coffer dam; 6—inspection galleries for instrumentation; 7—grout curtain; 8—concrete block; 9—surface grouting; 10—first-stage construction.

COMPONENTS OF EMBANKMENT DAM

An embankment dam generally consists of the following components:

- Cut-off
- Core
- Casing
- Internal Drainage system and foundations
- Slope protection
- Surface drainage

The following components are provided in special cases:

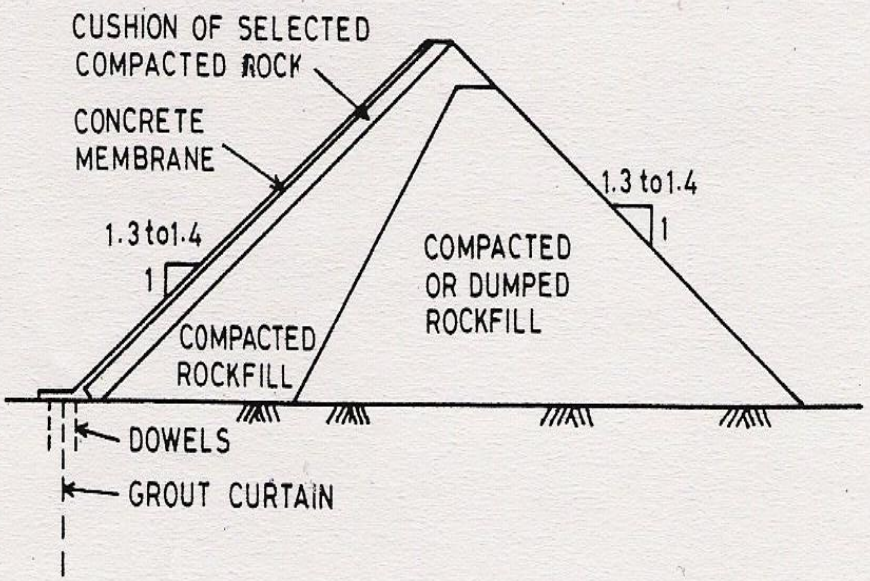
- Impervious blanket
- Relief well.

ROCK FILL DAMS WITH UPSTREAM FACE MEMBRANES

- **In this type the entire section consists of rock fill that is usually divided into different size gradations.**

- **The impervious element is provided by an upstream facing of cement-concrete or asphaltic materials.**

- **This type of section is suited to rock foundations at sites where suitable earth core material is not available in adequate quantity or where continuously rainy weather makes soil placement difficult.**



Typical section of rockfill dam with face membrane.

