Earth dam design

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ABSTRACT

Water is the most essential resource that supports all forms life that exists on earth. Unfortunately, this resource of life is not distributed evenly all over the world. Different locations in the world have varying supply of natural water in different seasons. Therefore, in this study I researched about earth dam for Talazait village. Cross-section of the dam is made of shell and core due to availability of the suitable materials for that purpose. To make the dam safe against seepage through the body and it is foundation a chimney filter connected to blanket filter is provided. The u/s and d/s side slopes of the dam that are select at preliminary design are check by Geo-studio and they are sufficient in all critical cases.

Contents

Definition and introduction to the dam

A dam is a hydraulic structure of fairly impervious material built across a river to create a reservoir on its upstream side for impounding water for various purposes. These purposes may be Irrigation, Hydro-power, Water-supply, Flood Control, Navigation, Fishing and Recreation. Dams may be built to meet the one of the above purposes or they may be constructed fulfilling more than one. As such, it can be classified as: Single-purpose and Multipurpose Dam.

Difference parts and terminology of dams

- Crest: The top of the dam structure. These may in some cases be used for providing a roadway or walkway over the dam.
- Parapet walls: Low Protective walls on either side of the roadway or walkway on the crest.
- Heel: Portion of structure in contact with ground or river-bed at upstream side.
- Toe: Portion of structure in contact with ground or river-bed at downstream side.
- Spillway: It is the arrangement made (kind of passage) near the top of structure for the passage of surplus/ excessive water from the reservoir.
- Abutments: The valley slopes on either side of the dam wall to which the left & right end of dam are fixed to.
- Gallery: Level or gently sloping tunnel like passage (small room like space) at transverse or longitudinal within the dam with drain on floor for seepage water. These are generally provided for having space for drilling grout holes and drainage holes. These may also be used to accommodate the instrumentation for studying the performance of dam.
- Sluice way: Opening in the structure near the base, provided to clear the silt accumulation in the reservoir.

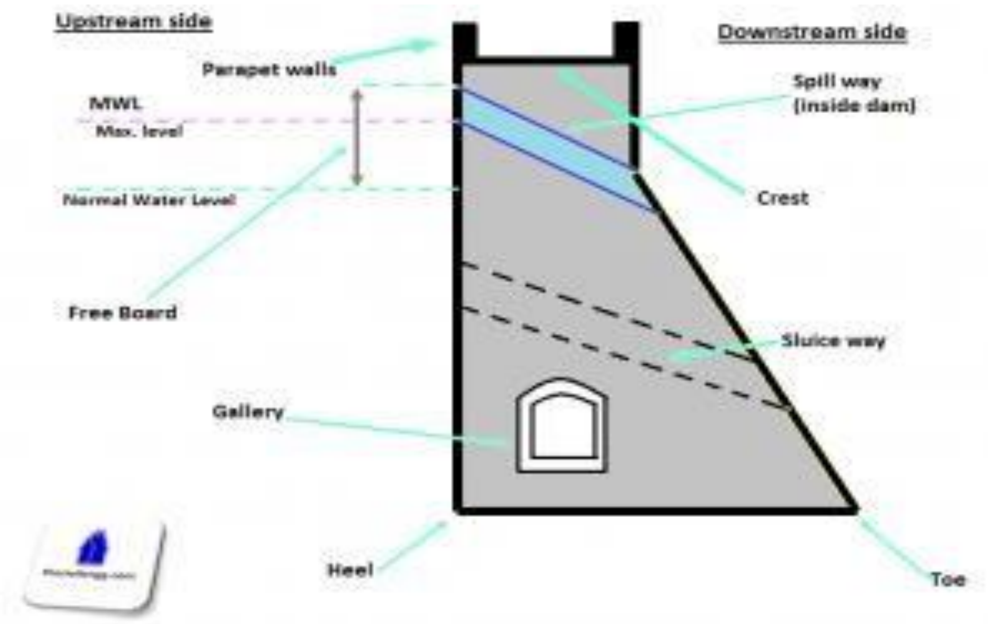


Figure : Illustration of dam-parts in a typical cross section

Free board: The space between the highest level of water in the reservoir and the top of the structure.

- Dead Storage level: Level of permanent storage below which the water will not be withdrawn.
- Diversion Tunnel: Tunnel constructed to divert or change the direction of water to bypass the dam construction site. The hydraulic structures are built while the river flows through the diversion tunnel.

Classification of Dams

Dams can be classified in number of ways. But most usual ways of classification i.e. types of dams are mentioned below:

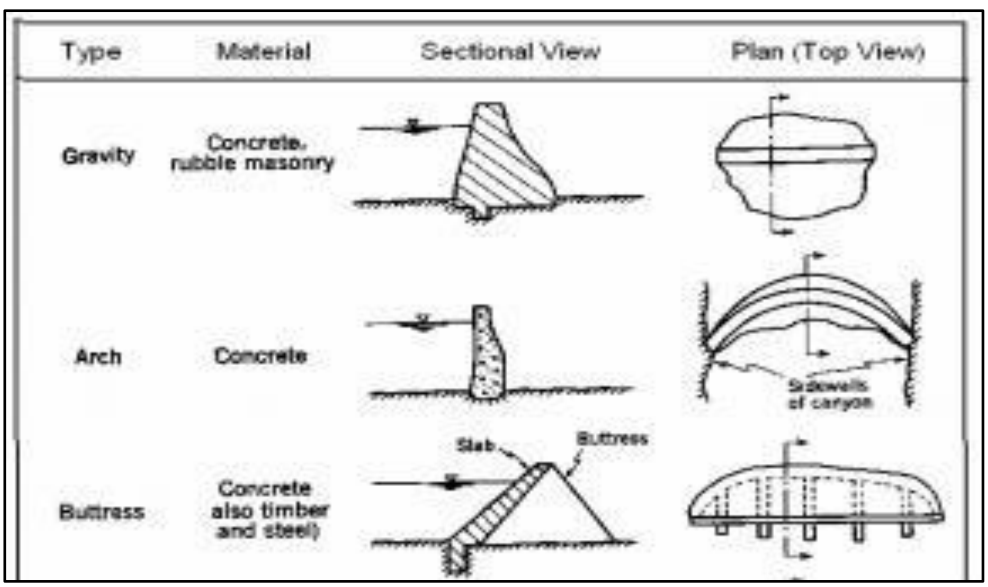
Based on the functions of dams, it can be classified as follows:

- Storage dams: They are constructed to store water during the rainy season when there is a large flow in the river. Many small dams impound the spring runoff for later use in dry summers. Storage dams may also provide a water supply, or improved habitat for fish and wildlife. They may store water for hydroelectric power generation, irrigation or for a flood control project. Storage dams are the most common type of dams and in general the dam means a storage dam unless qualified otherwise.

