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RECOMMENDED PRACTICE FOR CONSTRUCTION OF EARTH EMBANKMENTS AND SUBGRADE FOR ROAD WORKS

(First Revision)

INDIAN ROADS CONGRESS
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1 INTRODUCTION

1.1 Successful performance of an embankment depends as much on adopting standards of good compaction in construction as on careful pre-investigations regarding the selection of appropriate borrow soil and design features of the embankment. Therefore, all aspects deserve equal attention to improve performance and to make the embankment that is economical. Subgrades which are well-compacted possess high strength and resistance to deformation; and due to their increased stability, reduction in the overall thickness of the pavement is usually feasible. Since in a well compacted embankment, subsequent settlements of the fill are negligible, the permanent road structure can be safely placed on satisfactory completion of earthwork.

1.2 Realizing the advantages that can be had by going in for improved practices in Embankment construction, IRC:36 "Recommended Practice for the Construction or Earth Embankments for Road Works" was first published in 1970. The re-constituted Embankment, Ground Improvement and Drainage (H-4) Committee in its first meeting held on 07 March 2009, considered the urgent need to revise this Code and other related Codes of Practices dealing with the embankment design and construction aspects to keep pace with the changes in technology and improvements in the construction procedure as well as quality control expectations. It was also felt that IRC:10:1961 "Recommended Practice for Borrowpits for Road Embankment Constructed by Manual Operation" has become obsolete, since manual methods are no longer being adopted for road construction. It was accordingly decided that useful aspect of IRC:10 may be amalgamated with the proposed Code. Shri Mahesh Kumar, Engineer-in-Chief, Haryana PWD (B&R), (Convenor, H-4 Committee), alongwith Shri R. K. Kansal and Shri Vipin Sharma, both Executive Engineers, Haryana PWD (B&R) took responsibility of preparing the draft, based on their work Experiences.

Initially, this document was approved by the H-4 Committee in its fourth meeting held on 26 September 2009 for placing before the Highways Specifications and Standards (HSS) Committee for consideration. The HSS Committee in its second meeting held on 20 October 2009 referred back the document to H-4 Committee for some modifications as per comments offered by the HSS members. Modified document, [1]duly incorporating the comments offered by the HSS Committee members, was again approved by the H-4 Committee in its seventh meeting held on 09 April 2010. The modified draft document, thereafter, was placed before the HSS Committee during its third meeting held on 01 May 2010 and HSS Committee approved the same. The draft document was approved by the Executive Committee in its meeting

held on 10 May 2010 and was then placed before the IRC Council in its 191st meeting held at Munnar (Kerala) on 22nd May 2010 for consideration. The Council approved the document subject to some modifications in the light of comments offered by the Council Members. The document after incorporating comments of Council members was approved by the Convenor of Highways Specifications & Standards Committee for printing. The Composition of H-4 Committee is as given below:

Kumar, Mahesh	...	Convenor
Sharma, Arun Kumar	...	Co-Convenor
Mathur, Sudhir	...	Member Secretary

Members

Chand, Faquir	Rao, Prof. G.V.
Dhodapkar, A.N.	Rao, Prof. P.J.
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Praohan, B.C.	C.E., PWD, Meghalaya

Corresponding Members

Verma, M.S.

Ex-Officio Members

Liansanga	(President, IRC)
Sinha, A.V.	(Director General (RD)&SS, MoRTH)
Indoria, R.P.	(Secretary General, IRC)

2 SCOPE

2.1 The recommendations given in this Code shall apply to the construction of embankments, subgrades and of miscellaneous backfill with materials obtained either from excavation for road construction, or borrow pits, or other selected borrow areas. All embankments shall be constructed in accordance with this Code and in conformity with the alignment, levels, cross-sections, and dimensions shown on the plans or as directed by the Engineer-in-Charge.

3 MATERIALS

3.1 The material used in embankments, subgrades, earthen shoulders and miscellaneous backfills shall be soil, moorum, gravel, flyash, a mixture of these or any material approved by the Engineer-in-Charge. Such materials shall be free of logs, stumps, roots, rubbish, or any other ingredient likely to adversely affect the stability of the embankment/subgrade.

3.2 The selection of the material to be used in the construction of sub grades and embankments shall be made after necessary surveys and laboratory investigations.

4 SOIL SURVEYS AND INVESTIGATIONS

4.1 The purposes of the soil surveys are:

a) To determine the nature of the soils with a view to determine the suitability of embankments for the design of pavements.

b) To determine the proper methods of handling soils and the test requirements that should be incorporated in construction specifications.

c) To provide data so that in combination with construction records it serves as a basis for appropriate study of subgrades, road bases and surfaces.

