.Y.O.U.R . D.A.M.

ANSWERS

TO THE QUESTIONS MOST

FREQUENTLY ASKED ABOUT

THE INSPECTION AND

MAINTENANCE OF SMALL DAMS

DEPARTMENT OF WATER AFFAIRS

INSPECTION AND MAINTENANCE OF SMALL DAMS

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Q1: WHAT DO WE INTEND TO ACHIEVE WITH THIS PAMPHLET?

A: The principal aim is to establish a uniform level of routine inspection and maintenance on smaller dams as this will enhance the safety of our dams. Some unfamiliar words and terms will be discussed either in the text or the terminology section to ensure uniform usage of a particular word or term.

Q2: WHAT IS A SMALL DAM?

A: For the purpose of this pamphlet a small dam is defined as a dam with a maximum vertical wall height of 15 metres.

Q3: HOW DOES ONE TACKLE THESE INSPECTIONS?

A: A proper programme must be drawn up, indicating the items that require inspection and the time interval between inspections. Thereafter the programme must be strictly adhered to. The inspection programme will reveal all the items that should be inspected regularly - thus constituting a maintenance programme.

Q4: WHAT IS THE RELATION BETWEEN INSPECTION AND MAINTENANCE?

A: Areas requiring maintenance may be detected during an inspection. Similarly, areas of the dam already being maintained may be more closely inspected. One cannot therefore draw a definite line between inspection and maintenance.

Q5: HOW OFTEN SHOULD ROUTINE INSPECTIONS BE PERFORMED?

A: The frequency of routine inspections is determined by the type and size of the wall, the amount of water retained by the wall and the hazard the dam poses to human lives and downstream development. As a rule, quarterly inspections will suffice. Special circumstances may warrant more frequent inspections, for example the first filling of a dam or when problems are encountered.

Apart from routine inspections additional dam safety inspections are required in terms of dam safety legislation at five-yearly or longer intervals. These inspections are carried out either by the owner of the dam or a professional engineer or a team of engineers, depending on the classification of the dam. A dam safety inspection report is required to be submitted to the Director-General: Water Affairs for these inspections. The information recorded during the routine inspections is extremely useful for the person carrying out these inspections to assess the response of the structure.

Q6: ARE THERE DIFFERENT INSPECTIONS FOR DIFFERENT TYPES OF DAMS?

A: Broadly speaking all dams are inspected in the same way. There will obviously be different aspects to watch out for when inspecting an embankment dam as opposed to a concrete dam. These aspects will be discussed later.

Q7 HOW IS AN INSPECTION PERFORMED?

A: The whole structure must be inspected along its entire length, using the inspection programme as a guide to ensure that all areas are adequately inspected. It is good practice to WALK along the crest, inspecting both the crest and the upstream and downstream slopes. On the return, walk along the downstream toe, the toe drains and the downstream area.

Q8: INSPECTING AN EMBANKMENT DAM: WHAT MUST BE WATCHED OUT FOR?

A: Everything which can be described as unusual must be noted. The main items to look out for are the following:

- Differential settlement of the crest, slopes and surrounding areas (Q10)
- Erosion of slopes (Q11)

- Bulging on the slopes (Q12)
- Leaching along the waterline (Q13)
- Cracks along the crest and slopes (Q14)
- Burrows caused by burrowing animals (Q15)
- Ant/termite activity on crest and slopes (Q16)
- Vegetation (Q17)
- Seepage, wet spots and boils on the downstream slope and downstream area (Q18)
- Drainage system (Q19, 20)
- Condition of slope protection (Q21)
- Presence of dispersive soils (Q22)
- Crab holes along the waterline (Q23)
- Signs of piping (Q24)

Q9: WHEN ANY OF THE ABOVE-MENTIONED PHENOMENA ARE ENCOUNTERED, WHAT ACTION MUST BE TAKEN?

A: Each of the items mentioned requires special action. It may be best to discuss each in turn. Some of these items may require major maintenance work to correct the problem while others may require only continual observation.

Q10: CAN WE DISCUSS SETTLEMENT?