- Diversion dams: A diversion dam is constructed for the purpose of diverting water of the river into an off-taking canal (or a conduit).
- Detention dams: Detention dams are constructed for flood control. A detention dam retards the flow in the river on its downstream during floods by storing some flood water.
- Debris dams: A debris dam is constructed to retain debris such as sand, gravel, and drift wood flowing in the river with water. The water after passing over a debris dam is relatively clear.
- Coffer dams: It is an enclosure constructed around the construction site to exclude water so that the construction can be done in dry.

Based on the construction materials

- Concrete dams: the following figure shows different types of concrete dams which are gravity, arch, and buttress dams.



Types of dam

- Embankment Dams: An earth dam is made of earth (or soil) built up by compacting successive layers of earth, using the most impervious materials to form a core and placing more permeable substances on the upstream and downstream sides.

- Steel Dams: Dams: A steel dam consists of a steel framework, with a steel skin plate on its upstream face. Steel dams are generally of two types: (i) Direct-strutted, and (ii) Cantilever type. In direct strutted steel dams, the water pressure is transmitted directly to the foundation through inclined struts. In a cantilever type steel dam, there is a bent supporting the upper part of the deck, which is formed into a cantilever truss. Examples of Steel type: Redridge Steel Dam (USA) and Ashfork-Bainbridge Steel Dam (USA).
- Timber Dams: Main load-carrying structural elements of timber dam are made of wood, primarily coniferous varieties such as pine and fir. Timber dams are made for small heads (٢-٤ m or, rarely, ٤-٨ m) and usually have sluices; according to the design of the apron they are divided into pile, crib, pile-crib, and buttressed dams.

- Rubber Dams**:** A symbol of sophistication and simple and efficient design, this most recent type of dam uses huge cylindrical shells made of special synthetic rubber and inflated by either compressed air or pressurized water. Rubber dams offer ease of construction, operation and in tight schedules. These can be deflated when pressure is released and hence, even the crest level can be controlled to some extent. Surplus waters would simply overflow the inflated shell. They need extreme care in design and erection and are limited to small projects. Example of Rubber type: Janjhavathi Rubber Dam (India).

Importance of Dams and Their Benefits

Most of the dams are single-purpose dams, but there is now a growing number of multipurpose dams. Using the most recent publication of the World Register of Dams, irrigation is by far the most common purpose of dams. Among the single purpose dams, ٤٨ % are for irrigation, ١٧٪ for hydropower (production of electricity), ١٣٪ for water supply, ١٠٪ for flood control, ٥٪ for recreation and less than ١٪ for navigation and fish farming.

- Irrigation:

Presently, irrigated land covers about ٢٧٧ million hectares about ١٨٪ of world's arable land but is responsible for around ٤٠٪ of crop output and employs nearly ٣٠٪ of population spread over rural areas. With the large population growth expected for the next decades, irrigation must be expanded to increase the food capacity production. It is estimated that ٨٠٪ of additional food production by the year ٢٠٢٥ will need to come from irrigated land. Even with the widespread measures to conserve water by improvements in irrigation technology, the Construction of more reservoir projects will be required.

- Hydropower:

Hydroelectric power plants generally range in size from several hundred kilowatts to several hundred megawatts, but a few enormous plants have capacities near ١٠,٠٠٠ megawatts in order to supply electricity to millions of people. World hydroelectric power plants have a combined capacity of ٦٧٥,٠٠٠ megawatts that produces over ٢,٣ trillion kilowatt-hours of electricity each year; supplying ٢٤ percent of the world's electricity. In many countries, hydroelectric power provides nearly all of the electrical power. In ١٩٩٨, the hydroelectric plants of Norway and the Democratic Republic of the Congo (formerly Zaire) provided ٩٩ percent of each country's power; and hydroelectric plants in Brazil provided ٩١ percent of total used electricity.

- Water supply for domestic and industrial use:

It has been stressed how essential water is for our civilization. It is important to remember that of the total rainfall falling on the earth, most falls on the sea and a large portion of that which falls on earth ends up as runoff. Only ٢٪ of the total is infiltrated to replenish the groundwater. Properly planned, designed and constructed and maintained dams to store water contribute significantly toward fulfilling our water supply requirements. To accommodate the variations in the hydrologic cycle, dams and reservoirs are needed to store water and then provide more consistent supplies during shortages.

- Inland navigation:

Natural river conditions, such as changes in the flow rate and river level, ice and changing river channels due to erosion and sedimentation, create major problems and obstacles for inland navigation. The advantages of inland navigation, however, when compared with highway and rail are the large load carrying capacity of each barge, the ability to handle cargo with large-dimensions and fuel savings.

- Flood control:

  Dams and reservoirs can be effectively used to regulate river levels and flooding downstream of the dam by temporarily storing the flood volume and releasing it later. The most effective method of flood control is accomplished by an integrated water management plan for regulating the storage and discharges of each of the main dams located in a river basin. Each dam is operated by a specific water control plan for routing floods through the basin without damage.

Earth Dam and Their Types

Definition of embankment dam:

It is a dam in which the principal barrier is an embankment of earth or rock fill or combination of earth and rock fill.

Types of Earthen Dams:

- Homogenous Embankment Type
- Zoned Embankment Type
- Diaphragm Type

These types of dams are described below*:*

- Homogeneous Embankment Type:

The simplest type of an earthen embankment consists of a single material and is homogeneous throughout. Sometimes, a blanket of relatively impervious material may be placed on the upstream face. A purely homogeneous section is used for low to moderately high dams. Large dams are seldom designed as homogeneous embankment. A purely homogeneous section poses the problems of seepage and hug section are required to make it safe against piping, stability, etc. Due to this, a homogeneous section is generally added with an internal drainage system: such as a horizontal drainage filter, a rock toe, etc. The internal drainage system keeps the top seepage line well within the body of the dam, and steeper slopes, and thus, smaller section therefore, always provided in almost all types of embankment.

