Chapter

Levees / Dike

Definitons: Levees are barriers that hold back floodwaters. A levee is constructed of compacted soil and requires more land area. Floodwalls are built of manmade materials, such as concrete and masonry. These structures may completely surround the building or may tie into high ground at each end. If openings are left for the driveway and/or sidewalk, closures must be installed to seal these access points prior to a flood.

Applicability

Because levees and floodwalls are located away from the structure or area to be protected, they provide flood protection without altering the building.

Flood Hazard: Although levees and floodwalls can be built to any height, they are usually limited to four feet for floodwalls and six feet for levees (due to cost, aesthetics, access, water pressure, and space). The structure should be built at least one foot higher than the anticipated flood depth (freeboard protection). No matter how high the barrier is, it can always be overtopped by a larger flood, which would cause as much damage as if no protection were provided (or more). In areas with high velocity flow, erosion protection may be necessary to protect an earthen levee or prevent undermining of a floodwall. Flash flooding precludes the use of closures that require human intervention to install. If flooding lasts more than 3 to 4 days, seepage is more likely to pose problems.

Site requirements: A levee or floodwall is not feasible if it would impede flow or block natural drainage in a manner that results in damage to surrounding property. Considerable horizontal space is required for levees; floodwalls are generally more appropriate for small sites. The underlying soil must support the levee or floodwall and resist seepage of water under the structure.

Building characteristics: A house with a basement can still experience flood damage even if a levee or floodwater protects the structure from surface water. Saturated soil can exert hydrostatic pressure on basement walls, causing them to crack, buckle, or event collapse.

Access: Access to the structure can be enabled by providing a means of crossing over a levee or floodwall, such as a ramp or stairway. If this is not feasible, it may be necessary to design openings at driveways, sidewalks, or other entrances and a mechanism for closing all such openings. Designs that do not require human intervention are preferable. If a closure requires manual installation, the effectiveness of the flood protection system depends on the availability of a capable person who is aware of the flood threat and has sufficient time to install closures and make certain they are properly sealed.

Aesthetics: The rounded outlines of an earthen levee can be shaped to blend into the natural landscape. Floodwalls can be designed as attractive features by incorporating them into the landscape design and utilizing decorative bricks or blocks (although this will generally increase the cost).

Regulations: A levee or floodwall cannot be used to bring a substantially damaged or substantially improved structure into compliance with current floodplain development standards.

Costs

Depending on the availability of suitable local soil, levees may be less expensive than other floodproofing options. However, if suitable fill material is not locally available, the expense of transporting proper material to the site can be significant. The cost of floodwalls is usually greater than that of levees.

Techniques

- ***Levees:*** *To be effective, a levee must be constructed with compacted, impervious soils. The* practice of piling stream sediment on the bank does not provide flood protection. The embankment slopes must be gentle (usually a ratio of one vertical to two or three horizontal) to provide adequate stability and minimize erosion. The levee's width will thus be several times its height.
- ***Floodwalls:*** Floodwalls are generally constructed of solid concrete (alone or in combination with masonry). They must be designed to withstand water pressure without overturning or displacement.
- ***Closures:*** Mechanisms for closing access openings in a levee or floodwall include automated systems (usually expensive) or manually operated flood gates, stop logs, or panels. There are often hinges or sliding mechanisms for installation. If the closure is not permanently attached, it must be stored in a readily accessible location. Any sewers or drain pipes passing through or under a floodwall or levee require closure valves to prevent backup and flooding inside the building and protected area.
- ***Interior drainage:*** Rain, snow melt, and seepage water must be removed from the protected side of a levee or floodwall using drains (with flap valves to

prevent backflow during a flood) and a sump pump. An emergency power source for the electric sump pump enables operation during a power outage.

➢ ***Maintenance:*** Routine inspection enables identification and repair of problems while they are still minor.Levees should be checked for signs of erosion, settlement, loss of vegetation, animal burrows, and trees. Inspect floodwalls for cracking, spalling, or scour. Routine maintenance is needed to make sure that sump pumps, valves, drain pipes, and closures operate properly.

