UNIT-3

DIVVERSION AND IMPOUNDING STRUCTURES

PART-A

1) What is meant by canal escape? **(AU MJ2008)**

Canal escapes are the safety valves of canals &must be provided at regular intervals depending upon the importance of channel& availability of suitable drainage for the disposal of the exposed water.

2) State various kinds of dams. **(AU MJ2008)**

- Earth Dams
- Rock Fill Dams
- Solid Masonry Gravity Dams
- Timber Dams
- Steel Dams
- Arch Dams

3). State diff types of spillways. **(AU ND2008)**

- Straight Drop Spillway
- Ogee Spillway
- Trough Spillway
- Side Channel Spillway
- Shaft Spillway
- Syphon Spillway

4) Define gross commanded area. **(AU ND2008)**

It is the total area bounded with in the irrigation boundary of a project. It includes the cultivable as well as uncultivable areas.

5)What is weir? **(AU MJ 2009)**

The major part of the water is achieved by a raised crest or a small part is achievedby raising shutters then this barrier is known as weir.

6) What is tank sluices? **(AU MJ 2009)**

It is an opening in the form of culvert under the tank bund and supplying water to the distributor channel.

7) Forces acting on arch dams. **(AU ND 2009)**

- Water Pressure
- Uplift Pressure
- Earthquake Forces
- Silt Pressure
- Wave Pressure
- Ice Pressure

8) Define sluiceway. **(AU ND 2009)**

Pipe or tunnel provided for the withdrawal of water from the dams is known assluiceway.

9) What is spillway? **(AU MJ 2010, ND 2012)**

Spillway is a structure constructed at a dam site for disposing the surplus waterfrom upstream to downstream.

10) Types of earthen dams. **(AU MJ 2010)**

- Homogeneous Embankment Type
- Zoned Embankment Type
- Diaphragm Type.

11) Define barrage. **(AU ND 2010, MJ 2012)**

The most of the ponding is done by gates and a smaller of it is done by raisedcrest then the barrier is known as barrage.

12) What are the modes of failure in gravity dams? **(AU ND 2010, ND 2012)**

- By Over Turning About The Toe
- By Crushing
- By Development Of Tension
- By Sliding

13) Define diversion headwork. **(AU MJ 2011)**

Any hydraulic structure, which offers water to the off taking canal, is calleddiversion headwork.

14) What is gravity dam? **(AU MJ 2011)**

A structure which is designed in such a way that its own weight resist external forces and it is more durable.

15)Define stream line. **(AU ND 2011)**

it represent the path along which the water flows through the subsoil.at a givenpoint in upstream of hydraulic structure will travel its own path &will represented the stream line.

16). Types of aeration tanks. **(AU ND 2011)**

- Air Diffusion
- Mechanical Aeration
- Combined Aeration

17) Limitations of Bligh's creep theory. **(AU MJ 2012)**

- No Difference B\W Horizontal & Vertical Creep
- Horizontal Distance B\W Pipe Line Is Greater Than 2 Times The Depth
- No Idea About Exit Gradient

PART B

1 Explain Diversion Headwork (AU MJ 2008)

Diversion headwork.

Any hydraulic structure, which supplies water to the off-taking canal, is calleda headwork.A diversion headwork serves to divert the required supply in to the canal fromthe river.

The purposes of diversion headwork.

- It raises the water level in the river so that the commanded area can beincreased.
- It regulates the intake of water in to the canal.
- It controls the silt entry in to the canal.
- It reduces fluctuations in the level of supply in the river.
- It stores water for tiding over small periods of short supplies.

Weir

The weir is a solid obstruction put across the river to raise its water level anddivert the water in to the canal. If a weir also stores water for tiding over small periods of short supplies, it is called a storage weir.

The component parts of diversion headwork

- Weir or barrage
- Divide wall or divide groaned
- Fish ladder
- Head sluice or canal head regulator
- Canal off-takes
- Flood banks
- River training works

WEIR:

It is a dam over the crest of which water is discharged. It is also known as anuncut. It primarily raises the water level in the river and diverts it in to the canal,which takes off from the river. It is a solid obstruction built across the river. When the discharge in the river is large, it spills over the crest of the weir.