- Zoned Embankment Type:

Zoned embankments are usually provided with a central impervious core, covered by a comparatively pervious transition zone, which is finally surrounded by much more pervious outer zone. The central core checks the seepage, the transition zone prevents piping through cracks which may develop in the core. The outer zone gives stability to the center impervious fill and also distributes the load over a large area of foundations.

This type of embankments are widely constructed and the materials of the zones are selected depending upon their availabilities, clay, in spite of it being highly impervious, may not make the best core, if it shrinks and swells too much. Due to this reason clay is sometimes mixed with fine sand or fine gravel, so as to use it as the most suitable material for the central impervious core.

Silts or silty clays may be used as the satisfactory central core materials. Free draining materials, such as coarse sands and gravels, are used in the outer shell. Transition filter are provided between the inner zone and the outer zone.

This type of transition filters are always provided,

whenever there is an abrupt change of permeability from one zone to the other.

- Diaphragm Type Embankments:

Diaphragm type embankments have a thin impervious core, which is surrounded by earth or rock fill. The impervious core, called diaphragm, is made of impervious soil, concrete, steel, timber or much other material. It acts as a water barrier to prevent seepage through the dam.

The diaphragm may be placed either at the center as a central vertical core or at the upstream face as a blanket. The diaphragm must also be tied to the bed rock or to a very impervious foundation material, if excessive under seepage through the existing pervious foundation has to be avoided. The diaphragm types of embankments are differentiated from zoned embankment, depending upon the thickness of the core. If the thickness of the diaphragm at the elevation is less than ١٠ meters or less than the height of the embankment above the corresponding elevation, the dam embankment is considered to be of Diaphragm Type. But if the thickness equals or exceeds these limits, it is considered to be of zoned embankment type

SELECTION OF A SUITABLE SITE FOR THE EARTH DAM

The selection of a suitable site for the construction of a dam depends on various

factors which are briefly described below:

- There should be water tight for the reservoir formed by the surrounding hills up to the proposed elevation of the dam.

- The value of the property and land submerged in the reservoir created by the propose dam should be as low as possible. Suitable foundations should be available at the dam site. It's however possible to Improve the foundation conditions by adopting appropriate foundation treatments. Special site requirement for the spillway.
- For economy it's necessary that the length of the dam should be as small possible and for a given height it should store large volume of water. It therefore follows, that the river valley at the dam should be as narrow as possible and should open out upstream to create a reservoir with as far as possible large storage capacity often the dam is located on the downstream of the confluence of two rivers, So that advantages of both the valleys to provide larger capacity is available.
- As far as possible the dam should be located on high ground as compared to the river basin. This will reduce the cost and facilitate drainage of the dam section.
- A suitable site for the spillway should be available in the vicinity of the dam if the spillway is to be located separately from the dam.
- From the standpoint of economy the economy the bulk of the materials required for the Construction of dam should available at or near the dam site.
- Immediately on the upstream of the dam site
- Dam site should be such that the reservoir would not silt up soon.
- For this if any of tributaries of the river is transporting relatively large quantity of sediment, and then the dam site may be selected on the upstream of the confluence of this tributary with the river.
- It is preferable to select a dam site which is already connected or can be conveniently connected to a nearby rail head by road or rail, so that the dam site is easily accessible. This would facilitate transportation of men, machinery and various other essential items to the dam site.
- In the near vicinity of the dam site sample space with healthy environment must be available for establishing colonies for labor and other staff members associated with the construction of dam.

- The dam site should be such that it involves minimum overall cost of construction as well as minimum cost of subsequent maintenance.

FACTORS GOVERNING THE SELECTION THE TYPE OF EARTH DAMS:

Site conditions may lead to selection of an earth dam rather than a concrete dam due to the following reasons:

١. Topography:

Topography, to a large measure, dictates the first choice of type of dam: a wide valley with deep overburden would suggest an earth dam.

٢. Geology and Foundation conditions:

- Gravel foundations, if well compacted is suitable for earth dams.
- Silt or fine sand foundations can been used for earth dams, the main problems include settlement, prevention of piping, excessive percolation losses.
- Clay foundation may been used for earth dams but require flat embankment slopes because of relatively low foundation shear strength.

٣. Materials available:

The most economical type of dam will often be one for which materials can be found within a reasonable haul distance from the site, including material which must be excavated for the dam foundation, spillway, outlet works, powerhouses, and other appurtenant structures. Materials, which may be available near or on the dam site, include soils for embankments and riprap.
If suitable soils for an earth-fill dam can be found in nearby borrow pits, an earth dam may prove to be more economical.
In some cases where required excavation from the spillway channel can be utilized in the dam embankment, an earth dam may be advantageous.

٤. Environmental:

Recently environmental considerations have become very important in the design of dams and can have a major influence on the type of dam selected. The principal influence of environmental concerns on selection of a specific type of dam is the need to consider protection of the environment, which can affect the type of dam, its dimensions, and location of the spillway and appurtenances facilities.

FOUNDATION MATERIALS

It is possible to construct an earth-fill embankment on a suitable foundation if this has been thoroughly investigated and the design and construction procedures are adapted to site conditions. Some foundation conditions require construction measures that are relatively expensive which, in the case of small farm dams, cannot be justified. Sites with such foundation conditions ordinarily should be abandoned.

The best foundation comprises, or is underlaid by, a thick layer of relatively impervious, consolidated material, which occurs at a shallow depth. Such foundations cause no stability problems. Where a suitable layer occurs at the surface, no special measures are required. It is sufficient to remove the topsoil, and scarify or disc plough the area to provide a bond with the material in the dam wall.

A compacted clay cut-off trench can be constructed to extend from the surface of the ground into the impervious layer. This prevents possible failure by tunnelling and excessive seepage.

A detailed investigation should be made where the foundation consists of either pervious sand or a sand–gravel mixture, and the impervious clay layer is beyond the reach of equipment. While such a foundation might be satisfactory in terms of stability, corrective measures will be required to prevent excessive seepage and possible failure.

In the case of a foundation consisting of, or underlain by, a highly plastic clay or unconsolidated material, very careful investigation and design is required in order to obtain stability. Water stored on bedrock foundations rarely gives cause for concern unless the rock contains seams, fissures or crevices through which water may escape at an excessive rate. Where rock is encountered in the foundation, careful investigation of the type and physical properties of the rock is required. Foundations must be capable of supporting the weight of the dam and must be sufficiently watertight to prevent seepage under the dam. Springs, soaks or landslips indicate unstable soil conditions and should be avoided.