A: Settlement of the materials used during construction is a natural process in embankment dams. The subsequent minor settlement of the crest, for instance, will be regarded as normal if it is within the limits set by the designer. Minor settlement in the order of 1% of the height of the wall is considered acceptable but must be watched all the same. Any excessive settlement beyond design specifications will increase the risk of overtopping because it reduces freeboard (see Terminology). Excessive settlement should be investigated and backfilled (see Terminology) where necessary. This can constitute major maintenance works

Differential longitudinal settlement and cracking associated with a bulging at the bottom of the slope can be indicative of a slip, especially if wet spots or seepage water are in the vicinity. When in doubt contact an expert. In order to record the position where settlement of the materials has occurred it is helpful to install chainage beacons (see Terminology) along the crest in such a way that they can be read from the downstream toe as well as from the crest. The position of the settlement can be recorded by noting down its chainage (see Terminology) as well as its location relative to the longitudinal centre line of the crest.

Progressive settlement or movement of the embankment at the identified problem areas must be monitored at subsequent inspections of the dam.

Q11: EROSION OF THE CREST AND SLOPES: HOW IS IT HANDLED?

A: Erosion due to storm water or excessive irrigation is usually a maintenance task. By diverting the flow of storm water or doing backfilling, grassing or riprap repair, this problem can be eliminated effectively.

Q12: CONTINUING IN THIS VEIN, WHAT ABOUT BULGING?

A: Bulging usually indicates an impending slip. Where a bulge does appear, look for tell-tale longitudinal and transverse cracks in the vicinity of the bulge. Call experts for advice as a slip is not an easy matter to deal with. A slip is serious and can result in the failure of the dam.

Q13: LEACHING: CAN IT REALLY BE A PROBLEM?

A: Yes, but not one that can seriously threaten the stability of the structure. Where, because of wave action, fine material is washed from the upstream slope or from under the slope protection causing depressions on the slope, it must be rectified by providing adequate slope protection. This constitutes mainly a maintenance task.

Q14: WHAT ACTION IS PROMPTED BY THE DISCOVERY OF CRACKS?

A: The action depends on the position of the crack. Cracks on the crest or slope can be caused by differential settlement (see Terminology). By this we mean that the different materials or zones (see Terminology) in the embankment or foundation settle unevenly. The material in a particular zone of the embankment or foundation may settle more than the material in the adjacent zone, causing longitudinal and/or transverse cracks. In both homogeneous and zoned dams this may be an indication of an impending slip. (See Q12 on bulging.)

Transverse cracks necessitate immediate action as water must be prevented from entering the embankment through cracks.

A little maintenance work can prevent a lot of trouble and neglect could aggravate an already serious situation.

Q15: WHAT HARM CAN SMALL ANIMALS DO TO A DAM WALL?

A: Burrowing animals such as meercat and aardvark can cause probems and must in some way or other be scared off and prevented from digging holes in the embankment. Another maintenance job.

Q16: GRANTED, SMALL ANIMALS CAN BE A PROBLEM, BUT ANTS AND TERMITES?

A: Ants and termites are known to have caused the failure of small dams. Especially termites pose a problem as very few insecticides kill them off permanently.

The damage done by these little creatures is usually underground where they form internal piping and this is extremely difficult to detect. Be on the look-out for ant or termite activity as this may be the cause of the loss of the dam. (See Q24 on internal piping.)

Q17: WHAT POSSIBLE HARM CAN VEGETATION DO TO A DAM?

A: Not all vegetation is harmful. In fact, grass is usually planted on slopes as protection against erosion. Trees, however, can pose a problem as the root system penetrates deep into the embankment, providing ready-made tunnels for seepage, particularly when the tree dies and the roots rot or when a tree is uprooted by a strong wind.

Removing trees from the embankment is not a haphazard affair. Proper care must be taken, otherwise more harm can be done despite the good intentions. Consulting an expert is a sound policy.

Vegetation can also indicate seepage problems. Watch out for green patches and grass species known for their affinity for wet conditions as this can be an indication of readily available moisture. Further investigation is then necessary.

Q18: WHAT IS TO BE DONE ABOUT SEEPAGE?

A: Seepage occurs in all embankment dams. Where seepage is not excessive and the seepage water is clear and without sediment, it can be considered normal. If any sediment is detected in the flow, the origin of the sediment and the source of the flow must be determined. Canalisation of the seepage flow should be done where it is suspected that the flow is increasing as this will also allow for flow measurement and sediment observation. Where the flow is increasing and/or sediment is present, major maintenance work may be required to prevent a possible failure of the dam.