4.2 Preliminary Investigations

After the road alignment and longitudinal profile have been finalized, preliminary investigations shall be carried out to procure the following data:

a) The suitability of material for embankment work obtainable from excavation for road constructions or from borrow areas.

b) Information regarding the location of borrow areas shall consider the factors of lead, accessibility of earth moving equipments, initial cost, etc.

c) Information regarding the highest sub-soil water level and the nature and extent of inundation, if any, gathered from local enquiries or from previous official records.

d) The character of embankment foundations including the presence of any unstable strata, marshy areas, etc. In the case of high embankments and embankments located on unstable strata, information regarding the failure of earlier embankments in that area, together with the causes of failure, shall also be gathered from available records and experiences.

e) Any particular construction problem in the area or any other information likely to be useful.

4.3 Detailed Investigations

On the basis of the report of preliminary investigations, the programme for detailed investigations shall be drawn up. The survey procedure and information to be gathered shall conform to the outlines given below:

4.3.1 Test pits shall be dug in borrow areas from where the embankment material is to be obtained. When embankment material is obtained from selected borrow areas, adequate number of samples shall be taken from each such area. The depth of the test pits should not exceed the likely depth of the pits by more than 150 mm.

4.3.2 The general character of the material excavated out of the test pits shall be recorded. Representative samples of the soil shall be collected from the test pits for further detailed study in the laboratory [For sampling procedure refer to IS 2720 (Part 1)].

4.3.3 Along the alignment of the road where unstable strata or soft material is met with, below the foundation level, and particularly where the height of the fill will be considerable, the soil profile shall be drawn after determining, by way of boreholes, the type of soil at different levels. The boreholes may be at 500 m intervals, the depth being normally 1.25 to 1.5 m below existing ground level. In the case of high embankments (6 m or more) and problematic substrata, the minimum depth of boreholes should be twice the height of the embankment. However, a well informed decision based upon the available information needs to be taken in every case. A sample should be taken from each stratum found in each boring. Subsequently, on the basis of tests performed in the laboratory, the soil profile should be drawn. High embankments in all soils having height over 6 m shall be designed as per IRC:75.

4.3.4 Reliable information shall be collected at this stage regarding the probable highest sub-soil water level along the alignment of the embankment. If necessary, holes should be dug for this purpose and left for 12 to 24 hours for the water to rise in them to its final level before any observations are made. Alternatively, where the sub-soil water level is known to be quite low or where the digging of holes pose particular difficulty on account of the terrain being difficult, this information might be ascertained through local enquiries [**Refer** Clause **4.2 (c)**].

4.3.5 Samples of soil intended to be used in embankment work shall be tested in the laboratory for the following properties:

a) Sieve analysis or particle size distribution.
b) Liquid Limit.
c) Plastic Limit.
d) Plasticity Index.
e) Shrinkage Limit.
f) Free Swelling Index.
g) For working out the Optimum Moisture Content (OMC) from the moisture density relationship, in case of NHs, SHs and MDRs heavy compaction corresponding to IS 2720 (Part 8) be used while for rural roads comprising ODRs and VRs, light compaction corresponding to IS 2720 (Part 7) may be used.
h) Deleterious constituents*

However, in cases of high fills or embankments laid on soft foundations the substrata and fill soil for substrata shall be subjected to tests like shear strength and consolidation if considered necessary and so directed by the Engineer-in-Charge.

4.3.6 The tests mentioned above shall be carried out in accordance with the procedure laid down in IS 2720 (relevant part) "Methods of Test for Soils".

4.3.7 After carrying out the laboratory tests, each soil sample shall be classified (**Table 1**) according to the Indian Standard system of soil classification (IS 1498).

4.3.8 The results of laboratory investigations shall be presented in a concise form. The proforma given in **Table 2** may be used for this purpose.

4.3.9 In addition to the tests prescribed in Clause **4.3.5**, samples of soil to be used in embankment and subgrade (top 500 mm for NHs/SHs/MDRs and top 300 mm for rural roads) shall be tested in the laboratory for the determination of CBR as per Clause **4.3.5 (g)** after soaking the samples in water for four days. The results of these tests shall be used for the design of pavement**.

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*Only in salt-infested areas or where presence of salts is suspected.

**For guidance in this respect, see IRC:37 "Guidelines for the Design of Flexible Pavements" and IRC:15 for "Standard specification and Code of Practice for Construction of Chocrete Road."