The weirs are also provided with crest shutters. During heavy floods, the shutter maybe laid flat on the crest or may be raised vertically clear off the flood.If a weir also stores water tiding over small periods of short supplies, it is called astorage weir. A storage weir is shorter and stores the water supply for a short period.

BARRAGE OR REGULATOR:

It functions similar to a weir. The heading up of water is affected by theshutters alone. It consists of a number of piers having grooves with suitable flooringbetween them. The shutters move in the grooves. The shutters are raised or lowered asper requirements. In most of the cases, a road way is provided for the traffic. Thus itfunctions as a regulator and a bridge. The regulator serves as a weir without reallyobstructing the waterway. There is less silting and better control over the water levels.

It can be combined with a bridge. The only drawback is costly.

DIVIDE WALL OR DIVIDE GROYNE:

It is a long wall or embankment-constructed normal to the weir between theweir and the scour sluices. It extends a little beyond the head sluice on the upstreamside and to the end of the talus on the downstream side.It is normally built of solid masonry. If made of embankment, it is protectedon all sides by stone or concrete blocks. It is designed to withstand the water pressurefrom one side only. As a safe measure, the water thrust from the other side is ignoredin the design.

FISH LADDER

In big rivers, fish will always move up and down respectively in search ofclear and warm water. It is, therefore, essential for the provision of some space in theconstruction of weir. It is usually located between the weir and divide wall. It is suitednear the divide wall as there is always some water in the river section below the scoursluicesIt consists of an inclined trough with baffles with holes provided in them. Thebaffles reduce the velocity and provide compartments for the fish to rest. To haveeffective control, grooved gates are provided at the extreme upstream and downstreamend walls. The fish ladder should be designed to have a velocity of 3 m/s or less in thetrough.

HEAD SLUICE OR CANAL HEAD REGULATOR:

A head regulator is structures constructed at the head of a canal off take from reservoir behind a weir or a dam. It may consist of a number of spans separated bypiers and operated by gates.

FUNCTIONS OF A HEAD SLUICE:

- To make the regulation of supply in the canal easy.
- To control the silt entry in to the canal.
- To shut out river floods.
- To provide full supply required for irrigation at moderate velocities withsufficient allowance.

CANAL OFF TAKES:

These may be provided on one or both the sides of the river above the weir orbarrage. These should carry sufficient water for the aqueduct. These must be at suchlevels that they ensure the supply, by direct flow, to aqueduct

SCOURING SLUICES OR UNDER SLUICES:

They maintain a deep channel in front of head sluice and dispose of heavysilt and a part of flood discharge on the downstream side of the barrage or weir.

FUNCTIONS OF SCOURING SLUICES

- To preserve a clear and defined river channel approaching the regulator.

- To control the silt entry in to the canal.
- To scour the silt deposited in the river bed above the approach channel.
- To help in passing low floods without dropping the shutters of main weir.
- To provide additional waterway for floods, thus lowering the flood levels.

FLOOD BANKS:

The obstruction caused by the construction of a solid weir across the riverblocks the waterway. This raises the water level causing backwater. If the natural ground on either side of the weir is sufficiently higher than estimated maximumbackwater level, no protection work is required. If the ground level is lower than the maximum flood level, protective works are required. Such protective works are called flood banks. If flood banks are not provided at weir site, outflanking of the weir will result. This will cause serious damage to the weir resulting in its ultimate collapse. Hence, flood banks of suitable cross section are to be constructed on either side of the weir.

2) What are the different weir foundation? (AU ND 2009)

Types of weirs on permeable foundation.

On permeable foundation, the effective weight of the weir is reduced by upliftpressure. The uplift pressure on the heel of the weir is equal to the depth of water of the upstream and that on the toe is equal to the tail water depth. The weir is to bechecked for overturning, sliding and maximum stress. Generally the weirs constructedon permeable soils or sand are low and very long.