Where an internal filter is incorporated in the embankment, wet spots on the downstream slope may indicate that the filter system is not operating as designed. When in doubt, consult an engineer.

Q19: WHAT IS THE FUNCTION OF THE TOE DRAIN?

A: As seepage occurs through all embankment dams and their foundations, some form of drainage system should be provided for collecting and controlling the seepage. In the case of small embankments, the toe drain may be the only drainage system provided for this purpose. Where an internal drainage or filter system is incorporated in an embankment, the toe drain should be connected to this system in order to provide the outlet for the seepage.

Q20: THE TOE DRAIN: MUST IT BE INSPECTED REGULARLY?

A: It is sound policy to inspect the toe drain system regularly as it provides a good check on the correct operation of the drainage system and serves an important function in the dam safety monitoring of the embankment.

Regular inspection and careful monitoring of the toe drain will enable the inspector to locate the origin of unexplained increases in the flow as well as to detect the presence of sediment.

The presence of cloudy or muddy flows in the toe drain is a cause for concern. Muddy flows mean that particles are being removed from the embankment or foundation, leaving cavities or leading to the formation of piping or sinkholes in the embankment or foundation. These are major causes for concern.

Q21: SLOPE PROTECTION: WHY AND HOW CAN A SLOPE BE PROTECTED?

A: It is normal to protect the slopes against wave or rain erosion by using selected grasses, stone pitching (see Terminology), riprap or even concrete slabs. Whatever means has been used, the area

concerned has to be inspected regularly as indications of problems may also be detected here. Care must be taken to ensure that the protection remains in a state in which it fulfils the functions for which it was designed.

Q22: DISPERSIVE SOILS: WHAT ARE THEY AND WHAT INFLUENCE CAN THEY HAVE ON THE EMBANKMENT?

A: Previously people were warned against the use of brackish or dispersive soils (clays) in dam building. Today it is accepted that these soils can be used in dam walls but special care must be taken during construction. These soils have the property that when they come into contact with fresh water (i.e. water low in dissolved salts) they disperse. This means that the cohesive force between the clay particles in the soil is destroyed. The clay

particles are then easily removed by seepage water, resulting in piping and the subsequent failure of the embankment.
Dispersive soils can be identified by their distinctive erosion pattern which displays little pillars and tunnels. Where the presence of dispersive soils is suspected, consult experts in the field.

Q23: CAN CRABS POSE A HAZARD TO A DAM?

A: There is evidence that crab holes, which are usually close to the water line, formed seepage paths in the embankments and contributed towards the failue of dams during the 1987 floods in Natal. It cannot be stated conclusively that the crabs were the only cause of failure but their contribution is accepted as a fact. (Since crabs have difficulty in penetrating a non-cohesive casing of gravel the use of such a casing may prevent many problems.)

Q24: WHAT CAN CONTRIBUTE TO INTERNAL PIPING?

A: One of the principal causes of piping is dispersive soils in the embankment and/or foundation as previously discussed. The presence of a permeable layer in the embankment can also contribute towards piping. Tunnels caused by burrowing animals, crabs, tree roots, ants and termites can also lead to piping. Excessive or increasing seepage, boils (see Terminology) on the downstream slope or near the toe of the dam and depressions on the upstream slope can be indicative of incipient piping.

Q25: SOMETIMES WATER IS LET OUT OF A DAM BY MEANS OF A PIPE PASSING THROUGH THE DAM WALL. DOES THIS AREA WARRANT SPECIAL ATTENTION?

A: Yes. During construction effective compaction alongside the pipe is difficult. Therefore, watch for seepage or leakages at the exit point of the pipe. Where wet spots or seepage water are discovered a special investigation must be carried
out to discover the source. Turbid or cloudy flows ring alarm bells as these are indicative of piping formation in the soil along the side of the outlet

pipe. It is sound practice to provide a properly designed filter zone at the exit of a pipe to control seepage and prevent piping formation.

Q26: MECHANICAL EQUIPMENT: HOW DOES ONE MAINTAIN IT?