Therefore, the three main kinds of foundation material are:

- **Clay** Clay foundations are usually satisfactory, provided they are of the same material as that placed in the earth bank. However, if they are soft and saturated it may become necessary to remove them or place additional stabilizing fills. Highly expansive clays, which shrink and swell during cycles of wetting and drying, may be unsuitable because of risks associated with tunneling and high seepage rates.
- **Rock** Most rock can support the weight of the dam. Care must be taken to ensure that seepage does not occur between the rock foundation and the earth-fill dam so that weathering of the rock does not lead to weakening of the foundation, or that permeable zones are not created by joints and faults. Care should also be taken where expansive rock is being excavated, since elastic recovery (or expansion) of rock material occurs in response to reduced pressures, as the overburden is removed.
- **Sands** and The problem with this type of foundation are high seepage losses.
- **Gravels** While it is possible to build dams with these materials, the cost is frequently prohibitive. Such sites are best avoided, and an alternative location found.

Embankment materials Soils placed in dams must fulfil two conditions; they must be sufficiently impervious to keep the seepage at a safe rate, and they must have sufficient strength to ensure stable side slopes.

There are three kinds of gully dams: homogenous, zoned, and diaphragm. The homogenous dam is built from one type of soil and is the most common kind in Australia. A zoned bank consists of a center clay core with pervious material on either side. It is considered the most stable form of farm dam. The diaphragm dam is built when there is only a limited amount of clay available at the site. The bulk of the bank is constructed from relatively pervious material with a thin layer (that is, a diaphragm) of clay on the upstream slope. This layer varies from ٠٫٦ to ١٫٠ m thick, depending on the height of the dam.

Good, impervious material contains about ٢٥ per cent clay with the balance made up of silt, sand and some gravel. Too much clay results in the embankment being weak and prone to expansion and contraction with changes of moisture content. Insufficient clay can cause excessive seepage through the bank.

The usual method for exploring the material at a potential dam site is hand auger boring. This is the cheapest method, although it is very hard work for the operator and provides a disturbed sample. It is therefore advisable to sink a test pit or trench so that the soil can be examined in its natural state.

Dam sites are tested on a fixed pattern. Small dams (up to ٣ m high) have a minimum of six test holes, four in the center-line (including one on the spillway) and at least two in the borrow pit area. For larger farm dams the number of test holes is increased, with holes at ٢٠ m intervals in borrow pits where sites are steep or uncomplicated. This spacing can be increased to a ٧٠- ١٠٠ m grid when the site is flat or uncomplicated. The test holes on the center-line of larger dams are spaced at about ٣٠ m intervals. The test holes in the borrow pits are sunk to about ٣ m or to rock, while those in the dam center-line are put down to at least two-thirds of the dam height or to rock.

When the exploration has been completed, all test holes and pits should be carefully filled to prevent human and stock injury and compacted to prevent seepage/leaks.

Dam analysis and design

Selection preliminary section of earth dam:

A preliminary section is selected and then subjected to the stability analysis to check its safety. In the preliminary section, the following parameters are decided:

Crest width:

The crest width of an earth dam is determined only by the requirement of roadway at the top of the dam. In general the crest width varies ٦ to ١٢ m, with the wider dimensions being adopted for the higher and more important dams. However, a crest width less than ٦ m may also be provided but it should not be less than ٣ m because this is the minimum needed for an access road to permit maintenance work. For Talazait earth dam ١٠ m will be adopted as a preliminary crest width.

The width should be sufficient to keep the seepage line within the dam when the reservoir is full.

- For very low dams with height H<١٠m, top width: B = H/٥ + ٣
- For dams with height ١٠m<H<٣٠m: B = ٠,٥٥ H + H/٥
- For dams higher than ٣٠ m: B = ١,٦٥ (H + ١,٥)١/٣
- Top width should not be less than ٣ m for any height of the dam.

Side slopes:

No specific rules can be given for determining the side slopes of an earth dam. The general procedure is that on the basis of experience with similar dams side slopes are considered and the same are modified if necessary after the stability is carried out.

The side slopes of earth dams usually vary in the range between ٢ horizontal to ١ vertical and ٤ horizontal to ١ vertical. However, where the foundation is weak side.

Preliminary side slope

Type of material	U/S slope (H:V)	D/S slope (H:V)
Homogenous well graded	٢:١	٢:١
Homogenous coarse silt Homogenous silty clay (i) height less than ١٥ m (ii) height more than ١٥ m	٢:١ ٢,٢٥:١ ٢,٥:١ ٣:١	٢:١ ٢,٢٥:١ ٢,٥:١ ٣:١
Sand or sand and gravel with a central clay core	٢,٥:١ ٢,٥:١	٢:١ ٢,٢٥:١
Sand or sand and gravel with R.C. diaphragm	٣:١ ٣,٥:١	٢,٥:١ ٣:١

Free board:

Freeboard is the difference in the elevation of the crest of the dam and the maximum water level in the reservoir which will result when the maximum flood will occur. Sufficient freeboard must be provided so that there is no possibility whatsoever of the dam being overtopped.

The necessary freeboard is calculated by assuming that the maximum flood will occur when the reservoir is full and that the highest possible waves will develop at the same time. The minimum freeboard shall be ١,٥ times the wave height (for runup on riprapped slopes), plus a safety factor.

The height of wave may be compacted by Molitor's formula. The safety factor which generally varies between ٠,٦ to ٣ m is selected by considering the size of the reservoir, the height of the dam, the reliability of the data from which the flood computations are made, and the usual practice.

Freeboard is taken ١,٥ times the wave height:

FB = ١,٥ hw

For F<٣٢ km $h_w = ٠,٠٣٢٢\sqrt{FV} + ٠,٧٦٣ - ٠,٢٧١F^{٠,٢٥}$

For F>٣٢ km $h_w = ٠,٠٣٢٢\sqrt{FV}$

Where:

V = wind velocity in km/hr

F = fetch in km

h_w = wave height in meters

Settlement allowance:

Settlement of an earth dam may be caused by consolidation of the soil mass in the dam and in the foundation. It depends on the character of the soil mass in the dam and the foundation and the method of construction used. In order to allow for the settlement it is usual o construct earth dams to a somewhat greater height then the designed height so that there may be no reduction in the designed freeboard above the maximum water level in the reservoir. Generally a provision for settlement allowance of ١ to ٢ percent of the height of the dam above the designed top level may be made to account for the settlement of earth dams.