TYPES OF WEIRS ON PERMEABLE FOUNDATION:

- Type A – vertical drop on horizontal apron.
- Type B – sloping masonry apron.
- Type C – rock sloping apron.

TYPE A:

In this type, the water is made to fall vertically on to a horizontal apron.

Further, it may be divided as type A and type A1. In type A, surface of downstreamapron is at or below the low water level. In type A1, the downstream is partially orwholly above low water level. In these weirs the water impinges on the main apron with a vertical overfall producing greater stresses in the main apron. This type ispreferable if the riverbed is moderately hard and the overfill is less than 0.75 m.

TYPE B:

In this type, the apron is sloping and is built of masonry. The upstreamground must be of hard soil. The stress in this weir is very much less as there is novertical fall of water. The sloping apron does not offer any check on the velocity ofwater flowing down the weir. This entails greater velocities, and greater depth ofscour on the toe of the weir apron. Hence, the cost of maintenance will be too high. Ifthe foundation is sandy and the difference of level between the body wall crest andlow water level is considerable, type B is preferable.

TYPE C:

In this type, the apron is sloping and is made of rock fill. This type is usedwhere the stones are available in plenty in different sizes. Type C possesses the meritsof both type A and type B weirs

3 What are the different types of surplus work? **(AU ND 2010)**

TANK SURPLUS WORKS:

The surplus arrangements may be either weirs or flush escapes. The length ofsurplus works depends upon the estimated maximum flood.Weirs are classified in to two heads, depending upon the criterion of thedesign of their floors.

- Gravity weirs
- Non-gravity weirs

A gravity weir is the one in which the uplift pressure due to the seepage ofwater below the floor is resisted entirely by the weight of floor. In the non-gravitytype, the floor thickness is kept relatively less, and the uplift pressure is largelyresisted by the bending action of the reinforced concrete floor.

Depending upon the material and certain design features gravity weir can be subdivided

in to:

- Vertical drop weir
- Sloping weir:
- Masonry or concrete slope weir
- Dry stone slope weir.
- Parabolic weir.

VERTICAL DROP WEIR:

A vertical drop weir consists of a vertical drop wall or crest wall, with orwithout crest gates. At the upstream and downstream ends of the impervious floor,cutoff piles are provided. To safeguard against scouring action, launching aprons areprovided both at upstream downstream end of the floor. A graded inverted filter isprovided immediately at the downstream end of the impervious floor to relieve theuplift pressure.

MASONRY OR CONCRETE SLOPE WEIR:

They are suitable for soft sandy foundation, and are generally used where thedifference in weir crest and downstream river bed is limited to 3 m the surplus arrangements may be either weirs or flush escapes. The length ofsurplus works depends upon the estimated maximum flood.

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VERTICAL DROP WEIR:

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downstream end of the floor. A graded inverted filter isprovided immediately at the downstream end of the impervious floor to relieve theuplift pressure.

DRY STONE SLOPE WEIR:

A dry stone weir or a rock fill weir consists of a body wall and upstream anddownstream rock fills laid in the form of glacis, with few intervening core walls.

PARABOLIC WEIR:

A parabolic weir is similar to the spillway section of a dam. The body wall forsuch a weir is designed at a low dam. A cistern is provided at the downstream side todissipate the energy. The upstream and downstream protection works are similar tothat of a vertical drop or sloping glacis weir.

STEPPED WEIR:

In this type, water is delivered from the crest to a stepped apron. The water isdropped in a series of vertical falls or steps on to successive horizontal apron. Thistype of weir is usually the most suitable one for sites of soft soil and for dropsexceeding 900 mm.

4 what are causes of failure of earth dams and it remedies **(AU MJ 2009,ND2008)**

The causes of failure of earth dams are:

- Overtopping
- Piping
- Failure of upstream slope due to sudden draw-down
- Failure of upstream and downstream slopes
- Foundation slide
- Wave action
- Toe erosion
- Gullying
- Uneven settlement of foundation
- Flow slide
- Damage caused by burrowing animals and decayed roots
- Faulty construction and improper maintenance.