Table 1 Indian Standard System of Soil Classification (IS 1498)

Division	Sub-Division			Group letter symbol	Typical names	Value as Subgrade when not subject to frost action	Unit Dry Weight g/cm³	CBR Value percent
Coarse-Grained Soils More than half of material is larger than 75 micron IS Sieve Size (The 75 micron IS Sieve size is about the smallest particle visible to the naked eye)	Gravels More than half of coarse fraction is larger than 4.75 mm IS Sieve size	(For visual classification the 5 mm size may be used as equivalent to the 4.75 mm IS Sieve size)	Clean gravels (little or no fines)	GW	Well graded gravels, Gravel - sand mixtures; little or not fines	Excellent	2.00-2.24	40-80
				GP	Poorly graded gravels or gravel sand mixtures; little or no fines	Good to excellent	1.76-2.24	30-60
			Gravels with fines (appreciable amount of fines)	GM	Silty gravels, poorly graded gravel - sand silt mixtures	d'- good to excellent u'- good	2.00-2.32 1.84-2.16	40-60 20-30
				GC	Clayey gravels, poorly graded gravel - sand clay mixtures	Good	2.08-2.32	20-40
	Sands More than half of coarse fraction is smaller than 4.75 mm IS sieve size		Clean sands (little or no fines)	SW	Well graded sands, gravelly sands; little or not fines.	Good	1.76-2.08	20-40
				SP	Poorly graded sands or gravelly sands; little or no fines	Fair to good	1.68-2.16	10-40
			Sands with fines (appreciable amount of fines)	SM	Silty sands, poorly graded sand silt mixtures	d'- fair to good u'- fair	1.92-2.16 1.60-2.08	15-40 10-20
				SC	Clayey sands, poorly graded sand clay mixtures	Poor to fair	1.60-2.16	5-20

Cont'd

Division	Sub-Division	Group letter symbol	Typical names	Value as Subgrade when not subject to frost action	Unit Dry Weight g/cm³	CBR Value percent
Fine -Grained Soils More than half of material is smaller than 75 micron IS Sieve Size . (The 75 micron IS Sieve size is about the smallest particle visible to the naked eye)	Silts and clays with low compressibility and liquid limit less than 35	ML	Inorganic silts and very fine sands, rock flour, silty or clayey fine sands or clayey silts with none to low plasticity	Poor to fair	1.44-2.08	15 or less
		CL	Inorganic clays, gravelly clays, sandy clays, silty clays, lean clays of low plasticity	Poor to fair	1.44-2.08	15 or less
		OL	Organic silts and organic silty clays of low plasticity	Poor	1.44-1.68	5 or less
	Silts and clays with medium compressibility and liquid limit greater than 35 and less than 50	MI	Inorganic silts, silty or clayey fine sands or clayey silts of medium plasticity	Poor to fair	1.44-2.08	15 or less
		CI	Inorganic clays, gravelly clays, sandy clays, silty clays, lean clays of medium plasticity	Poor to fair	1.44-2.08	15 or less
		OI	Organic silts and organic silty clays of medium plasticity	Poor	1.44-1.68	5 or less
	Silts and clays with high compressibility and liquid limit greater than 50	MH	Inorganic silts of high compressibility, micaceous or diatomaceous fine sandy or silty soils, elastic silts	Poor	1.28-1.68	10 or less
		CH	Inorganic clays of high plasticity, fat clays	Poor to fair	1.44-1.84	15 or less
		OH	Organic clays of medium to high plasticity	Poor to very poor	1.28-1.76	5 or less
Highly organic soil		Pt	Peat and other highly organic soils with very high compressibility	Not suitable	–	–

*d - when liquid limit is ≤ 25% and PI ≤ 5, *u - when liquid limit is >25% and PI >5.

Table 2 Proforma for Presenting Laboratory Investigation Results

Name of the Laboratory.....	..... Date			
Reference (Data concerning location of sample, etc)				
Test information (Origin of soil sample, etc)				
No. of Samples tested..... 2.00 mm IS Sieve 425 micron IS Sieve 75 micron IS Sieve				
Liquid Limit				
Plastic Limit				
Plasticity Index				
Shrinkage Limit				
Free Swelling Index				
Maximum Dry Density (Standard Proctor's/Modified Proctor's test) Optimum Moisture Content.....				
Soil Classification as per IS:1498				
CBR (For subgrades)				
General Remarks (i.e. suitability of embankment material, safe side slopes, etc)				

4.3.10 For selection of soil, refer **Table 1** on Indian Standard Soil Classification System (IS 1498), classification being based on anticipated embankment performance.

4.4 Acceptance Criteria/Physical Requirements

4.4.1 The materials used in embankments, subgrades, earthen shoulders and miscellaneous backfills shall be soil, moorum, gravel, reclaimed material from pavement, fly-ash, (pond ash), a mixture of these or any other material approved by the Engineer-in-charge. Such materials shall be free of logs, stumps, roots, rubbish or any other ingredient likely to deteriorate or affect the stability of the embankment/ subgrade.

i) The following types of material shall be considered unsuitable for embankment construction.

   a) Materials from swamps, marshes and bogs.

   b) Peat, log, stump and perishable material; any soil that classifies as OL, OI, OH or Peat in accordance with IS 1498.

   c) Materials susceptible to spontaneous combustion.

   d) Materials in a frozen condition.

   e) Clay having liquid limit exceeding 70 and plasticity index exceeding 45.

   f) Materials with salts resulting in leaching of the embankment.

   g) Expansive clay having free swelling index exceeding 50 percent. However, in case of non availability of suitable soil in adjoining areas, the available soil shall be suitably modified.

ii) The following types of material shall be considered unsuitable for subgrade construction.

   a) Materials from swamps, marshes and bogs.

   b) Peat, log, stump and perishable material; any soil that classifies as OL, OI, OH or Peat in accordance with IS 1498.

   c) Materials susceptible to spontaneous combustion.

   d) Materials in a frozen condition.

   e) Clay having liquid limit exceeding 50 and plasticity index exceeding 25.

   f) Material with salts resulting in leaching of the embankment.

   g) Expansive soils.