Advantages

- Levees and floodwalls can protect a building and the surrounding area from inundation without significant changes to the structure if the design flood level is not exceeded.
- There is no pressure from floodwater to cause structural damage to the building.
- These barriers are usually less expensive than elevating or relocating the structure.
- Occupants do not have to leave the structure during construction.

Disadvantages

- This technique cannot be used to bring a substantially damaged or improved structure into compliance with floodplain development standards.
- May violate floodplain development standards, particularly in floodway locations, by causing obstructed flow or in increased flood heights.
- Failure or overtopping of a levee or floodwall results in as much damage as if there was no protection (or more).
- May restrict access to the structure. If human intervention is required for closures, there must be adequate warning time.
- May be expensive.
- For buildings with basements, hydrostatic pressure from groundwater may still cause damage.
- Local drainage can be affected, possibly creating water problems for others.
- Interior drainage must be provided.
- Levees require considerable land area.
- Require periodic maintenance.
- No reduction in flood insurance premiums.
- Do not eliminate the need to evacuate during floods.

Advantages of using soil and sand in Levee/Dike Construction

Levee/Dike generally consists of soil and sand. The advantages of using soil and sand are as follows:

1) *Reasonable cost because of the availability of materials.*
2) *Almost no deterioration for long term (it will last more than a hundred years).*
3) *It could easily be mixed with the foundation ground.*
4) *It follows the transformation (and subsidence) of foundation ground well.*
5) *When flood control plan would be upgraded, it is easy to enlarge it.*
6) *When the dike will be destroyed by earthquake or some other inevitable disaster, it is easy to restore.*
7) *For environmental consideration.*

Main causes of damage

Main causes of damages on dike are as follows:

1. **Erosion (Scouring)**
2. **Overflow**
3. **Seepage**
4. **Earthquake**

Countermeasures for Design

EROSION: The surface of dike should be covered with vegetation for protection against gully erosion. The riverside should be protected with revetment if required.

OVERFLOW: It depends on the design height of the dike, but it should be considered that there is a possibility of overflow.

SEEPAGE: For large/wide river, the flooding time is very long, crest width of dike is required to be enlarged/widened to prevent the collapse of dike slope caused by seepage inside the dike. Embankment materials for the dike should be consisted of impervious soil in the riverside, and pervious soil in the inland side. Drainage structures and related facilities works should be provided at the inland side to drain accumulated water.

EARTHQUAKE: There is a concept that earthquake and flood would not occur at the same time. In case of earthquake, the dike may be damaged, and requires immediately repaired after the earthquake. If the ground level of the flood prone area is lower than the water level (in the case of seashore dike), the design of the dike should consider earthquake.

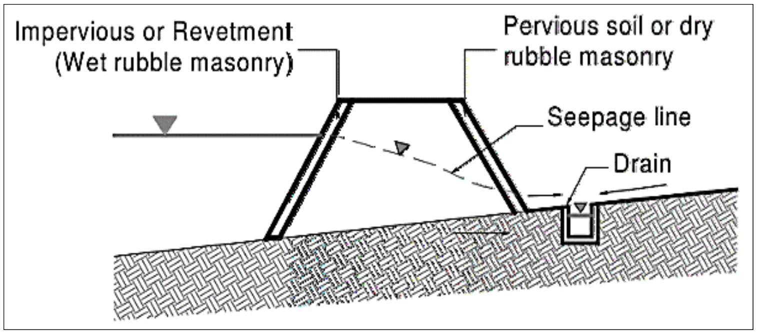


Fig.: Countermeasures against seepage

Forms of Dike Construction

The major forms of dike construction are to construct new dike and to enlarge the existing dike (*including raising*).

1) Construction of New Dike

For new dikes, the construction is required in flood prone area without dikes (including floodway and cut off), and the backward displacement at narrow path. Excluding the inevitable case for dike alignment plan, unstable (peat & muck) foundation of the dike such as weak subsoil like quicksand portions shall be avoided to prevent the subsidence of the dike's foundation.

2) Enlargement of Existing Dike

The enlargement shall be preferably made on the landside. In the case of enlarging existing dike, whether enlargement is made on the landside or waterside it is decided according to the position of the design alignment, and in general it is desirable to enlarge the dike towards the landside to leave the stable waterside slope as it is.