Overtopping:

It is due to inadequate capacity of the spillway and insufficient free board.Hence, free board and surplus arrangements with breaching sections should beadequate.

PIPING:

When the core is cracked or when there are pervious seams in the foundationor when boundary seepage along conduits in poor soil takes place, the conduits areformed by flowing water. Erosion takes place progressively from downstream end. Itoften leads to internal washout of the dam. The remedy is proper compaction andtreatment of foundation, and the selection of right type of materials for the core. Alsothe use of adequate filters at all such places whenever there is a sudden change ingradation of materials

FAILURE OF UPSTREAM SLOPE DUE TO SUDDEN DRAWDOWN:

This failure occurs due to sudden draw down when the upstream slope steep,the soil used in the construction is poor and cohesive, and the compaction isinadequate. Flat slope using right type of soil with proper consolidation will producestable embankment.

FAILURE OF UPSTREAM AND DOWNSTREAM SLOPES:

When the upstream and downstream slopes are steeper than required and thesoil used is poor with inadequate compaction, saturation and softening of soil due to rainfall and seepage causes the sliding of slopes. Adequate compaction using righttype of soil to the required slope as per structural necessity, and provision of invertedhorizontal filter at the bottom of the dam and rock-toe will prevent such failures.

FOUNDATION SLIDE:

When the foundation is made up of soft soil or weak soil or when there isexcess water pressure on confined sand, sliding of entire dam or part takes place dueto excessive shear stress induced in the foundation soil. This should be kept down bycompacting the soil properly and by flattening the slopes. A reverse filter should beprovided at the bottom extending from the center of the dam to the toe drain. This willkeep the saturation level of the downstream portion to its minimum. Key trenchesshould also be made in the natural soil to bond effectively the new soil in the damsection.

TOE EROSION:

The seepage force due to downstream end causes erosion and slip. Provisionof proper and necessary artificial drainage of filter on the downstream slope maysafeguard this failure

GULLYING:

The run off resulting from heavy rainfall may run along the downstream slopeforming gullies. These gullies may damage the dam by erosion. By providing chutesfrom top to toe and turfing the downstream slope, this damage may be avoided.

UNEVEN SETTLEMENT OF FOUNDATION:

After the construction of the earth dam, due to excessive load on loosefoundation, settlement of foundation takes place because of its consolidation. If thesettlement is uneven, it causes cracks in the main section of the dam. Hence failureoccurs. If the foundation is poor, the foundation should be compacted well after removingloose materials. Key trenches may be provided to avoid sliding and to act as seepagebarrier. Bentonite grouting may be done before commencing the laying of earth forconstruction work.

FLOW SLIDE:

If there is loose sand or silt in the dam and foundation, the soil in the damgenerally collapses and flows down on the upstream slope due to liquidation. Use ofright type of soil will prevent this kind of failure.

DAMAGE CAUSED BY CRACKS, BURROWING ANIMALS AND DECAYED

ROOTS:

Failures may also occur due to bores created in the embankments either due tocracks or due to burrowing by animals or due to decaying of roots of trees. Water seepthrough these holes thus formed. The following precautions may be taken to preventsuch failures:

Constructing the dam with right type of soil to prevent cracking.

Covering the upstream slope with stone revetment with good gravel filterbacking to avoid wave erosion and burrowing of animals.Keeping the embankment free from trees and removing the roots of deadtrees and thoroughly compacting the embankment.

FAULTY CONSTRUCTION AND IMPROPER MAINTENANCE:

Even the design is exact and correct, if proper attention is not paid to theconstruction and maintenance of an earth dam, it may fail. Hence, it should beconstructed by paying proper attention. Also, whenever the dam section gets spoiled,it should be brought back to its original profile by regular maintenance.