4.4.2 Expansive clay exhibiting marked swell and shrinkage properties "free swelling index" exceeding 50 percent {when tested as per IS 2720 (Part 40)} shall not be used as a fill material. Where an expansive clay having "free swelling index" value less than 50 percent is used as a fill material, subgrade and top 500 mm portion of the embankment just below subgrade shall be non-expansive in nature.

4.4.3 Any fill material with soluble sulphate content exceeding 1.9 grams of sulphate (expressed as SO_3) per litre when tested in accordance with BS:1377 Test 10, but using a 2:1 water soil ratio shall not be deposited within 500 mm distance (or any other distance described in the Contract), of permanent works constructed out of concrete, cement materials or other cementitious material.

Materials with a total sulphate content (expressed as SO_3) exceeding 0.5 percent by mass, when tested in accordance with BS:1377 Test 9 shall not be deposited within 500 mm, or any other distance described in the Contract, of metallic items forming part of the Permanent Works.

4.4.5 The size of the coarse material in the mixture of earth shall ordinarily not exceed 75 mm when placed in the embankment and 50 mm when placed in the subgrade. However, the Engineer-in-charge may at his discretion permit the use of material coarser than this, if he is satisfied that the same will not present any difficulty as regards the placement of fill material and its compaction to the requirements of these specifications. The maximum particle size in such cases, however, shall not be more than two-third of the compacted layer thickness.

4.4.6 Ordinarily, only the material satisfying the compaction and density requirements given in **Tables 3 and 4** shall be employed for construction of the embankment and the subgrade.

Table 3 Compaction Requirements of Embankment and Subgrade Materials

Sl. No.	Type of Work/Material	Relative Compaction as Percentage of Max. Laboratory Dry Density as per IS 2720 (Parts 7 or 8)
1)	Subgrade and earthen shoulders	Not less than 97 percent
2)	Embankment	Not less than 95 percent
3)	Expansive Clays (Soils having free swelling index exceeding 50% when tested as per IS 2720 part 40) a) Subgrade b) Embankment (allowed after suitable treatment)	 Not allowed Not less than 95 percent

Table 4 Density Requirements of Embankment and Subgrade Materials

Sl. No.	Type of Work	For NHs/SHs/MDRs Maximum Laboratory Dry Unit Weight When Tested as per IS 2720 (Part 8)	For Rural Roads Maximum Laboratory Dry Unit Weight When Tested as per IS 2720 (Part 7)
1)	Embankments upto 3 m height, not subjected to extensive flooding.	Not less than 15.2 kN/cu.m	Not less than 14.4 kN/cu.m
2)	Embankments exceeding 3 m height or embankments of any height subject to long period of inundation	Not less than 16.0 kN/cu.m	Not less than 15.2 kN/cu.m
3)	Subgrade and earthen shoulders/ verges/backfill	Not less than 17.5 kN/cu.m	Not less than 16.5 kN/cu.m

NOTE: Table 4 is not applicable for light weight fill material, e.g. cinder, pond ash/flyash, etc.

5 STRUCTURAL FEATURES OF THE EMBANKMENT

5.1 The structural features and other details regarding the construction work shall be decided by the Engineer-in-Charge on the basis of the soil survey results. Where the embankment is to be supported by a soil stratum deficient in shear strength and foundation or embankment failures may be likely because of the superimposed load of the embankment, it shall be necessary to specially design it and adopt remedial measures. High embankments in all soils having height over 6 m shall be designed as per IRC:75. In case of embankments on soft soil conditions or where the stability of the embankment needs improvement, suitable ground improvement techniques may be considered and employed.

5.2 Where possible, the embankment may be built to side slopes ranging from 1.5H:1V to 2H:1V in uninundated conditions and from 2H:1V to 3H:1V in inundated conditions. These slopes are recommended mainly from the consideration of traffic safety. It is desirable to construct wider embankment and then trim the same to achieve the required slopes. However, where the cost of construction for bids going in for such liberal slopes, the slopes and the slope angle may be selected depending upon the type of the soil along with provisions for adequate safety measures like crash barriers etc. The side slope required should be determined from slope stability analysis, giving due weightage to sub soil characteristics.

5.3 Wherever required due to constraints of space or otherwise, slopes steeper than those suggested in Clause **5.2** above can also be provided. In such situations, the slopes should be mechanically stabilized and other related safety requirements should also be attended to.