When the land acquisition is very difficult or when the water way is wide with sufficient high water cross sectional area, enlargement may inevitably be made on the waterside. However, when the toe of dike slope is close to the low-flow channel in case of a compound cross section, it is desirable to avoid enlargement on the waterside even if there is sufficient river width.

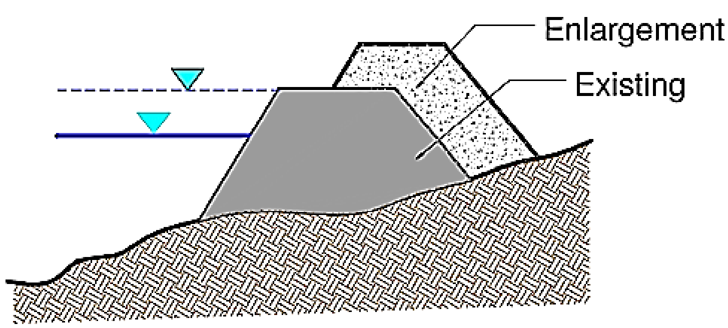


Fig.: Enlargement of Existing Dike

Height

The height of a dike is based on the design flood level with a required freeboard added to it. Actually in many cases, the design flood level is not fixed, then the height of the dike is usually decided based on past maximum flood level and in consideration with the hinterland elevation. In this case, flood water levels should be calculated and consider the longitudinal gradient of provisional design flood level.

For determination of the design discharge, the existing flow capacity should be calculated roughly by Manning's Formula or Non-uniform flow calculation methods. The calculated flow capacity from the above methods should be used as the Design Flood Discharge for fixing the freeboard height.

Freeboard

The freeboard of a dike is an allowance in height and shall not be less than the value given in Table 6.2.4, according to the design flood discharge. When the ground height in the inland adjacent to the dike concerned is higher than the design *flood level*, *the freeboard can be* ***0.6 m*** *or more even if the design flood discharge is 200* m^3/s *or more*.

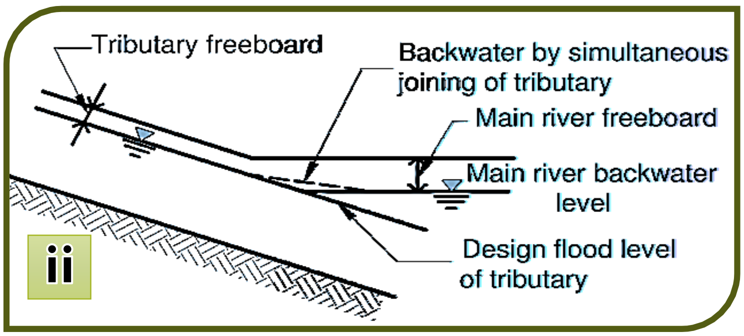
Design flood discharge (m^3/s)	Freeboard (m)
Less than 200	0.6
200 and up to 500	0.8
500 and up to 2,000	1.0
2,000 and up to 5,000	1.2
5,000 and up to 10,000	1.5
10,000 and over	2.0

Basically, freeboard is a margin of the height that does not allow overflow against the design flood level. In general, the dike is made of earth and sand and is very weak to overflow. Therefore, it is provided with adequate freeboard in preparation for the temporary rises of the water level caused by wind and waves on the occasion of a flood, swell and hydraulic jump, etc.

There is no such actual fixed design flood discharge in almost all rivers because there is always a high possibility that overflow will occur. So it is better to provide adequate freeboard for margin of flood discharge. However, too much freeboard leads to high potential of damage in case collapse/failure of dike occurs.

In case of bridge design, it is very important to set the freeboard. When the design flood discharge is not calculated, the possibility is very high that the existing flow capacity is insufficient for the design flood level. In this case, the provisional flood level should be set on the full level of the dike. Especially in mountain areas, the freeboard of bridge should be designed sufficiently in consideration to the types of floating debris such as logs, uprooted trees, etc. that passes underneath the bridge structure.

For the backwater phenomena in a tributary, the height of the dikes shall be so decided such that its elevation shall not be lower than the dike's height in the main river. It must be as high as the dike of the main river or even higher at the confluence in order to prevent inundation in the subject areas as a result of the construction of the dikes in the main river. In general, the dike's height of the main river at the confluence point is brought horizontally and is decided based on the design flood discharge of the main river.