5 What are factors affecting the selection of type of a dam: (AU MJ 2010)

The selection of a type of a dam at a given site depends upon many physicalfactors such as topography, geological and foundation conditions, available materials,suitable site for spillway, data about earthquake etc.Before selecting the best type of dam at a particular site, one must considerthe characteristics of each type of dam, as related to the physical feature of the siteand the adaption to the purposes the dam is suppose to serve, as well as economy,safety and other pertinent limitation. The choice of the dam may also be guided bymany local problems such as availability of labour and equipment, assessibity of site,limitation imposed by outlet works and cost of protection needed from spillwaydischarge as well as time required for its construction. Some of the physical factorgoverning the selection of type of dam discussed below:

TOPOGRAPHY:

First choice of dam is usually governed by topography for the site. A lowrolling plains country suggests an earth dam with a separate spillway. A low narrow Vshaped valley suggest an arch dam, provided the top width of valley is less than one fourth its height and separate site for spillway is available. A narrow stream flowingbetween high rocky walls (giving rise to U-shaped valley) would suggest a concreteoverflow dam. For intermediate conditions other factors such as foundation condition,location of suitable site for spillway and availability of materials of construction playan important role in the selection of the type.

GEOLOGY AND FOUNDATION CONDITIONS:

If the foundation consists of sound rock, with no fault or fissures, any type ofdam can be constructed on it. Rocks like granite, gneiss and schist make verysatisfactory foundation for gravity dam. However, these rocks may have seams orfractures. The removal of disintegrated rock together with the sealing of seams andfractures by grouting will frequently be necessary. Poor rock or gravel foundations aresuitable for earth dam, rock fill dam or low concrete gravity dam. Since there will beconsiderable under seepage in this case, effective water cutoff or seals have to beprovided. Silt or fine sand foundation have the problem of settlement, seepage and toeerosion. Hence such foundations are suitable only for either earth dam or low concretegravity dam but not rock fill dams. Clay foundations have often the problems of longrange consolidation under the weight of the dam, resulting in cracks. Hence, onlyearth dams are suitable with proper foundation treatment. Gravity dams or rock filldams are not suitable on clay foundations.

MATERIALS OF CONSTRUCTION:

The cost of construction of a particular type of dam will depend upon theavailability of the materials in nearby area so that transportation charges are reduced.If sand, gravel and crushed stone is available, a concrete gravity dam may be moresuitable. If, however, coarse and fine grained soils are available an earth dam may besuitable. The preliminary selection of a particular type, based on the first two physicalfactors, must correspond with the easy availability of the materials required for itsconstruction otherwise that type of dam should be dropped.

SPILLWAY SIZE AND LOCATION:

The safe discharge of flood water through dam is very essential, and for thatsuitable site for spillway should be required. If the area is such that a large spillwaycapacity is required an overflow concrete gravity dam should be preferred. Wheresmall spillway capacity is required and where separate site for spillway location isavailable, an earth dam may be preferred. Where large discharges are to be derivedduring the construction of dam, a concrete gravity dam is preferred to an earth dam. Ifno other site is available for spillway, it has to be accommodated with the main damacross the main river section. In that case, a concrete gravity dam having overflowsection in this middle would be a better choice, through an earth dam can also beconstructed with central overflow section of concrete.

ROADWAY:

If a roadway is to be passed over the top of the dam, an earth dam or gravitydam would be preferred

LENGTH AND HEIGHT OF DAM:

If the length of the dam is very long and its height is low, an earth dam wouldbe a better choice. If the length is small but height is more, gravity dam is preferred.

LIFE OF DAM:

Concrete or masonry gravity dams have very long life. Earth ands rock filldams have intermediate life. However, timber dams are adopted only for temporarystorages.

6 What are the Favourable conditions, advantages, disadvantages, pressure distribution andelementary profile of a masonry dam. (AU ND,MJ 2011)

FAVOURABLE CONDITIONS FOR A GRAVITY DAM:

- Good rock is available for foundation.
- A narrow gorge exists to reduce cost and length of dam.
- Construction materials are available closely in plenty.
- A good site for the surplus weir exists.