6 SETTING OUT CONSTRUCTION LIMITS

6.1 On new works, as a first step towards start of construction, the alignment of the road finalized in the design office shall be marked on the ground. The marking procedure shall consist of setting out the centre-line of the road with the help of a theodolite and total station survey equipment and establishing centre line pegs at intervals along the road. Where horizontal curves break tangent sections, pegs shall be planted at the beginning and the end points of the curves and at the points of intersection of the straights connected by the curves.

6.2 Centre-line and Reference Pegs : On tangent sections, points on transit shall be fixed at least every 10 m in plain terrain and 5 m in rolling and hilly terrain. The centre-line pegs in case of points of transit may preferably consist of concrete hubs driven flush with the ground. These points shall be referenced by means of what are called 'reference pegs' fixed normal to the centre-line peg so as to be in a position safe from interference by clearing or other earthwork operations. Reference pegs shall consist of angle irons embedded in concrete or permanent bench mark pillars of design approved by the Engineer-in-Charge.

Reference pegs shall be established on curved sections as well where these may be located at a distance of 10-12 m away from the apex points of the curves in extension of the tangent lines.

6.3 Batter Pegs: After centre line pegs have been established, batter pegs marking the limits of the embankment shall be fixed on both the sides.

Batter pegs are meant as guides for the plant and machinery when commencing the earthworks. To ensure their safety, it will be desirable to fix the pegs about 0.5 m back from the actual limit of the fill and to paint them in a distinctive colour.

6.4 Sketches explaining the setting out of control pegs for embankment construction are given in **Fig. 1**.

7 PRELIMINARY OPERATIONS

7.1 Prior to the commencement of earthwork, the site shall be cleared of any obstructions, including buildings, fences, utility lines, abandoned drainage structures, and vegetation such as trees, roots, undergrowth, grass, rubbish etc., within limits specified by the Engineer-in-charge and delineated by means of clearing