A: All mechanical equipment must be operable at all times. An outlet pipe of small diameter may not play a great role in ensuring the safety of the structure during floods. However, in the event of malfunction, it will prevent the dam from performing the function for which it was designed.

Instructions for the inspection and maintenance of mechanical equipment are usually supplied by the manufacturer and will not be discussed here.

In the design of the dam and the mechanical items, provision must be made for access to and/or removal of the mechanical items which require regular maintenance. If such provision is not made, drawing down the water level or other drastic steps may be required to carry out inspection, repairs or maintenance of certain items.

Q27: DOES ONE INSPECT MECHANICAL EQUIPMENT TOO?

A: All mechanical equipment must be inspected frequently for oil leaks, rust, corrosion, malalignment, etc. It must also be tested for operational readiness during an inspection.

Q28: THUS FAR WE HAVE BEEN LOOKING AT EMBANKMENT DAMS ONLY. WHAT IS THE POSITION FOR CONCRETE DAMS?

A: You inspect the entire length of the wall along the crest as well as along the toe in much the same way as for an embankment dam. In larger dams, an apron and gallery may be present and these should be inspected as well.

Q29: ARE THERE SPECIAL ASPECTS TO WATCH OUT FOR IN CONCRETE DAMS?

A: Yes. A list would include the following:

. Cracks (Q30)

. Leaks (Q31)
. Calcite deposits (Q32)
. Differential movement or
. Deterioration of concrete due to corrosion, cavitation, ageing, alkali-aggregate reaction, etc. (Q35)
. Drainage and pressure relief systems (Q36, 37)

Q30: OF WHAT SIGNIFICANCE ARE CRACKS IN A CONCRETE DAM?

A: Cracks are as important as the position in which they occur. Small surface cracks can be largely ignored. On the other hand, structural cracks extending more deeply into the concrete must be watched closely. Seasonal changes in crack width must be expected due to expansion and contraction of the concrete, resulting from temperature variations.

Where cracks widths' are monitored, a mark should be made on the crack where the width can be measured during every inspection.

By marking the ends of cracks in the gallery or on the wall, any lengthening of a crack can be detected without difficulty.

Cracks on the upstream and downstream slopes of the wall can be watched by drawing the cracks on a sketch and comparing changes during subsequent inspections.

Q31: LEAKS: HOW MUST THEY BE TREATED?

A: All leaks on the downstream slope or in the vicinity of the toe must be recorded and the flow

of the water measured, if possible. Increased flow and/or signs of material that has been removed from the foundation would indicate piping or foundation failure and this should be checked by an expert. Plugging of the leak can be attempted from the upstream side of the wall but in most cases this will prove unsuccesful without suiable prior investigation.

Q32: DOES THE APPEARANCE OF CALCITE DEPOSITS SIGNIFY PROBLEMS?

A: The formation of calcite can, where not excessive, be regarded as more or less normal. The calcite can be discoloured by certain substances in the concrete or in the reservoir water. When in doubt take a sample and have it analysed by a competent laboratory. Rust from reinforcing steel, for instance, can stain calcite a reddish colour.

Q33: OF WHAT IMPORTANCE ARE CONTRACTION JOINTS?

A: Contraction joints are the vertical joints, usually transverse, between the individual "blocks" of a concrete structure. Their primary function is to allow the structure space for movement due to shrinkage and temperature-related movements. It is important to watch for the expected movements but equally important to be alert to any abnormal changes such as differential movement or settlement (see Terminology) between blocks or the appearance of water, etc.

Q34: WHAT IS MEANT BY DIFFERENTIAL MOVEMENT OR SETTLEMENT?

A: Differential movement or settlement is the movement of one part of the structure in relation to an adjacent part. Where such difference in movement is encountered the cause will have to be determined. There is a variety of reasons for this phenomenon and if the movement continues with time an expert must be consulted.

Q35: DETERIORATION OF CONCRETE: WHAT CAN CAUSE THIS?

A: There are many causes for the deterioration of concrete. Some of the main causes are corrosion, cavitation, ageing, alkali-aggregate reaction, etc. Each of these will be discussed separately.

(i) Corrosion: Sometimes the water in the reservoir is corrosive because of the presence or absence of certain salts in the water. Water causes corrosion of the concrete by the removal of chemicals from the concrete. This is usually visible on the surface of the concrete but is seldom serious.