ADVANTAGES OF GRAVITY DAM:

- Relatively more strong and stable.
- More suitable as an overflow spillway crest
- Can be constructed to any height on good foundation
- Specially suitable for areas which may experience heavy rains.
- Requires least maintenance.
- Failure of dam, if any, is not sudden.
- Deep-set sluices can be provided to retard silt deposition.
- Cheaper in the long run since it is more permanent.
- More suitable across gorges having very steep slopes.

DISADVANTAGES OF GRAVITY DAM:

- Requires sound rock foundations.
- High initial cost.
- Takes more time for construction.
- Requires skilled labour or mechanized plants for construction.
- Unless specific provisions have been made in the design, it is very difficult to increase the height subsequently.

PRESSURE DISTRIBUTION OF A GRAVITY DAM

Let AB, the base of the section = b

O, the center of the base i.e. AO= b/2

R, the resultant acts at D with eccentricity, e.

Now, let us introduce forces W at O both in upward and downward directions.

The three vertical forces are,

W acting at O (downwards),

W acting at O (upwards),

W acting at D (downwards),

Consider unit length of the dam,

Moment produced by the couple acting at O and D = We

Bending stress due to any moment = M y/I

Bending stress produced at the base = We x b/ [(1/12) 1xb3]

= 6 We/b2

Direct stress due to W at the base = W / area of base

= W / (1x b)

= W / b

Therefore, stress produced at the base.□ = (W / b) □ (6We / b2)

= W / b (1 □ 6e/b2)

Case (1):

If, e = b / 6, □ = 2W/b or 0

i.e., maximum stress = 2W/b

minimum stress = 0

Case (2):

If, e = 0, □ = W/b

ELEMENTARY PROFILE OF A MASONARY DAM:

The most economical profile of a masonry dam is obtained,

- When the vertical resultant force cuts every horizontal section and the base offront extremity of the middle third if the reservoir is empty, and
- When the resultant pressure cuts the base at the rear extremity of the middlethird if the reservoir is full
- A right angled triangle having the water face vertical with apex at the water surfaceand base width, b = H / s fulfills the conditions of an economical section. Such asection is called elementary profile.

Let, b = base width

H = depth of water

S = specific gravity of the material of the dam

□ = specific weight of water

W = weight of masonry

Considering unit length of the dam, horizontal water pressure, p = □ H^2 / 2 acts at H/3

from base.

Weight of masonry, W = (bH/2)x □ s, acts at b/3 from upstream face.

Taking moments about the rear extremity of middle third,

Wb / 3 = PH / 3

(bH / 2) *□ s * b/3 = (□ H2 / 2)* H / 3

b = H / s

This section is safe against overturning and failure due to tension.

Safe design of earth dam.

- The embankment must be safe against overturning during occurrence ofthe inflow design flood by the provision of sufficient spillway and outletworks capacity.
- The dam must have sufficient free board so that it is not overtopped bywave action.
- The seepage line should be well within the downstream face so that nosloughing of the slope takes place.

- Seepage flow through the embankment, foundation and abutments must becontrolled by suitable design provisions so that no internal erosion takesplace. The amount of water lost through seepage must be controlled so thatit does not interfere with planned project functions.
- There should be no opportunity for the free passage of water fromupstream to the downstream either through the dam or through thefoundation.
- The portion of the downstream of the impervious core should be properlydrained.
- The upstream and downstream slopes should be so designed that they aresafe during and immediately after the construction.
- The downstream slope should be so designed that it is safe during steadyseepage case under full reservoir condition.
- The upstream slope should be stable during rapid drawdown condition
- The upstream and downstream slopes of the dam should be flat enough sothat shear stress induced in the foundation is enough less than the shearstrength of the material in the foundation to ensure a suitable factor ofsafety.
- The dam as a whole should be earthquake resistant.
- The upstream slope must be protected against erosion by wave action, andcrest and down stream slope must be protected against erosion due to windand rain.