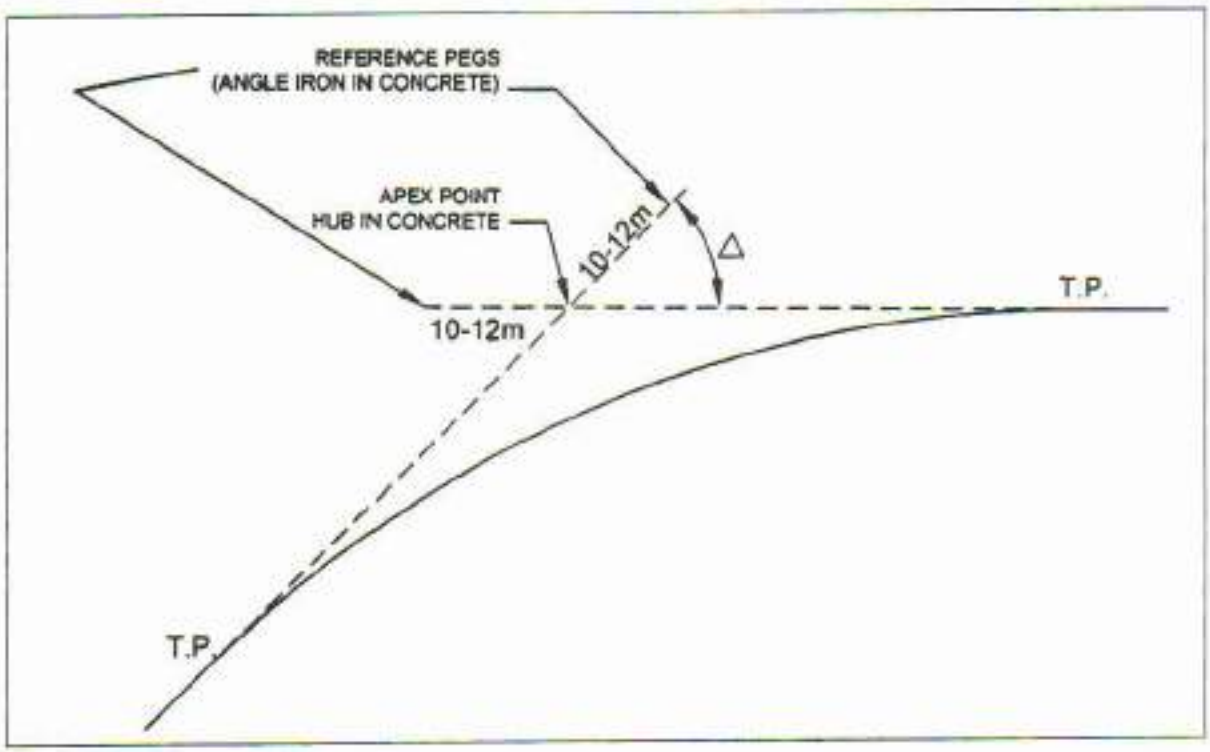

Fig. 1a Reference Pegs at Curve

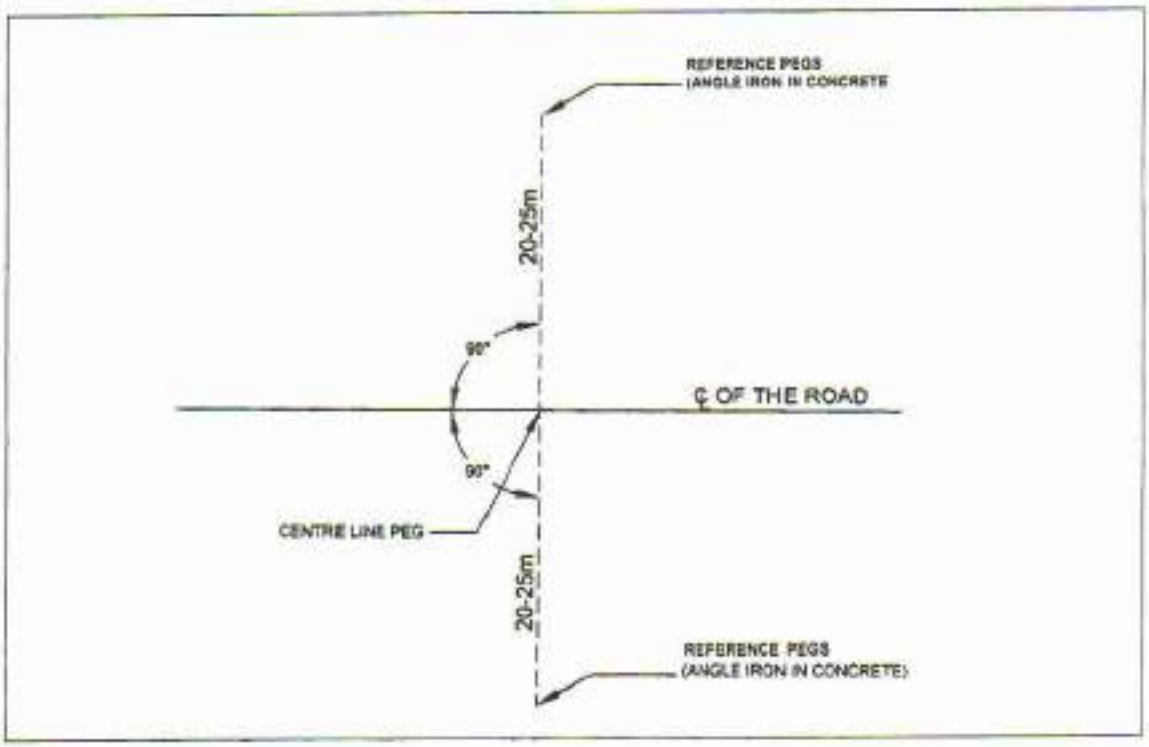

Fig. 1b Reference Pegs at Point Transit

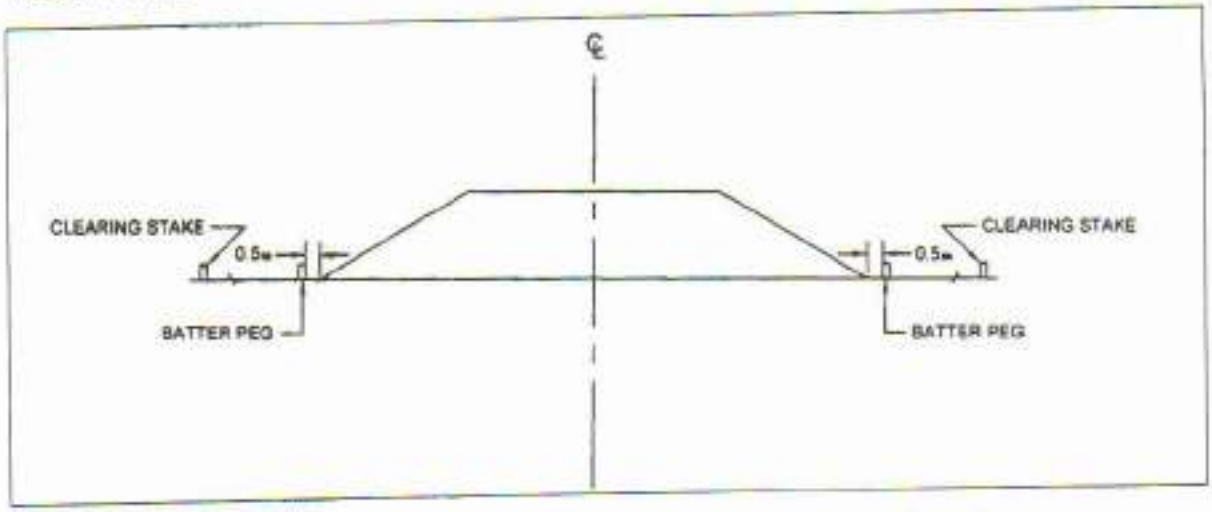

Fig. 1c Batter Pegs for Defining the Limits of Embankment

stakes (**see Fig.1**). Except where it may be desirable to retain the vegetation for the sake of appearance, shade or other reasons, complete clearance shall be carried out within the construction limits. In addition, it may be necessary to remove some trees and undergrowth adjacent to the construction area for one or more of the following reasons:

a) To provide adequate sight distance for safe travel;

b) To improve the landscape and afford opportunity to view scenic attraction;

c) To remove decayed or dead trees which might otherwise fall on the highway;

d) To remove obstructions to drainage;

e) To permit access to and use of borrow pits and other source of materials.

All trees and shrubs which are not likely to interfere with the construction and use of the highway should be preserved.

7.2 Existing trees should be preserved as far as possible and indiscriminate felling of trees should not be resorted to while upgrading/widening and improving the highway. Trees located on embankment slopes have proved to be potential traffic hazard to vehicles going off the carriageway and hitting against them. Therefore, wherever the trees are either on the embankment slope itself or too close to it, constituting safety hazard, these shall be replaced systematically by alternative plantation.

The existing trees by the side of the embankment, which in the opinion of the Engineer-in-Charge, are serious threat to safety should be removed immediately, after obtaining the approval of competent authority. Other trees within 10 m of the centre line of extreme traffic lane should be removed gradually after planting alternative trees.

7.3 Materials possessing any salvage value among the removed bushes and stumps shall be stacked as directed by the Engineer-in-Charge. The remaining materials shall, in all cases, be cleared away to waste areas at locations away from the road side.

7.4 Care shall be taken to see that unsuitable waste materials are disposed of in such a manner that there is no likelihood of their getting mixed with the materials proposed to be used for embankment or any other construction.

7.5 Stripping and Storing of Top Soil : In localities where most of the embankment materials are not conducive to plant growth, or when so directed by the Engineer-in-Charge, the top soil suitable for plant growth existing over the embankment foundation areas shall be stripped and stored for covering embankment slopes, cut slopes or other disturbed areas where re-vegetation is desired.

7.6 Compacting Original Ground : In all cases, where conditions permit, the original ground shall be leveled and compacted as much as reasonably possible, by rolling and where rolling is not feasible, by way of other means like tamping. Any empty pockets or depressions left in the soil as a result of clearing and grubbing operations shall be filled and compacted.

7.7 Normally the height of the road embankment should be so decided that bottom of subgrade is 0.6 m to 1.00 m above HFL or ground level whichever is higher. However, when difference between top of subgrade and original ground level is less than 500 mm and the maximum dry density of the original ground level is less than the requirement of **Tables 3 and 4**, the same shall be loosened upto a depth of 500 mm and re-compacted in layers at optimum moisture content to achieve the required density. If the next 150 mm depth of the original ground below this excavation does not have the stipulated compaction, it should be compacted until the required density as per **Tables 3 and 4** is obtained. In case of NHs, SHs and MDRs, compaction values corresponding to IS 2720 (Part 8) be used while for Other District and Village Roads compaction values corresponding to IS 2720 (Part 7) be used.

7.8 Any unsuitable materials occurring in the embankment foundations shall be removed and replaced by approved materials.

7.9 Where an embankment is to be placed on steep sloping ground, the surface of the ground shall be benched in steps or trenched, or broken up in such a manner that the new materials will bond with the existing surface.

7.10 Embankment work shall not proceed until the foundations have been approved by the Engineer-in-Charge.

8 CONSTRUCTION OF EMBANKMENT

8.1 Only approved materials shall be utilized in the embankment. The work shall be so planned and executed that the best available materials are saved for the top portion of the embankment, i.e., subgrade. Where inevitable and earth has to be borrowed from land close to the embankment, following principles regarding the location, depth and drainage of borrow pits shall be adopted so that the ill effects of borrow pits are kept down to the minimum:

8.1.1 Earth available from road cuttings and excavations, if suitable, should be used in the first instance.

8.1.2 Borrow pits should be rectangular in shape with one side parallel to the centre line of the road.

8.1.3 No borrow pits should be dug within 5 m of the toe of the final section of the road embankment, after making due allowance for future development.

8.1.4 The depth of borrow pits should be so regulated that the borrow pits do not cut an imaginary line having a slope of 1V in 4H projected from the edge of the final section of the bank as illustrated in **Fig. 2**.