CAUSES OF DAM FAILURE

Main causes od Dam Failure

Overtopping

Piping in embankment dam

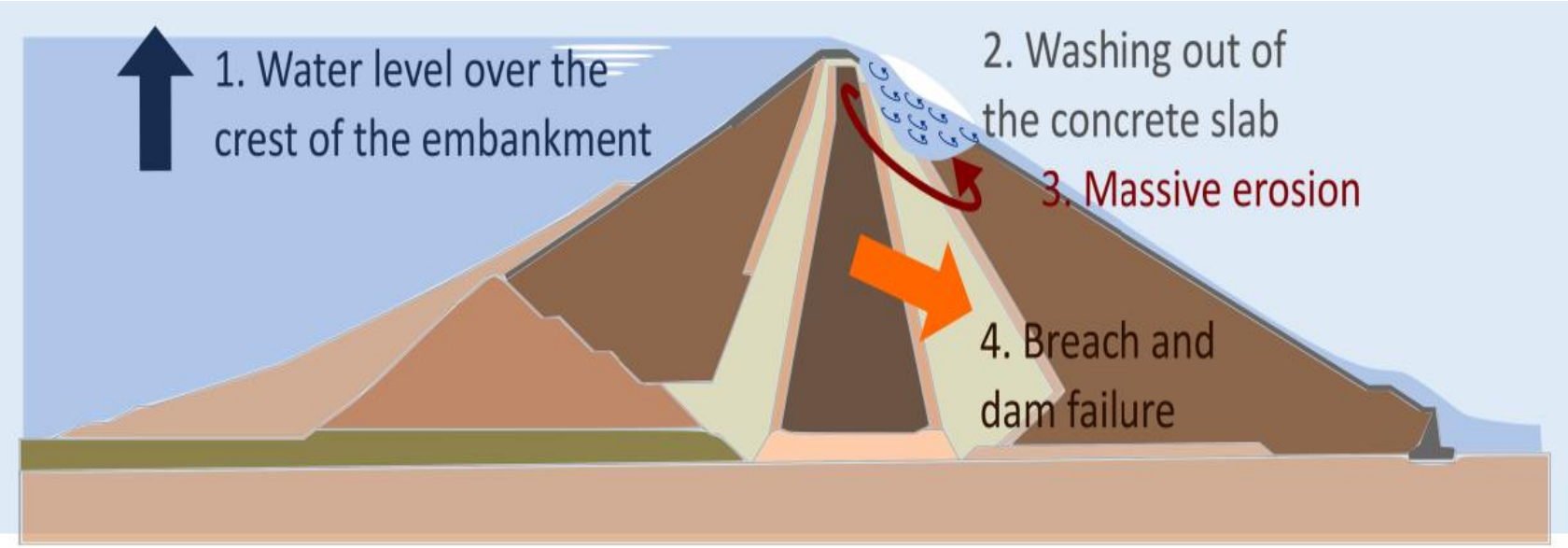
Sliding of slope in embankment dam

Poor design

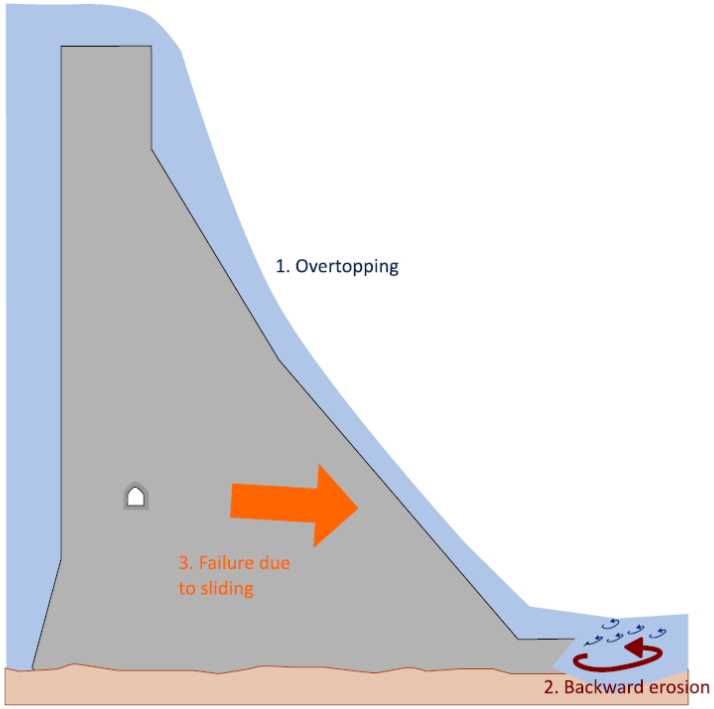
Poor construction material and technique