GEOTECHNICAL DESIGN PARAMETER

The geological and geotechnical evaluation reports are submitted separately, the required tests were carried out at the dam axis and the quarry materials near the dam site.

FOUNDATION

Three boreholes are drilled at dam axis, and the table below presents summary for borehole results, it shows that the watertable is higher than the invert of cutoff trench which means that there is a need for dewatering during construction of the dam.

Cut slope were found based on the geotechnical cross section shown on boreholes BH١, BH٢. Overburden layer shall be removed therefore a cut depth between ٣ to ٤ m are used.

According to low permeability and sound foundation at dam site, there is no need for curtain grouting or consolidation grouting; the below table summarizes the results for permeability test. And all logs information is listed.

DAM CONSTRUCTION MATERIAL

Construction material is available near the dam site. Samples were taken and required tests were carried out. The embankment construction materials are available in the vicinity of the dam. The quality and availability of the materials were proved by extensive site and laboratory geotechnical investigation works as presented in the geotechnical report. The below table shows the location, distance to dam axis, surface area and approximate volume of materials.

Description of Site Materials

Material Type	Quarry No.	Location name	Easting	Northing	Area Distace From pond km	Surface Area $m^{٢}$	Approxi-mate Volume $m^{٣}$
Clayey Materials	QC١	Alyawa	٥٣٩٨٠٩	٣٩١٢٩٣٢	٢,٠	٥٠٠٠	٢٠٠٠٠
	QC٣	Tilazet	٥٤١٤٣١	٣٩١١٥٠٢	٠,١	٢٥٠	٧٥٠
Granular Materials	QG١	Bakhan	٥٣٧٠٢٠	٣٩١١٦٥٠	٥,٥	٥٠٠٠	٢٠٠٠٠
	QG٢	Bakhan	٥٣٧٧١٨	٣٩١٠٨٢٠	٥,٠	٥٠٠٠	٢٠٠٠٠

According to the required quantities for impervious clay core and shells, which is about ٦,٣٠٠m٣ for clay core and ٢١,٠٠٠m٣ for shells, the available materials is enough to cover the dam construction.

SIDE SLOPE ANALYSIS:

Cross-sectional design for dam will be support by adequate slope stability analysis. The analysis model should adequately represent the geometry and zoning, shear strength parameters, material unit weights, and seepage conditions, external loading, and other relevant factors of the critical cross section or sections.

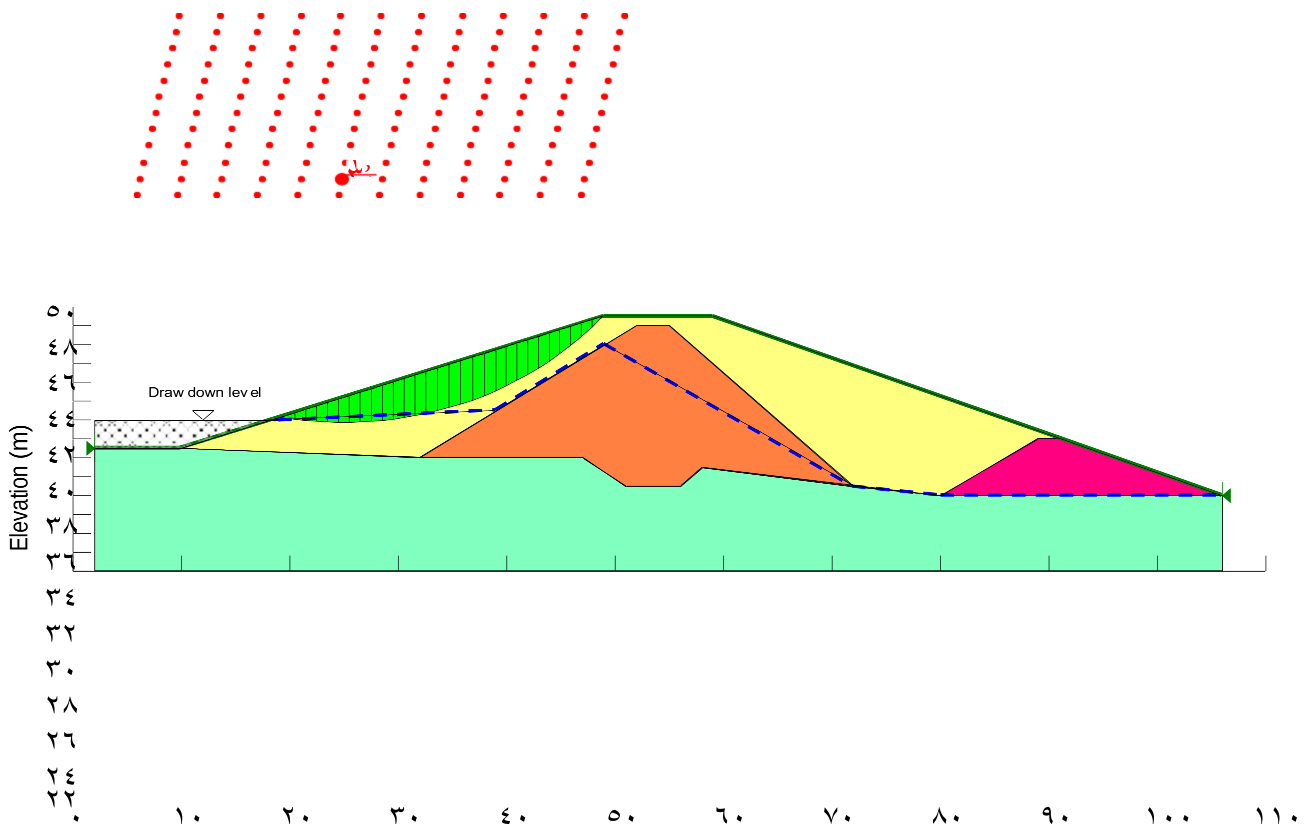
Dams should be designed to provide the following minimum factors of safety from the stability analysis:

- The d/s slope during steady-seepage conditions (١,٣).
- The u/s slope during sudden draw down conditions (١,٣).
- Analysis of u/s and d/s with earthquake consideration (١,٠).