(ii) Cavitation: Where cavitation of a concrete surface is left unchecked, large cavities can be formed in concrete requiring major maintenance work. To eliminate the problem, design changes may be necessary. (Also see Terminology.)

(iii) Ageing: This is a natural process that takes place over the years. The effect, usually visible on the surface of the concrete, may also be limited to the surface only. To determine the total effect, core samples may have to be taken and analysed.

(iv) Alkali-aggregate reaction: Because of the presence of certain chemicals in the cement produced by some factories, a reaction takes place between the cement and certain aggregates used in the concrete mix. The reaction causes the concrete to expand, thus producing cracks. The cracks have a distinctive random pattern. A whitish deposit or greyish jelly can sometimes be seen on the concrete surface. Occurrence of alkali-aggregate reaction must be watched carefully and recorded in detail.

Q36: WHAT IS THE FUNCTION OF THE DRAINAGE AND PRESSURE RELIEF SYSTEMS?

A: Concrete dams are generally founded on rock. As no foundation is totally impervious, the pressure relief system is provided in order to control the seepage water flowing into the foundation rock and to prevent the buildup of water pressure below the base of the wall.

The drainage system serves a similar purpose and refers to the internal drains provided within the concrete to control seepage water flowing through the concrete and prevent the buildup of water pressure within the concrete section of the wall.

Without the drainage or pressure relief system, the water pressure buildup within the wall or below the base of the wall may result in failure of the dam. Where one or both of these drainage systems have been omitted from a dam, this must be accounted for in the design. Depending on the size and thickness of the wall, the drainage and pressure relief system may be located in a gallery within the wall or it may be located at the downstream toe of the wall.

Q37: THE DRAINAGE AND PRESSURE RELIEF SYSTEMS: MUST THEY BE INSPECTED REGULARLY?

A: Where present, it is important that these drainage systems be inspected regularly in order to check on their correct operation. Careful monitoring of flows from the drains both individually and as a whole will provide an indication as to how the permeability of the foundation rock is changing with time and with depth of water in the dam.

The presence of calcite, sediment or algae in the seepage water may result in the gradual blocking up of the drains. As this could cause problems with the safety of the dam, the drains should be regularly cleaned out by means of compressed air and water, and where holes are completely blocked these should be redrilled. The cause of blockage should be recorded, particularly where sediment is present and if this is the case, the seepage water should be monitored for sediment content in order to determine whether piping is occurring in the foundation rock.

In some holes gases may be escaping from the foundation. Where this occurs, the gas should be identified and the necessary precautions taken in order to prevent accidents occurring either as a result of asphyxiation or explosion.

Q38: AS MOST ASPECTS ARE CHECKED DURING AN INSPECTION, IS IT NECESSARY TO RECORD ANYTHING?

A: This is the most important part of an inspection and maintenance programme. Every item must be recorded as no person is permanent. It is useless to inspect and maintain a dam if the next person has to do everything over again and has no previous record to check against.

In order to expedite the recording of information, chainage beacons, readable from the downstream toe, must be erected along the downstream shoulder of the crest.

For concrete dams, contraction joints should be numbered and identified on site by painting the joint number on the downstream face of the wall and on the non-overspill crest and, where applicable, on the joints in the gallery. This will simplify the task of sketching all cracks, calcite marks, etc.

Q39: SURELY NOT EVERYTHING CAN BE DRAWN ON A SKETCH?

A: True. Indicate only major cracks, large calcite deposits and noticeable wet spots.

The condition of mechanical equipment will have to be entered in a logbook, kept especially for this purpose.

A check-list can be prepared for a specific dam. Some aspects covered in this pamphlet may not apply to all dams and need not appear on the check-list. Check-lists should make provision for maintenance tasks to be performed.

Q40: SO INSPECTION AND MAINTENANCE DO GO HAND IN HAND?

A: Yes. During an inspection it is quite likely that aspects will be discovered that are in need of repairs i.e. maintenance work. This proves that maintenance and inspection go hand in hand.

