*भारतीय मानक*

# नदी तटबंध के नियोजन तथा डिजाइन के मार्गदर्शी सिद्धांत

*( पहला पुनरीक्षण )*

*Indian Standard*

# GUIDELINES FOR PLANNING AND DESIGN OF RIVER EMBANKMENTS (LEVEES)

*(First Revision)*

ICS 93.160



**BUREAU OF INDIAN STANDARDS**
MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG
NEW DELHI 110002

*October* 2000

**Price Group 3**

River Training and Control Works Sectional Committee, WRD 22

FOREWORD

This Indian Standards (First Revision) was adopted by the Bureau of Indian Standards, after the draft finalized by the River Training and Control Works Sectional Committee had been approved by the Water Resources Division Council.

An embankment (levee) is an artificial bank built along banks of a river for the purpose of protecting adjacent land from inundation by flood. Such type of structure is also called 'embankment', 'stop-bank', 'bund' or 'dyke'. Construction of embankment to control flood is an age-old practice and is still being followed due to its proven suitability.

This standard was first published in 1987. In this revision technological changes and improvements, as a result of experience gained over the last decade, have been incorporated.

There is no ISO standard on the subject. This standard has been prepared based on indigenous data/practices prevalent in the field in India.

For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated, expressing the result of a test or analysis, shall be rounded off in accordance with IS 2 :1960 'Rules for rounding off numerical values (*revised*)'. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

*Indian Standard*

# GUIDELINES FOR PLANNING AND DESIGN OF RIVER EMBANKMENTS (LEVEES)

*( First Revision )*

## 1 SCOPE

This standard covers planning and design of river embankments (levees) on dry land.

## 2 REFERENCES

The following standards contain provisions which through reference in this text, constitute provisions of this standard. At the time of publication, the editions indicated were valid. All standards are subject to revision and parties to agreements based on this standard are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below:

| *IS No.* | *Title* |
|---|---|
| 7894 : 1975 | Code of practice for stability analysis of earth dams |
| 8408 : 1994 | Planning and design of groynes in alluvial river — Guidelines (*first revision*) |
| 10751 : 1994 | Planning and design of guide banks for alluvial river — Guidelines (*first revision*) |
| 11532 : 1995 | Construction and maintenance of river embankments (levees) — Guidelines (*first revision*) |
| 12169 : 1987 | Criteria for design of small embankment dams |

## 3 PLANNING

### 3.0 General

For planning of embankments the following three aspects need to be looked into:

a) The area to be protected,

b) Degree of protection to be provided, and

c) Alignment and spacing of embankment.

### 3.1 Area to be Protected

**3.1.1** *Classification*

It is necessary to know the importance of the area to be protected in order to determine the degree of protection (*see* **3.2**) to be provided. At present, there are two classifications made according to land utilization of the area as given below:

a) Predominantly agricultural areas, and

b) Townships or areas having industrial or other vital installations.

**3.1.2** *Collection of Data*

For preparation of a suitable flood protection scheme, information on topography, characteristics, and hydrology of the river, history of past floods and works is necessary. The basic data required is as follows:

a) *Topography*

  1) Index plan showing the area affected in the past (including lands, villages and property) and the area likely to be affected in post-project conditions.

  2) Contoured survey plan of the area prone to inundation.

  3) Plan showing past river courses.

  4) Plan of soil survey of the area where embankments are proposed.

  5) Plan and section of the flood protection works already existing or executed.

  6) Plan of structures likely to be affected due to construction of embankment as a result of increase in flood level.

b) *River characteristics and hydrology*

  1) Characteristics of the river whether alluvial, incised, aggrading or degrading; meandering or braided.

  2) Qualitative and quantitative analysis of the silt of river at sites of proposed work or upstream.

  3) Nature of the soil of the bank and the bed at site of the proposed work.

  4) Gauge and discharge data of the main river and its tributaries, preferably at sites of proposed work or otherwise upstream.

  5) Recorded maximum flood discharge, velocity and level.

  6) Safe carrying capacity of the river (where work is proposed).

  7) Extent of the flood spill and the quantity of the spill to be controlled.

8) Cross-section and L-sections of the river particularly in the reaches where works are proposed.

9) Rainfall data for the basin for the past years.

c) *History of past floods*

A brief history of the past floods indicating duration of floods, flood discharges and corresponding water levels, stage of the river at which the damage was most pronounced, extent of damage and their effect on the river regime, measures adopted earlier for the protection against floods and their effect on the river courses, river sections, bed levels, etc, as well as the present condition of the existing flood control works.