The shell and the core materials properties which are used in the analysis of this dam are according to the geotechnical report. The soil properties are as follows:

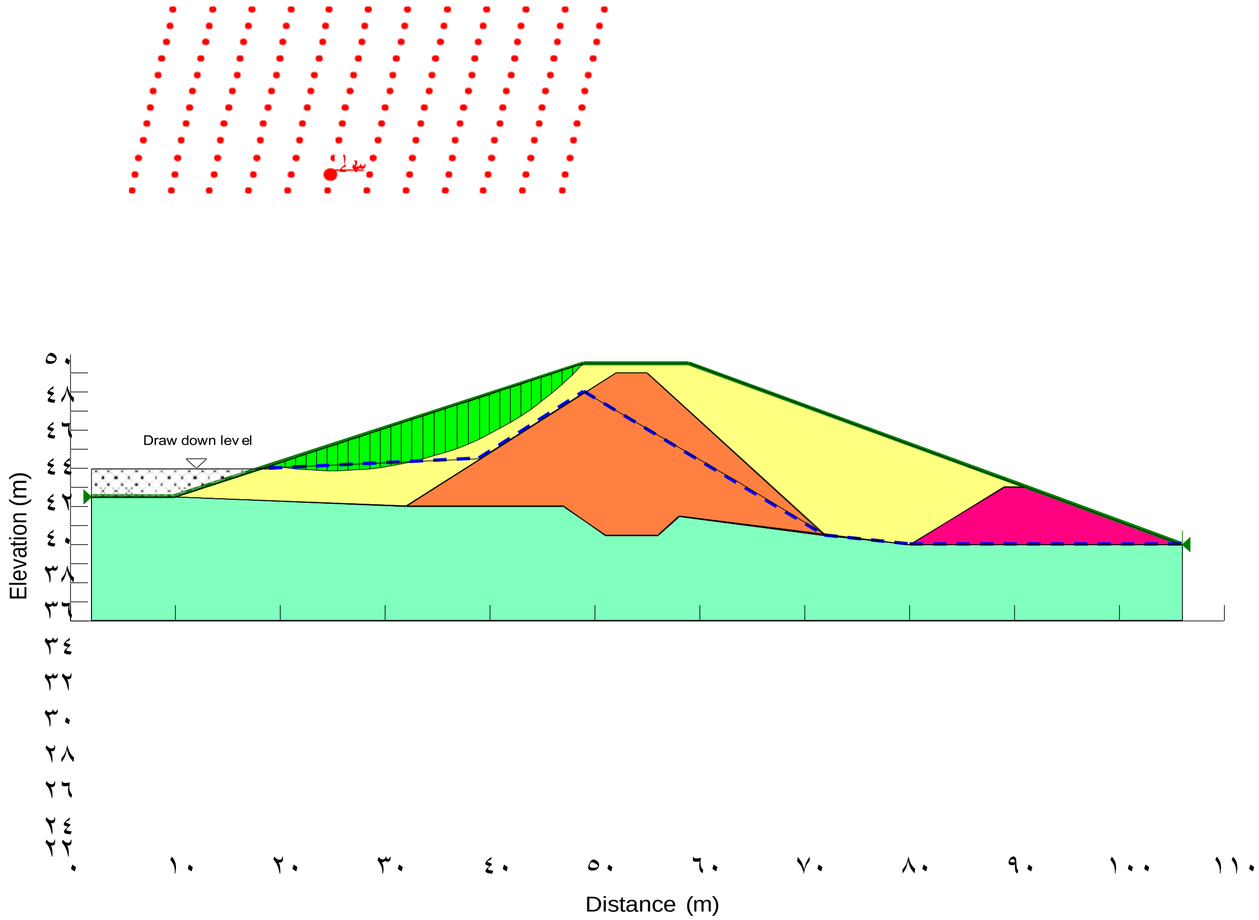
Material properties (adapted from the geotechnical report)

Zone in the dam	Ɣ (unit wt)	Ø(internal friction)	C(cohesion)
Core	١٨,٥	١٣	١٢٠
Shell	٢١	٣٢	٨

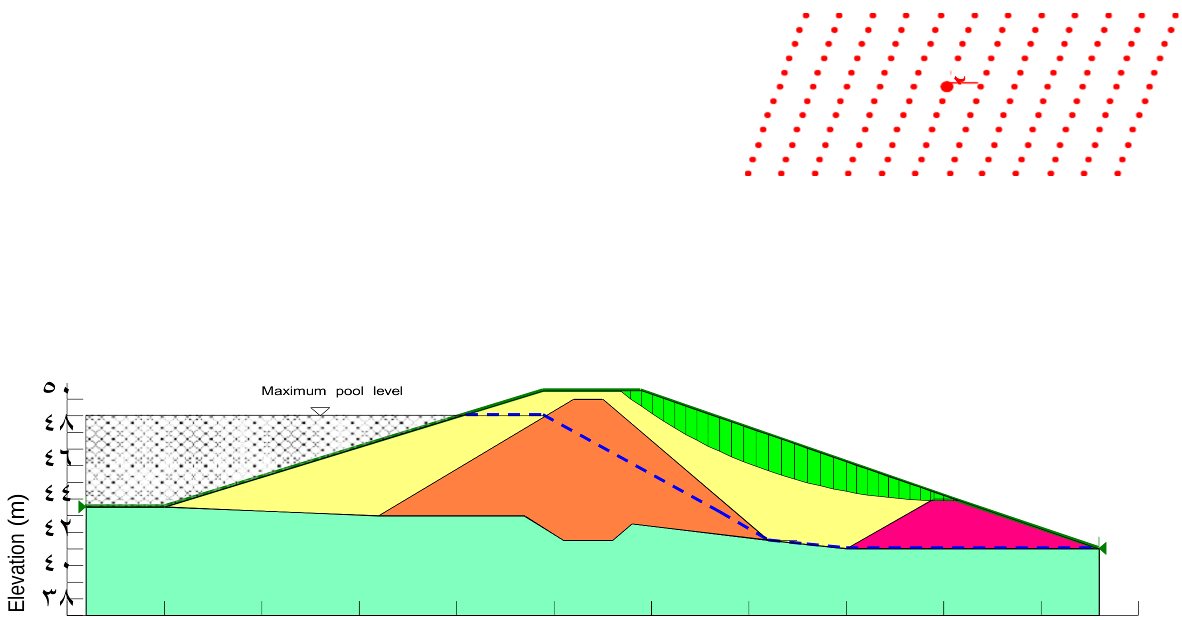


Distance (m)

Upstream slope analysis during sudden drawdown condition.