Landslide in reservoir

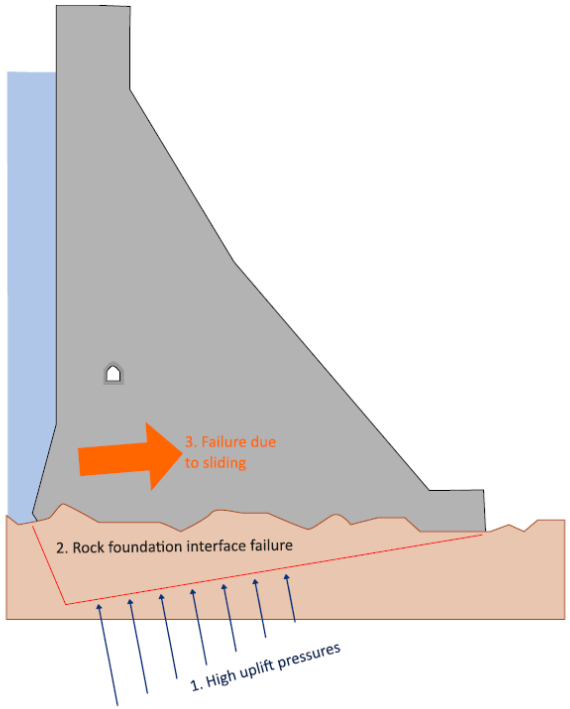
Failure due to overtopping



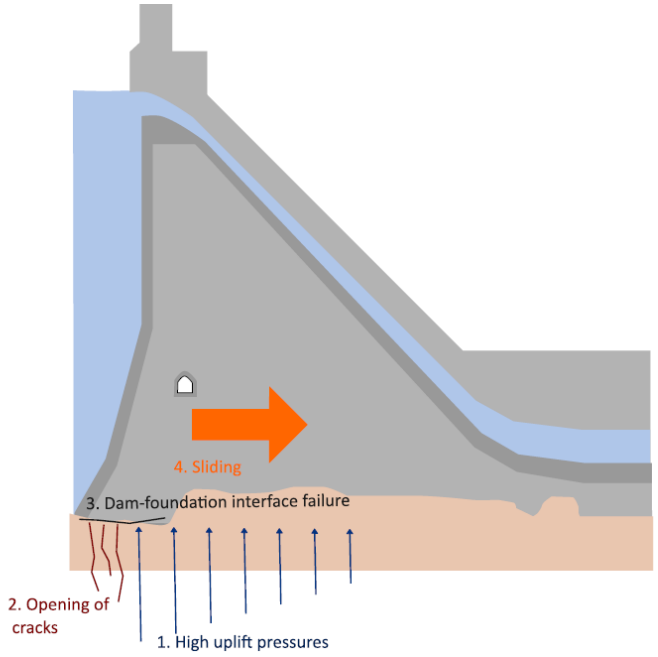
Failure due to overtopping



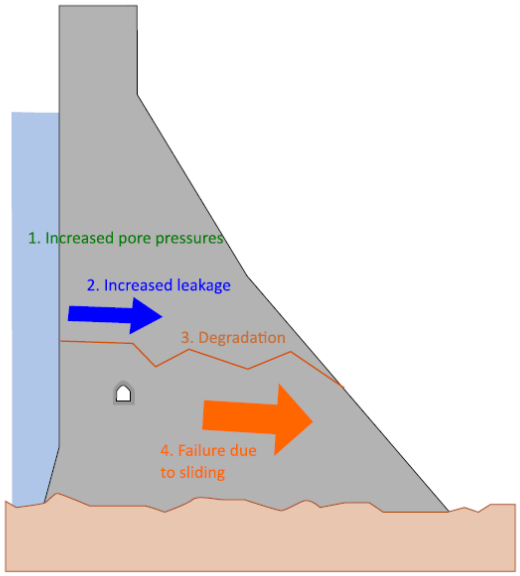
Sliding Failure along a surface in rock foundation



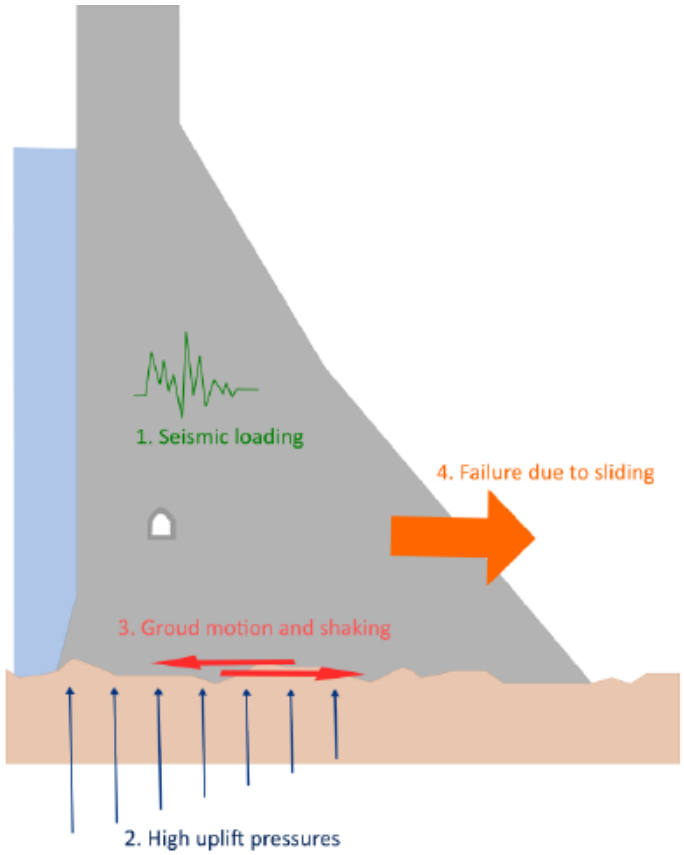
Sliding Failure along a concrete-rock surface