**3.1.3** After determining the type of the area to be protected and degree of protection to be given, the extent of area to be protected economically should be decided upon. For economic viability, the benefit-cost ratio (B.C. ratio) should be more than unity.

**3.2 Degree of Protection**

The height of the embankment and the corresponding cost and B.C. ratio should be worked out for various flood frequencies taking into account the damage likely to occur. The degree of protection which gives the maximum benefit cost ratio should be adopted.

However, till such time as the details of all relevant parameters are available, embankment schemes should be prepared for a flood of 25 years frequency in the case of predominantly agricultural areas and for flood of 100 years frequency for works pertaining to protection of town, important industrial and other vital installations. In certain special cases, where damage potential justifies, the maximum observed flood may also be considered.

**3.3 Alignment and Spacing of Embankments**

**3.3.1** As far as possible, embankments should be aligned on the ridge of the natural banks of the river, where land is high and soil suitable for the construction of embankments.

The alignment should be determined in such a way that the high velocity flow which can erode the embankment material is sufficiently distant from them. Hydraulic models are useful guides in this regard.

**3.3.1.1** Embankments should be aligned so that important towns and properties along the river bank are left outside the embankment. Where it is not possible to set back embankments to avoid the high velocity flow, some form of protection is necessary. Protrusions and sudden changes in the alignments and forming kinks should be avoided as far as possible.

**3.3.1.2** The spacing between the embankments in jacketted reach of river should not be less than 3 times Lacey's wetted perimeter for the design flood discharge. In no case should an embankment be placed at a distance less than Lacey's wetted perimeter from the river bank or one and a half times the Lacey's wetted perimeter from the midstream of the river. This should also be ensured in case of embankment on only one bank of the river. Alignment of embankments should also be planned so that land acquisition for embankment construction is feasible and is not prolonged.

**3.3.1.3** In the tidal reach of a river, embankments should be constructed with due regard to their effect on the navigation requirements in the channel as embankments in such cases may substantially reduce the tidal influx causing a reduction in the available navigation depth. As such no recommendation on spacing and alignment of levee can be generalized in view of the fact that each river is unique in its behaviour. Thorough knowledge of the river behaviour and studies of the effects of the embankments along different alignments are prerequisites for taking decision on spacing and alignment. Vulnerability to river attack, rise of high flood level on account of reduction in flow area, increase in discharge due to cut off in valley storage, as well as optimization of benefit, etc, should reflect in the decision making.

**3.3.2** *Length of the Embankment*

Length of embankment directly depends upon the alignment. However, it is to be ensured that both ends of the bund are tied up to some high-ground or existing highway or railway or any other embankment nearby conforming to the design height of the embankment.

**4 DESIGN OF EMBANKMENT**

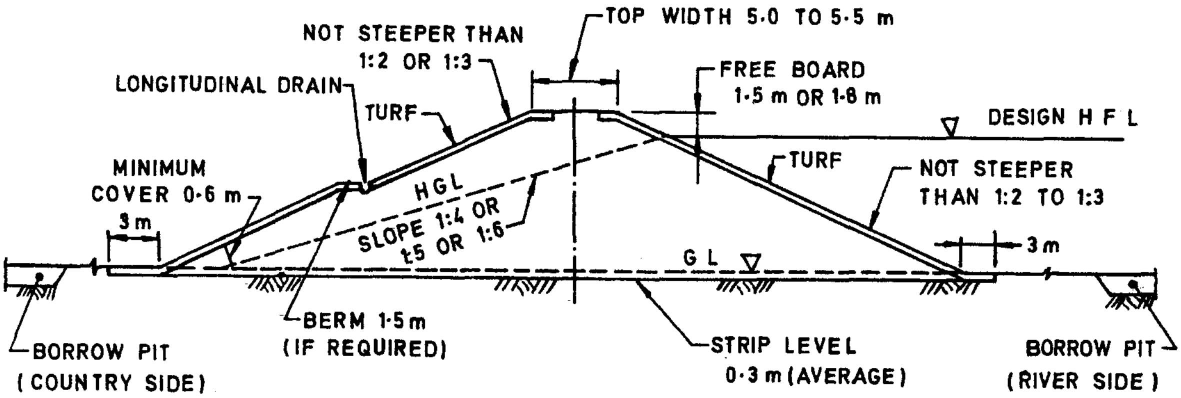
**4.1 Types**

Embankments can be classified into two types as given below:

a) *Homogeneous Embankment*— It consists of practically uniform material throughout. There is no designed plan of material distribution other than the coarsest or most pervious material being placed at the outer slopes (*see* Fig. 1).

b) *Zoned Embankment*— It essentially consists of an inner or impervious section supported by two or more outer sections of relatively pervious materials (*see* Fig.2).