Perhaps not enough stress has been placed on the fact that proper record-keeping (of both inspection and maintenance) is absolutely essential. An up-to-date, neat and complete report will provide a comprehensive history of the dam and will be extremely useful should a major problem ever arise.

TERMINOLOGY

Some terms used in the text (as well as some which do not appear in the text) are explained here.

APRON: This is the area immediately downstream of the spillway. Water flowing over the spillway will fall on the apron. The apron can either be left with the natural rock
exposed or the rock may be covered by a layer of concrete. Its main function is to withstand the force exerted by falling flood water. Erosion of the apron can cause undermining of the toe of the dam with disastrous consequences.

BACKFILL: The meaning of the word obviously cannot present any problems. What needs to be explained is that the material used in backfilling a hole or settled area must, as far as possible, have the same properties and characteristics as the material in the hole or the area being backfilled.

BOIL: A boil may occur at the exit point of seepage flow from the foundation or the embankment. As a result of an increased permeability of the material through which seepage water is flowing, high pressures may develop around the exit point of the seepage. The pressures may lead to the material at the exit point being kept in suspension by the water, resulting in a visible agitation, similar in appearance to boiling, of the suspended soil particles in this area.

BULGING: Bulging may occur on the slope or the foundation area of the structure. It is the movement of the material beyond the surface level to which it was originally constructed.

CAVITATION: When water flows at high velocity over irregular surfaces, a vacuum or
partial vacuum can be formed in the water. This results in the formation of vapour pockets or bubbles which are carried along in the water until a higher pressure area is reached, where the bubbles suddenly collapse or implode. This entire process is known as cavitation and if the vapour bubbles are near to a solid boundary when they collapse, the forces exerted by the liquid rushing into the bubbles create very high localised pressures that cause pitting of the solid surface.

Cavitation is accompanied by noise and vibrations that have been described as similar to gravel going through a centrifugal pump.

CHAINAGE: This term has been derived from the use of chains which were used in the past for measuring distances. In present-day terms, chainage is the distance in metres from a zero or reference point to the point of interest. For a dam wall, the zero point is generally taken to be on the centre line of the crest at the left bank, when facing downstream, where the crest meets the original ground level. In certain instances, the zero point may be moved an additional distance up the left bank in order to allow for future raising of the wall or work on the crest.

CHAINAGE BEACONS: These are small beacons, constructed on the crest of the wall at regular intervals, on which the chainage distance is clearly marked in metres. They are usually placed on the downstream edge of the crest in such a way that they can be read from the downstream toe and from the crest.

COHESION: All materials have an attractive force between the particles they consist of, which causes those particles to stick together. (This means that some force is necessary to separate the particles.) This attractive force is called cohesion.

CONSTRUCTION JOINTS: These are horizontal joints which are formed between two consecutive placings of wet concrete during construction. They are usually visible as horizontal lines on the concrete face.

CONTRACTION JOINTS: These vertical joints are formed in concrete dam walls to accommodate movement due to shrinkage and expansion of the concrete caused by temperature variations.

DIFFERENTIAL SETTLEMENT: By this is meant that the various zones of different materials in the embankment or foundation settle unevenly. This results in undulations or abrupt changes in level, with associated cracks that appear along the surface of the embankment or foundation. This movement is more commonly observed on the crest of the embankment. (Also refer to Q14.)

DISPERSIVE SOILS: Dispersive soils have the property that when they come into contact with fresh water (i.e. water low in dissolved salts) they disperse.

This means that the cohesive force between the clay particles in the soil is destroyed allowing the clay particles to be easily removed by the seepage water. (Also refer to Q22.)

DRAIN: The filter system is called a drain. There are various types of drains, e.g. a chimney drain, a blanket drain, finger drains, etc., all named according to the position (zone) they occupy in the embankment.

DRAINAGE HOLES: These holes are drilled into the concrete, often from the gallery, to relieve pressure in the concrete.

FILTER: A filter zone is sometimes built into an embankment to drain seepage water from within the embankment, thus relieving the pore water pressure. The grading of the filter material must be coarse enough to allow drainage, but fine enough to prevent the removal of soil particles from the embankment. The filter usually contains well graded sand.

FREEBOARD: The difference in height between the spillway and non-overspill crest.

FULL SUPPLY LEVEL: This usually is the level of the overspill or spillway. The level denotes the height to which the water can rise before it flows freely over the spillway and out of the dam.