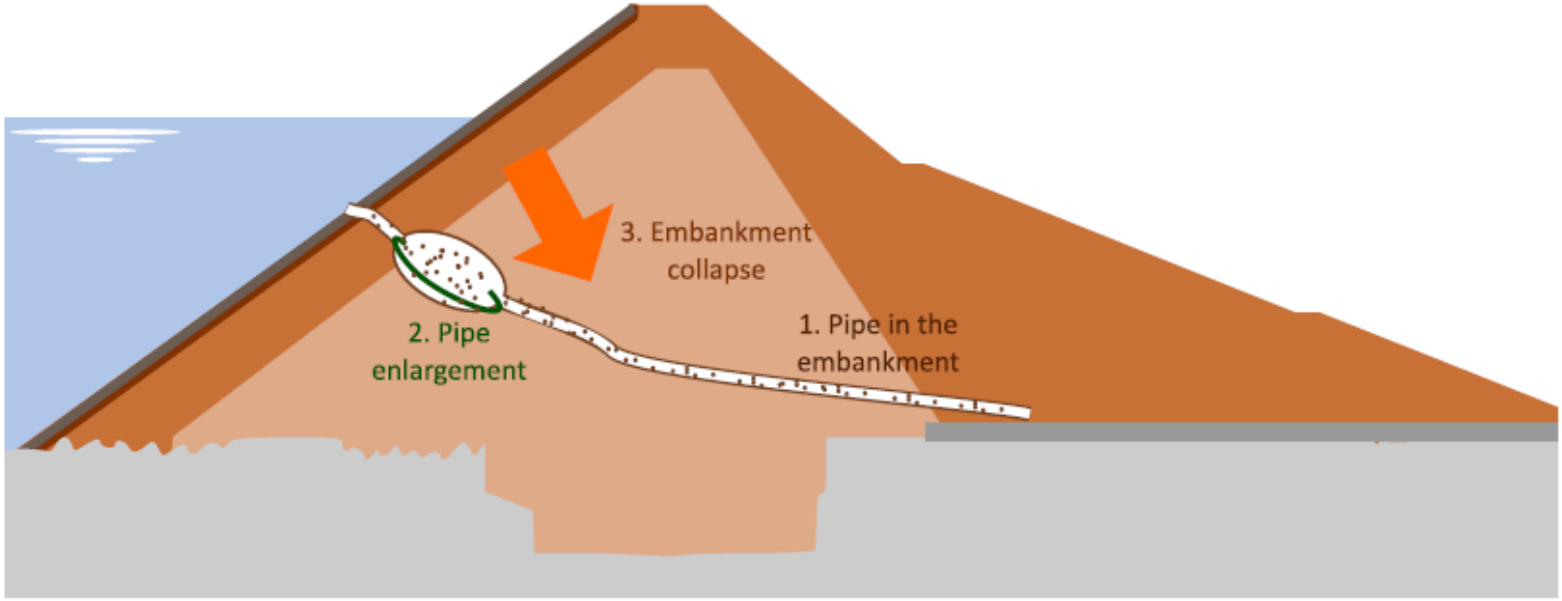
Sliding Failure along a degraded surface in dam