**4.1.1** The essential requirements for design of the embankment are the determination of the design high flood level (HFL), hydraulic gradient, free board, side slopes, top width, etc. The stability of the structure should be checked under all stages of construction, condition of saturation and drawdown. The embankment




NOTES

1 Regarding alternate dimensions shown in the figure, refere to the various clauses relating to design aspects given in the standard.

2 The depth and distance of borrow pits shall be as per the requirements given in IS 1153.

3 Spacing of cross-drains are as per IS 8237 'Code of practice of protection of slope for reservoir embankments (*first revision*)'.

4 Strip level is shown as it is an obvious feature of construction work.

FIG. 1 TYPICAL CROSS-SECTION OF HOMOGENEOUS EMBANKMENT

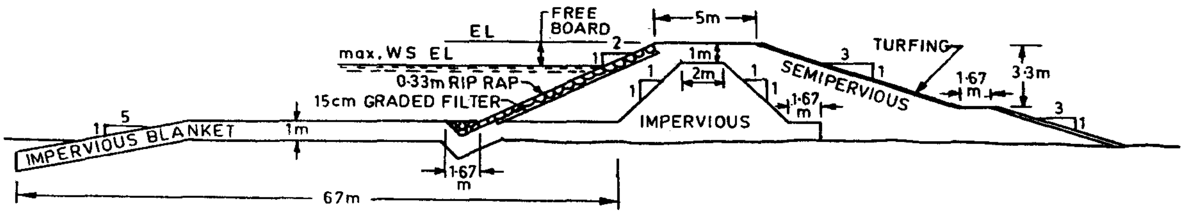



FIG. 2 TYPICAL CROSS-SECTION OF ZONED EMBANKMENTS

should be safe against cracks due to unequal moisture contents in different parts and unequal settlement (*see* IS 7894 and IS 12169).

### 4.2 Design HFL

Correct assessment of the HFL is an important item in the design of embankment. A general problem encountered in determining HFL is non-availability of adequate data. Depending on data, the approach to determine HFL is divided into the following three categories:

a) *Where Long-Term Discharge and Gauge Data are Available* — Firstly gauge discharge relationship should be established. Then available discharge data should be subjected to frequency analysis for the return period according to land utilization pattern of area (*see* **3.2**) using standard statistical methods.

b) *Where Discharge and Gauge Data are Available for a Short Period* — A suitable gauge discharge relationship should first be established. Then a relationship between storm, rainfall and peak discharge should be established based on the data for the period for which discharge data is available. Utilizing all available past rainfall data, a suitable return period value should be chosen for design storm rainfall intensity. Land-use and nature of the area should also be taken into consideration to find out the design peak flood discharge from the rainfall peak discharge relationship. The design flood level is to be obtained from gauge discharge relationship already established. The design flood level so obtained should be verified on the basis of observed cross-sections, slopes and velocities of the river in the recent years.

c) *Where No Discharge and Gauge Data are Available* — Synthetic unit hydrograph approach should be used for estimating the desired return period flood. For this purpose flood estimation reports prepared by Planning and Coordination Committee and published by the Directorate of Hydrology (Small Catchments), Central Water Commission, New Delhi for the country as a whole under the short-term plan and for each sub-zone under long term plan may be used.

**4.2.1** In the case of embankment on both sides of river, rise in the water level due to jacketting of the river should be kept in view in determining the design HFL.

**4.3 Free Board**

The top of the embankment should be so fixed that there is no danger of over-topping even with intense wave wash or any unexpected rise in the river levels due to sudden change in the river course or shortening of river course due to unforseeable causes or aggradation of river bed or embankment settlement. The height of the wave depends upon the wind velocity and the fetch. There are many formulae for determining the height of the wave; however, the formula proposed by Stevenson, modified by Molitor to include wind velocity, should be used as given below:

$$h_w = 0.032\,(VF)^{1/2} + 0.76 - 0.27\,(F)^{1/4}$$

where

$h_w$ = height of wave from trough to crest in metres,
$V$ = wind velocity in kilometres per hour, and
$F$ = fetch or straight length of water subject to wind action in kilometres.

**4.3.1** The height of the wave is measured from trough to crest of the wave but as the waves will travel up the slope of the embankment, $h_w$ may be taken as height above the flood level.