GALLERY: In some walls a "tunnel" is constructed for inspection purposes. Cracks, contraction joints, drainage and the performance of any pressure relief drain can be studied in these galleries.

HEEL: In a concrete dam the heel is the point of contact between the upstream face of the dam wall and the natural ground level. The same area for an embankment dam is called the upstream toe.

HOMOGENEOUS EMBANKMENT: This is in contrast to a zoned wall. Instead of having zones of different materials only one type of soil is used throughout the embankment.

LEACHING: Leaching is the removal of fines from a material as a result of some erosive action. For example, wave action on the upstream slope of an embankment may result in the removal or leaching out of the finer material from around and under the slope protection material.

NON-OVERSPILL CREST: That part of the dam wall designed not to be overtopped. Usually this part consists of a roadway or walkway.

OVERTOPPING: This happens when the water level in a dam rises to such a level that it flows over the non-overspill crest. The main cause of overtopping is inadequate spillway capacity, i.e. the spillway cannot accommodate the flood flow.

PIPING: When the progressive removal of particles from the embankment by seepage takes place, a "pipe" is formed from the downstream end. Piping occurs more often in dispersive soils.

PORE WATER PRESSURE: Any soil consists of different sized particles with voids between the particles. These voids are called pores and the water present in the pores exert a pressure called the pore water pressure.

PRESSURE-RELIEF DRAINAGE HOLES: These holes are usually drilled from the gallery into the foundation rock, the purpose being to relieve uplift pressure in the rock as well as at the rock/concrete interface. Pressure-relief holes must be cleaned regularly to ensure their continued effectiveness. Where holes become permanently blocked new ones must be drilled.

RIPRAP: This refers to a layer of blasted or natural rock placed on the slope of an embankment to protect the slope against wave action in the case of the upstream slope, or rainfall erosion in the case of the downstream slope. The riprap can either be left roughly finished or "smoothed off" by machine or hand labour. The thickness and size of the rock on the upstream slope should be designed according to the size of the waves expected, and filters should be provided under the riprap to prevent leaching out of the fines from the underlying earthfill.

SLIP: If the slope of an embankment (or a cutting) is made too steep or is affected by pore water pressure, the strength of the material in the slope may be insufficient to prevent movement of the soil down the slope. The slope may fail as a result of a massive movement of soil. Such a failure is often referred to as a slip and the shape of the failure surface may be circular, hence the term "circular slip failure".

The slope failure may vary from a sudden and catastrophic failure to a gradual minor movement.

SLOPE: This is the inclined part of a dam wall upstream and downstream of the crest.

SLOPE PROTECTION: A means of protecting a slope against erosion caused by storm water or waves. This can be achieved in a variety of ways:
grass: By establishing a good grass cover on a slope. Irrigation may be applied, but care must be taken to prevent erosion of the soil before the grass cover is well established.
Stone pitching: The slope can be covered with stones placed by hand.
Concrete slabs: Another method is to cover the slope with concrete slabs.
Riprap: Stones and boulders are dumped on the slope. The size of the boulders can vary with a maximum size of up to two metres in diameter.

SPILLWAY: That part of the dam wall through or over which flood water is designed to flow.

SPILLWAY GATES: These are used to control the flow over the spillway. They have a variety of shapes and operating mechanisms.

STONE PITCHING: This comprises rock that is carefully hand placed against the slope. The ideal method of placing is to have the longest face of the rock perpendicular to the slope in order to provide the maximum resistance to wave or rainfall action. Well designed filters should be placed under the pitching in order to prevent leaching out of the fines from the underlying earthfill.

TOE: In an embankment dam this is the point of contact between the upstream and downstream slopes and the natural ground level.

TOE DRAIN: This is a drainage system running along the downstream toe of the embankment, often consisting of pipes embedded in a filter system, along which drainage water (seepage) is led to an outlet into the river. Manholes are built in the system for inspection purposes.

ZONE: Embankments are sometimes composed of different materials, i.e. materials with different properties of grading, permeability, density, etc. These materials are placed within the wall in different zones according to the particular characteristics of the various materials. In this way one can have a core zone which is highly impermeable flanked by more permeable zones.

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