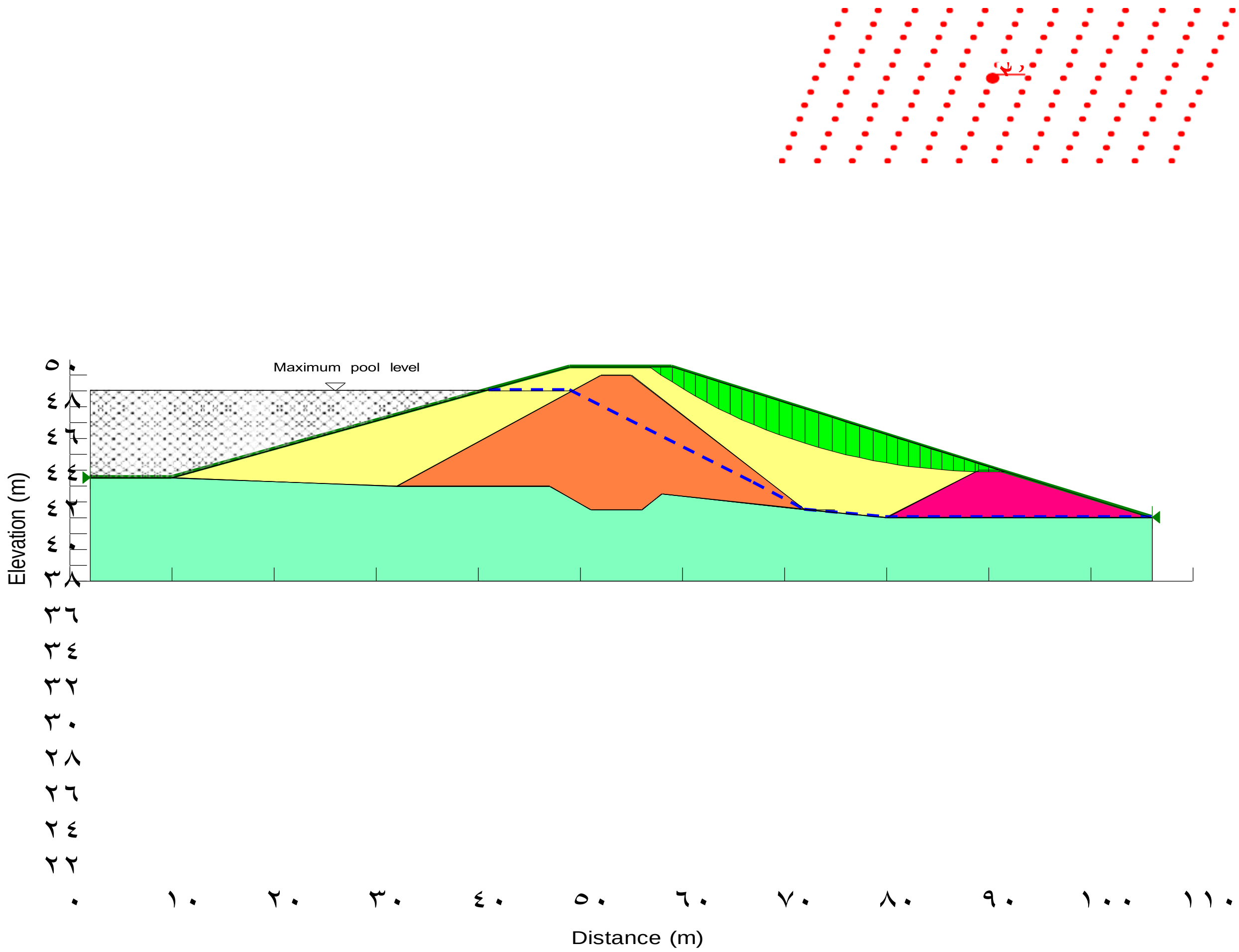


Upstream slope analysis considering earthquake effect



٣٦
٣٤
٣٢
٣٠
٢٨
٢٦
٢٤
٢٢
٠ ١٠ ٢٠ ٣٠ ٤٠ ٥٠ ٦٠ ٧٠ ٨٠ ٩٠ ١٠٠ ١١٠
Distance (m)

Downstream slope analysis during steady seepage condition.



Downstream slope analysis considering earthquake effect.

All the above stability calculation made in accordance with slip circle method using Bishop's method. According to the above results it is found that the selected cross section is safe against sliding under various load conditions.

DETERMINATION OF SEEPAGE LINE

Seepage occurs in all earth dams which will saturate the soil in the lower portion of the dam while the soil in the upper portion of the dam remains relatively dry or moist. The seepage line is defined as the line within a dam section below which the soil is saturated and there are positive hydrostatic pressures in the dam. It is also known as saturation line or phreatic line or top flow line. On this line itself the hydrostatic pressure is equal to atmospheric pressure or zero. Above this line there will be a capillary zone in which the hydrostatic pressures are negative. Since the flow through the capillary zone is insignificant it is usually neglected and hence seepage line is taken as the dividing line between the saturated soil below and dry or moist soil above in a dam section. However, the capillary action leads to increased intergranular pressures and greater shear strength within the soil but this effect is usually neglected thus slightly increasing the margin of safety.

Seepage takes place through and under the dam. The seepage line or phreatic line may be defined as the line above which there is no hydrostatic pressure and below which there is hydrostatic pressure.

Hand calculation of seepage

The determination of seepage line in earth dams is essential, because it helps in:

١. Determining the line dividing the dry and wet or submerged soil in the dam section.
٢. Determining and drawing flow net diagram because it represents the top streamline.

Helping that the seepage line does not cut the D.S. face of the dam

Seepage Line in Homogeneous Dams with Rock Toe:

The portions DC (Δa) and CF (a) are related as follows:

b=٢,٩٢٥+.٧٥+٣+١٠,٥= ١٧,١٧٥m

h=١٣ m

$Y_o=\sqrt{(h^٢ + b^٢)} - b$, $Y_o=\sqrt{(١٣^٢ + ١٧,١٧٥^٢)}$ - ١٧,١٧٥ = ٤,٣٧ m

$$Y=\sqrt{(Y_٠^٢ + ٢ \times X \times Y_٠)}$$

Seepage line coordinates

X (m)	Y(m)
٠	٤,٣٦٥٢
٢	٦
٤	٧,٥
٦	٨,٤٥
٨	٩,٥٥٦
١٠	١٠,٣١٣
١٢	١١,١٢٧
١٤	١١,٨٨
١٦	١٢,٦
١٧,١٧٥	١٢,٩٩

α=١/tan * ١/٠,٧٥ = ٥٣,١٣º

α=٣٠º Δa/a+Δa=٠,٣٦

α=٦٠º Δa/a+Δa=٠,٣٢

α=٥٣,١٣º Δa/a+Δa=٠,٣٢٩١٦ by Interpolation

Δa/a+Δa = Yo/١-cosΘ, Δa/a+Δa = ٤,٣٦٥٢/١-cos٥٣,١٣ = ١٠,٩

Δa/١٠,٩ = ٠,٣٢٩١٦

Δa = ٣,٥٩٢

a = ٧,٣

k = (٣,٣ × ١٠$^{-٧}$ + ٢,٦ × ١٠$^{-٧}$) Cm/sec. / ٢ = ٢,٩٥ * ١٠$^{-٧}$ cm/sec.

k = ٢,٩٥ * ١٠$^{-٩}$ m/sec.