**4.3.2** As a guideline, minimum free board of 1.5 m over design HFL including the back water effect, if any, should be provided for the river carrying design discharge up to 3 000 m$^3$/s. For higher discharges or for aggrading/flashy rivers, the minimum free board should be of 1.8 m. This should be checked also for ensuring a minimum of about 1.0 m of free board over HFL corresponding to 100 years frequency flood (*see also* **3.2**).

**4.4 Top Width**

For facilitating transport of material during construction and maintenance work, it is desirable to make the top sufficiently wide to accomodate two-lane vehicular traffic and to be used as inspection road. The criteria given below may be considered as general guideline for top width (*see* IS 11532).

**4.4.1** The top width of the embankment should be of 5.0 m. The turning platforms, 15 to 30m long and 3.0m wide with side slope 1:3 along the countryside of the embankment should be provided at every kilometre (*see* Fig. 3).

**4.4.2** The top width should be adequate for the type of vehicular traffic designed to use the embankment. Clear berms of 1 m width on either side sloping towards the outer edges of the embankment may be provided for drainage. No water should be allowed to collect over the embankment at any stage. Suitably designed gutter-drains may be provided on both side slopes at intervals.

**4.5 Hydraulic Gradient**

It is always desirable to know, approximately at least, the line of seepage in the cross-section of a proposed embankment. This line should never be allowed to intersect the outside countryside slope of bank above GL and care should be taken so that a cover of 0.6 m is available on HG line.

**4.5.1** Hydraulic gradient line should be determined on the basis of the analysis of soils which are to be used in the construction of embankment. However, the following guidelines are recommended:

| *Type of Fill* | *Hydraulic Gradient* |
|---|---|
| Clayey soil | 1 in 4 |
| Clayey sand | 1 in 5 |
| Sandy soil | 1 in 6 |

**4.6 Side Slope**

The side slopes are dependent upon the nature of the material of which the embankment is made, the method of construction, the height of the embankment and the length of time that the embankment is likely to be subjected to the action of flood waters. They shall also be stable against slipping under conditions of saturation and sudden drawdown (*see* IS 7894).

**4.6.1** *River Side Slope*

The river side slope should be flatter than the under water angle of repose of the material used in the fill. Up to an embankment height of 4.5 m, the slope should not be steeper than 1 in 2 and in case of higher embankments slope should not be steeper than 1 in 3,

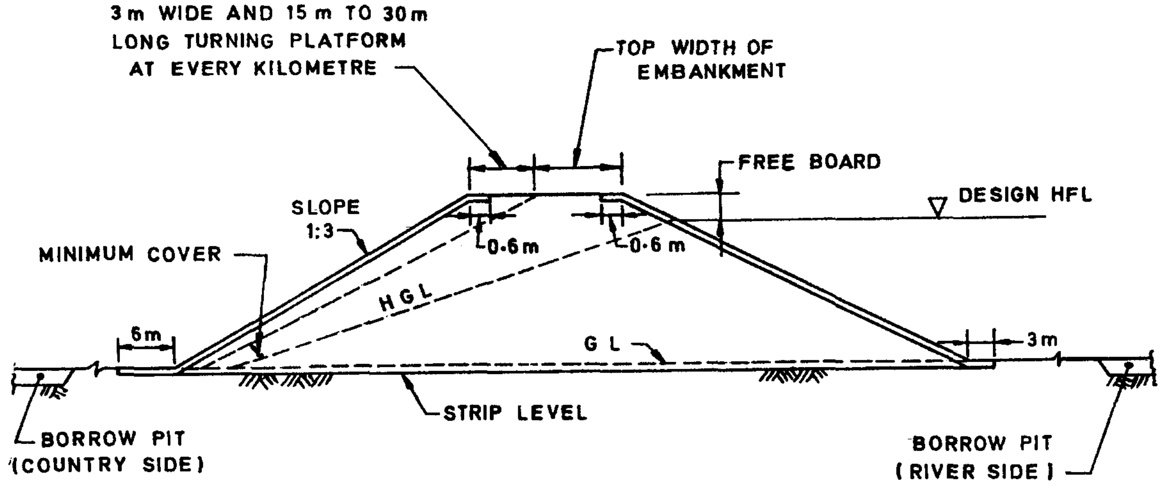



FIG. 3 TYPICAL CROSS-SECTION SHOWING TURNING PLATFORM

when the soil is good and to be used in the most favourable condition of saturation and drawdown.

a) In case of higher embankment protected by rip-rap, the slope of embankments up to 6 m high may be 1 in 2 or 1 in 2.5 depending upon the type of slope protection;

b) If the construction material is sandy, the slope should be protected with a cover of 0.6 m thick good soil; and

c) It is usually preferable to have more or less free draining material on the river side to take care of sudden drawdown. In case of high and important embankment stone rip-rap either dry dumped or hand placed and concrete pavements/concrete blocks with open joints are adopted to protect the embankment against drawdown and/or erosive action of the river (*see* IS 8408); in less important embankments where rip-rap is costly, willow mattress can be used.