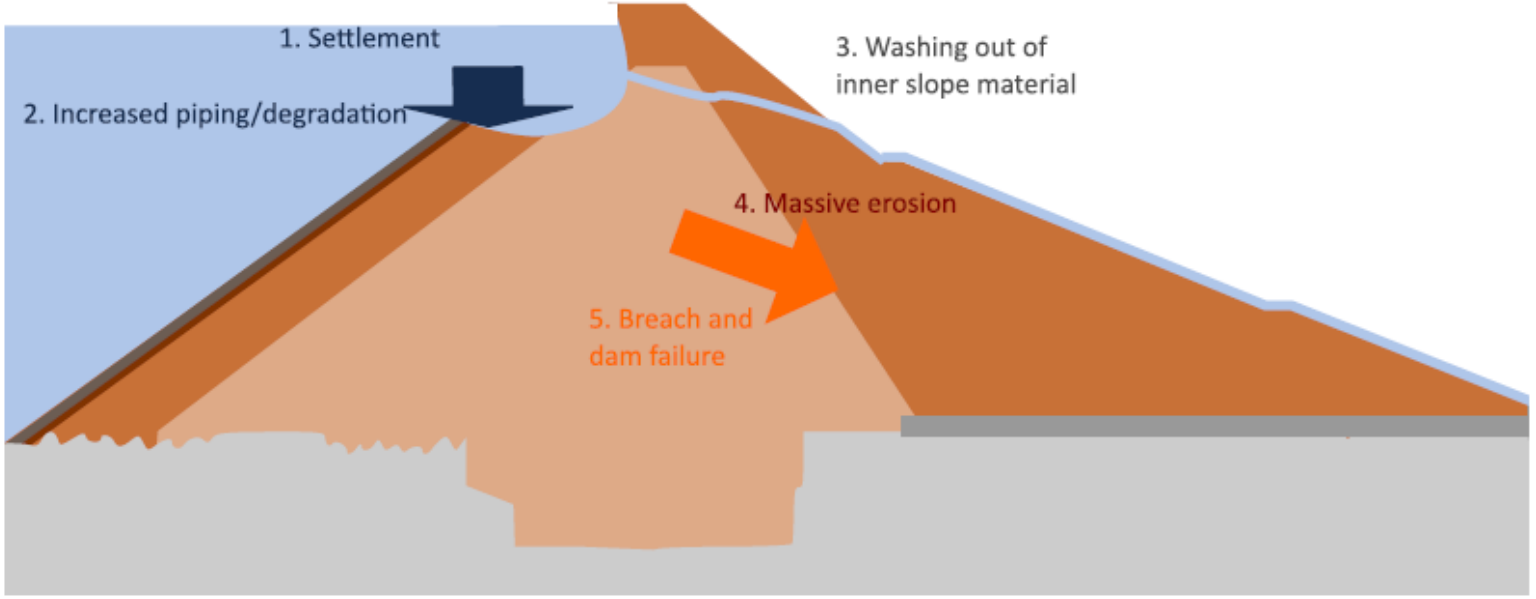
Sliding Failure during a seismic event



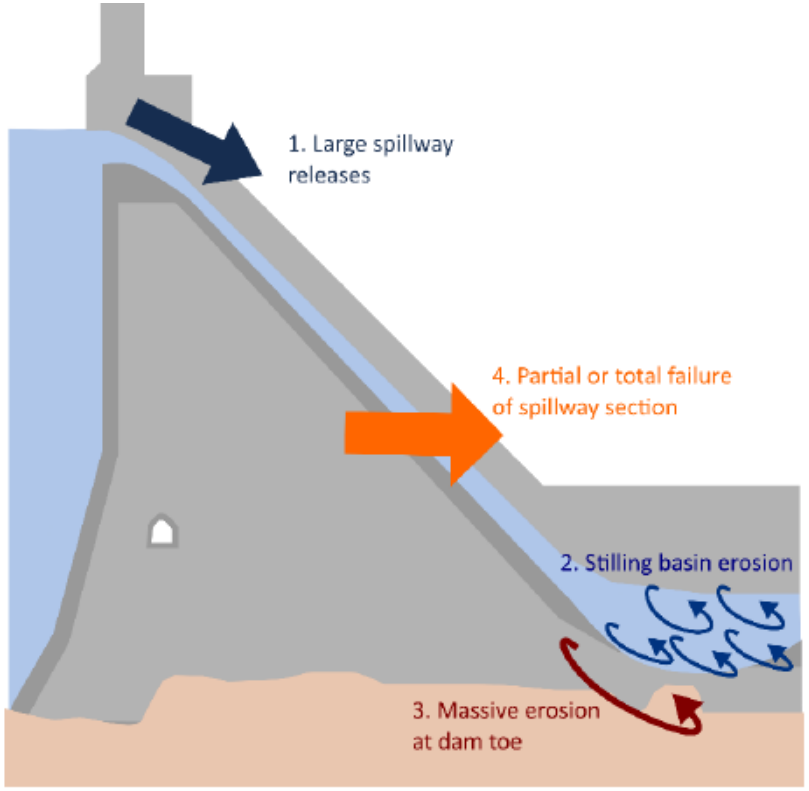
Failure due to internal erosion



Failure due to settlement of upstream face



Stilling basin failure



Around 40% failure of dams in the world is due to overtopping. Around 30% failure of dams is due to piping. Rest 30% failure are due to other reasons.

Most of the failures are in small embankment dam.

Most failure in embankment dams occurred after first filling or within 5 years of commissioning.