7 what are the different Forces acting on a gravity dam. (AU ND,MJ 2012)

- Water pressure
- Weight of dam
- Uplift pressure
- Pressure due to earthquake
- Ice pressure
- Wave pressure
- Silt pressure

Water pressure:

This is the major external force acting on a dam. When the upstream face ofthe dam is vertical, the water pressure acts horizontly.The intensity of pressures variestriangular with a zero intensity at the water surface, to a value wh at any depth hbelow water surface. When the upstream face is partly vertical and partly inclined, theresultant water pressure can be resoled into component.(i) Horizontal component P(ii) Vertical component P1 due to weight water supported by the inclined face.Horizontal force P= wH2 / 2This force acts at a height H/3 from the base of the dam.Vertical component, P1 = weight of water contained by column AA’C’B and acting atthe C.G.of the area.Horizontal pressure P2 = WH’2/2Vertical pressure P3 = weight of water contained by column EF’

Weight of the dam:

The weight of the dam is major resisting force. For analysis purpose,generally, unit length of the dam is considered. The cross section of the dam may bedivided into several triangles and rectangles and the weights w1, w2, w3, etc.of eachof these may be computed conveniently, along with determination of their lines ofaction. The total weight w of the dam acts at the C.G of its section

Uplift pressure:

Water has a tendency to seep through the pores and fissures of the foundationmaterial. It also seeps through the joints between the body of the dam and itsfoundation at the base, and through the pores of the material in the body of the dam.The seeping water exerts pressure and must be account for in the stabilitycalculations.The uplift pressure is defined as the upward pressure of water as it flows orseeps through body of the dam or its foundation. A portion of the weight of the damwill be support on the upward pressure of water; hence net foundation reaction due tovertical force will reduce.

Pressure due to earthquake:

The wave imparts accelerations to the foundations under the dam and causesits movement. In order to avoid rupture, the dam must also move along with it. Thisacceleration introduces an inertial force in the body of dam and sets up stressesinitially n lower layers and gradually in the whole body of the dam. Earthquake wavemay travel in any direction.

Ice pressure:

The ice pressure is more important for dams constructed in cold countries, orat higher elevations. The ice formed on the water surface of the reservoir is subjectedto expansion and contraction due to temperature variations. The coefficient of thermalexpansion of ice being five times more than that of concrete, the dam face has to resistthe force due to expansion of ice. This force acts linearly along the length of the dam,at the reservoir level, and its magnitude varies from 2.5 to 15 kg/cm3 depending upontemperature variations. An average value of 5 kg/cm2 may be taken as allowableunder ordinary conditions.

Wave pressure:

Waves are generated on the reservoir surface because of the wind blowingover it. Wave pressure depends on the height of the wave developed.

Wave height

may be calculated by,

hw = (0.032 V.F.) + 0.763 – (0.271 F1/4) For F < 32 km

hw = (0.032 V.F.) For F > 32 km

hw = height of waves in m, between trough and crest

V = wind velocity in km per hour

F = fetch or straight length of water expanse in km

The pressure intensity due to waves PW = 2.4 w hw (t/m2)

Where, Pw = the maximum pressure which occurs at (1/8) hw meters above still water surface.

The pressure distribution is curvilinear. For design purpose, the pressure distribution

may be assumed to be triangle of height = (5/3) hw.
Hence, total pressure
Pw = (2.4 w hw) 1/2 (5hw/3)
= 2 w hw
2 (t/m)
= 2000hw
2 (kg/m)
Its act at a distance of 3hw / 8 above the reservoir surface.

Silt pressure:
The river brings silt and debris along with it. The silt load gets deposited to anappreciable extent when dam is constructed. The dam is, therefore, subjected to siltpressure in addition to the water pressure. If □ ' is the submerged unit weight of siltand □ is the angle of internal friction and h is the height to which the silt is deposited,
the silt pressure is given by,
Ps = (1/2) □ ' h2 (1-sin □) / (1+sin □)

Wind pressure;
It is a minor force and need hardly be taken in to account for the design ofdams. Wind pressure is required to be considered only on that portion of the superstructure, which is exposed to the action of wind. Normally wind pressure is taken as100 to 150 kg / m2 for the area exposed to the wind pressure.