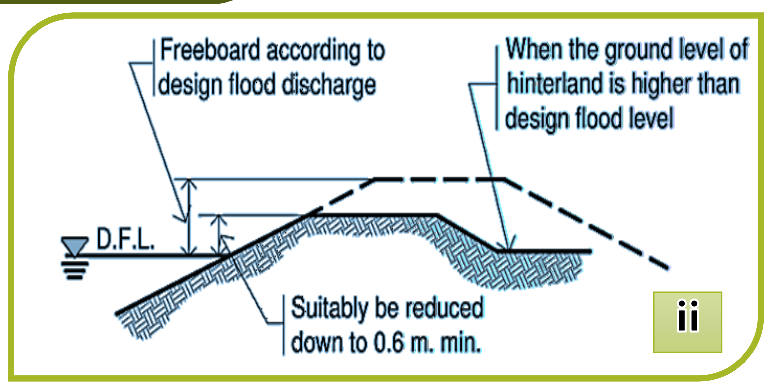
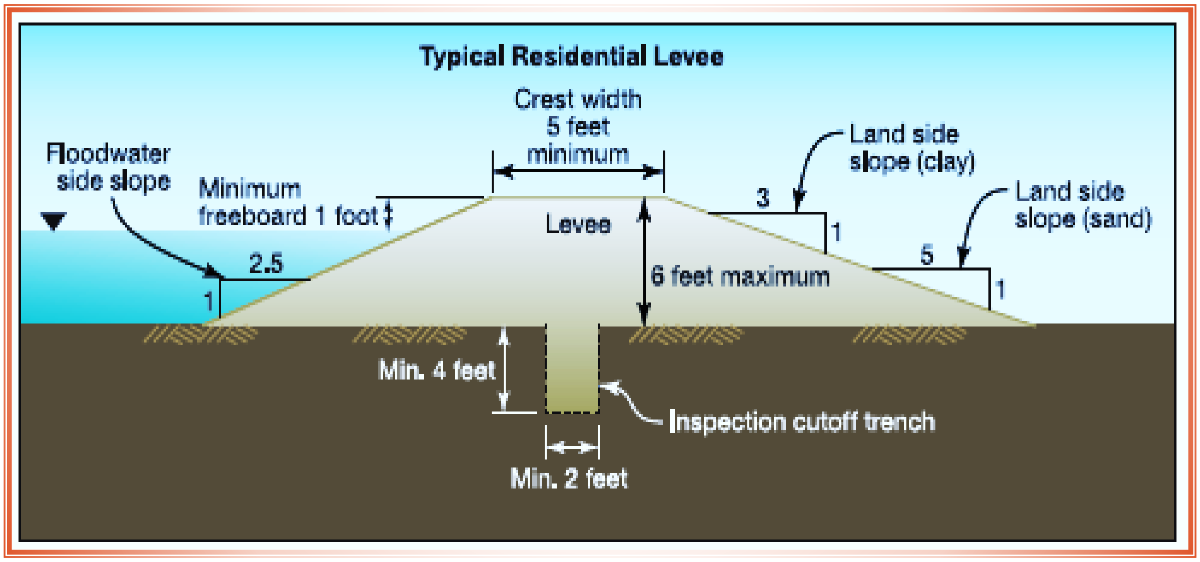


Fig. i.*Backwater & **ii.** Freeboard when hinterland is higher than design flood levee.*

Standard design Criteria

- φ Maximum settled levee height of **6 feet**
- φ Maximum levee crest width of **5 feet**
- φ Levee floodwater side slope of **1 vertical on 3.5 horizontal**
- φ Levee land side slope: Soil type may require flatter slopes
- φ **One foot** of freeboard


Typical Residential Levee
Crest width
5 feet
minimum
Floodwater
side slope
Minimum
freeboard 1 foot
Levee
Land side
slope (clay)
Land side
slope (sand)
3
1
5
1
2.5
1
6 feet maximum
Min. 4 feet
Inspection cutoff trench
Min. 2 feet