**4.6.2** *Countryside Slope*

A minimum cover of 0.6 m over the hydraulic line should be provided.

a) For embankment up to 4.5 m height, the countryside slope should be 1 in 2 from the top up to the point where the cover over HG line is 0.6 m after which a berm of suitable width, with the countryside slope of 1:2 from the end of the berm up to ground level, should be provided;

b) For embankments of height between 4.5 to 6.0 m, the corresponding slopes with respect to **4.6.2** (a) should be 1 in 3. Berms should be of width 1.5 m normally;

c) For embankments of height more than 6.0 m, detail design should be made.

**4.6.2.1** For drainage, longitudinal drains should be provided on the berm and cross drains at suitable places should be provided to drain the water from the longitudinal drains (*see* IS 10751).

**4.7 Safety Measures in Design**

Structure should be stable under all stages of construction and conditions of saturation and draw-down. It is therefore necessary that stability checks for various conditions should be done to ensure safety of the structure. Seismic forces should also be considered for high embankments. The factor of safety should be **1.3** or greater. (*see* IS 7894).

**4.7.1** *Safety Against Cracks Due to Unequal Settlement and Wetting*

Unequal settlements can be largely avoided by preparing the foundations properly and by selecting suitable material for construction. Where the foundation soil is weak, suitable strengthening measures may be taken. Clayey soils containing organic matter or soils containing decaying vegetables matter such as remains of plants and roots should be rejected. Well graded homogeneous materials are most suitable for construction. In case of difficulty in getting full quantities of the same material, zonal sections with impervious core and a pervious casing may be adopted. In high embankments it is desirable to mechanically compact the earth fill in suitable layers with a view to achieve optimum density with appropriate moisture content. Breaking of big clods specially in clayey soils is to be done and organic/vegetable matter separated to safeguard against leakage/piping.

**4.8 Sluices**

Sluices with regulating arrangement should be provided for countryside drainage. The size of sluices will depend upon the intensity of the rainfall and the catchment area to be drained.

**4.9 Treatment on Top of Embankments**

An embankment should be provided with suitable soling over filter for proper drainage. For embankments protecting towns in industrial and places of strategic importance, the necessity of providing all weather road surfaces of 3 to 3.5 m width should be examined to ensure maintenance work for reaches which are not easily accessible.

**4.10** In order to provide communication from one side of embankment to the other, ramps at suitable places should be provided as per requirement to obviate subsequent interference.

This Indian Standard has been developed from Doc : No. WRD 22 (263).

**Amendments Issued Since Publication**

| Amend No. | Date of Issue | Text Affected |
|---|---|---|
| | | |
| | | |
| | | |

BUREAU OF INDIAN STANDARDS

Headquarters:

Manak Bhavan, 9 Bahadur Shah Zafar Marg, New Delhi 110 002
Telephones : 323 01 31, 323 33 75, 323 94 02

Telegrams : Manaksanstha
(Common to all offices)

| Regional Offices : | | Telephone |
|---|---|---|
| Central | : Manak Bhavan, 9 Bahadur Shah Zafar Marg<br>NEW DELHI 110 002 | 323 76 17<br>323 38 41 |
| Eastern | : 1/14 C. I.T. Scheme VII M, V. I. P. Road, Kankurgachi<br>CALCUTTA 700 054 | 337 84 99, 337 85 61<br>337 86 26, 337 91 20 |
| Northern | : SCO 335-336, Sector 34-A, CHANDIGARH 160 022 | 60 38 43<br>60 20 25 |
| Southern | : C. I. T. Campus, IV Cross Road, CHENNAI 600 113 | 235 02 16, 235 04 42<br>235 15 19, 235 23 15 |
| Western | : Manakalaya, E9 MIDC, Marol, Andheri (East)<br>MUMBAI 400 093 | 832 92 95, 832 78 58<br>832 78 91, 832 78 92 |

Branches : AHMADABAD. BANGALORE. BHOPAL. BHUBANESHWAR. COIMBATORE. FARIDABAD. GHAZIABAD. GUWAHATI. HYDERABAD. JAIPUR. KANPUR. LUCKNOW. NAGPUR. PATNA. PUNE. RAJKOT. THIRUVANANTHAPURAM.

Printed at : Prabhat Offset Press, New Delhi-2