$q = k\ y_o$ when α > ٣٠^o

q = ٢,٩٥ * ١٠$^{-٩}$ * ٤,٣٧ = ١,٢٨٩ * ١٠$^{-٨}$ m^{٢} / sec. this is the seepage through the dam body. α Δ a / (a + Δ a)

For: Horizontal filter: α = ١٨٠

Rock toe: α = ٩٠ or more

Dam without drainage system: α = less than ٩٠

Where: α = angle between horizontal and discharge face.

The seepage discharge can be calculated from the following equation:

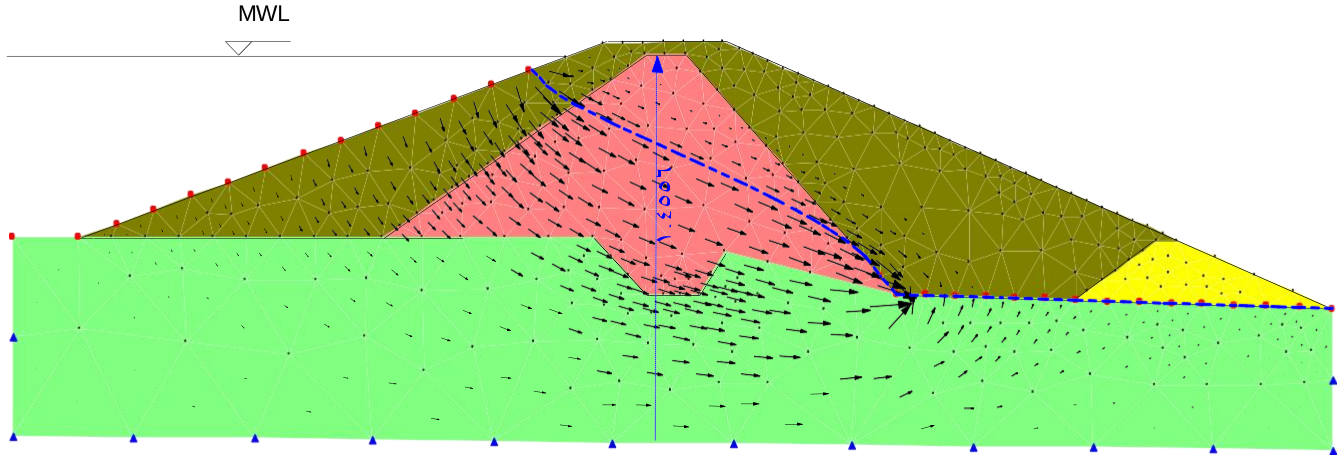
$$q = k\ y. = k[\sqrt{(b^{٢} + h^{٢})} - b]$$

When the angle of discharge face α is less than ٣٠ the following equation may be used:

q = k a sin ٢a.

Seepage calculation using Geo-studio

Depending on the above data Talazait dam is modeled using the Seep/W of Geo-Studio ٢٠٠٤, by GEO-SLOPE International, to calculate the seepage through the dam body and its foundation, the results are shown below. As it appears in the figure the seepage quantity at the deepest section is $١,٤ \times ١٠^{-٥}\ \frac{m^{٣}}{sec}/m$.



Seepage vectors through the dam and its foundation

STAGES OF THE DAM CONSTRUCTION

The principal factors that determine methods of stream control are the hydrology of the stream, the topography and geology of the site, and the construction schedule. The term stages is limited here to construction of an embankment over a period of time with substantial intervals between stages, during which little or no fill is placed. For Talazait dam three stages are recommended to be adopted as below:

Stage ١

Since river diversion is a critical operation in constructing a dam, the method and time schedules for diversion are important elements of design. So first of all the following should be done:

- Cleaning the area where the dam and the spillway to be constructed.
- Construct the diversion conduit with the main outlet conduit (including the intake tower of the outlet) while the stream is flowing in its natural position except at the downstream where it needs to deviate the stream from its natural direction.

Stage ٢

During the next construction period, at a time when flood possibility is low and favorable embankment placement conditions are likely, a cofferdam is constructed to divert the stream through the diversion and the outlet works. Moreover, in this stage it is preferable to construct the rock toe.

Stage ٣

In the period following diversion, the embankment is completed to a given height as rapidly as possible in preparation for high water. In the final period, the entire dam is brought up to full height, the plugging manhole is plugged and the water will accumulate gradually.

CONCLUSION:

Embankment dams are the most popular type of dams built in the world due to the availability of its construction materials and equipment. In this study the Talazait earth dam is designed by selecting a preliminary cross section of shell and core due to availability of the suitable materials for that purpose. Stability analysis on the selected cross section to make sure its stability in different critical conditions by using the slope/W of Geo-Studio ٢٠٠٤, by GEO-SLOPE International. The u/s and d/s side slopes of the dam, which are select at preliminary design, are checked and they are sufficient in all critical cases. The seepage analysis is also made for that section to compute the seepage through the dam body and its foundation.

Bibliography

١. Barry, L. (٢٠٠٢). *Farm dams Planning, Construction, and Maintenance.* Australia: Landlinks Press.

٢.Bureau of reclamation. (١٩٨٧). *Design of small dams.* Wshington DC: Water Resources Technical Publication.

٣. Bureau of Reclamation. (٢٠٠٢). ١٠٠ *Years of Embankment Dam Design and Construction.* Denver, Colorado.

٤. Christian, C. (١٩٩٧). *Earth and rockfill dams principles of design and construction.* Rotterdam: A.A. Balkema.