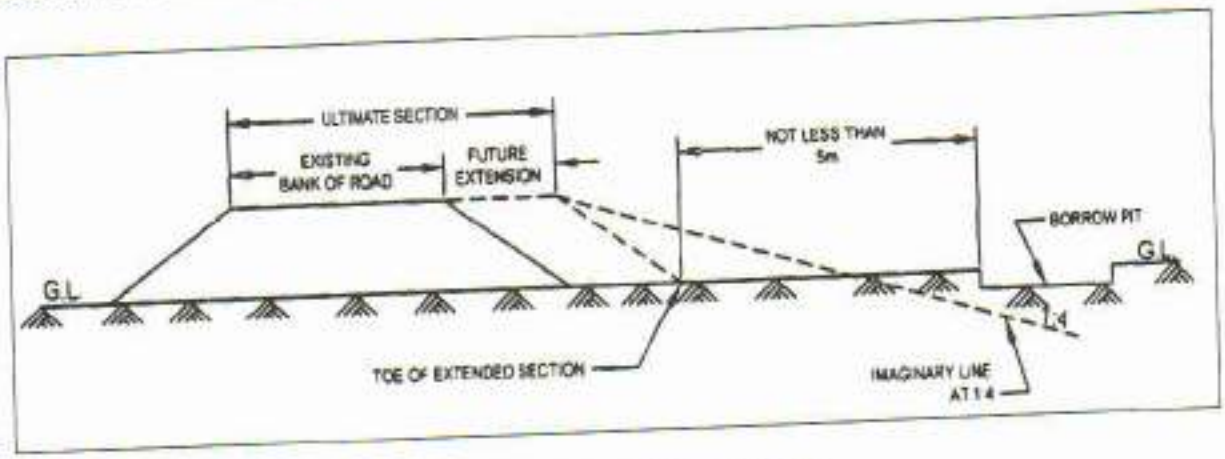

Fig. 2 Location of Borrow Pits

8.1.5 Borrow pits should not be dug continuously. Ridges of not less than 8 m width should be left at intervals not exceeding 300 m. Small drains should be cut through the ridges, if necessary, to facilitate drainage.

8.1.6 To prevent breeding of mosquitoes, where other conditions permit, borrow pits should be well drained. To ensure efficient drainage, the bed level of the borrow pits should, as far as possible, slope down progressively towards the nearest cross drain, if any, and should not be lower than the bed of the cross drain.

8.1.7 When it becomes necessary to borrow earth from temporarily acquired cultivable lands, the depth of borrow pits should not exceed 1 m. The top soil to a depth of 150 mm should be stripped and stacked aside. Thereafter, soil may be dug out to a further depth not exceeding 850 mm and used in forming the embankment. The top soil should then be spread back on the land. It is most important to adopt this practice when soil is borrowed from rich cultivable land.

8.1.8 In waterlogged areas where the water table is near the surface, the lowering of the level of the land even by 300 mm which will result from the practice suggested in Clause **8.1.6**, may make cultivation impossible. In such cases, borrow pits should take the form of deep narrow continuous ditches (connected with natural drainage where possible) so as to conserve as much land as possible. In all such cases, special anti-malaria measures may have to be adopted near habitations, in consultation with the Public Health Authorities.

8.1.9 Borrow pits should not be dug within 800 m of towns or villages. If unavoidable, they should not exceed 300 mm in depth and should be properly drained.

8.2 Capillary Cut-off

At locations where the water table is high and the soil has potential for rapid and relatively great migration of moisture by capillarity, a granular layer, impervious membrane, or barrier of another approved medium shall be inserted at a suitable level by way of a cut-off, or the height of the embankment suitably increased, if found more economical, so that the moisture is not able to rise to the subgrade level. The capillary cut-off, when provided, shall extend across the full width of the embankment. For details about the suitable types of capillary cut-offs, and their provision, refer to IRC:34 "Recommendations for Road Construction in Waterlogged Areas" and relevant clause in Section **300** of MORTH Specifications.

8.2.1 The capillary cut-off may be a layer of coarse or fine sand, graded gravel. Layer thicknesses recommended for different situations are given in **Table 5**. Whenever sand is used as cut-off layer, the layer shall not be provided at the edges but should be replaced with suitable filter of graded granular material with or without non-woven geo-textile material for preventing loss of fines.

Table 5 Recommended Thickness of Layer for Capillary Cut-off

Sl. No	Situation	Minimum Thickness of Layer (mm)		
		Coarse sand	Fine sand	Graded gravel
1)	Subgrade 0.6 – 1.0 m above HFL (PI > 5)	150	350	150
2)	Subgrade 0.6-1.0 m above HFL, the subgrade soil being sandy in nature (PI<5, sand content not less than 50 percent)	100	300	100

8.2.2 Cut-off with bituminised (suitably mixed with anti stripping agent) or other materials may be provided in any of the following ways:

i) Bituminous impregnation using primer treatment

Bituminous emulsion applied at the rate of 6-15 kg per 10 sqm.

ii) Heavy-duty tarfelt:

Enveloping sides and bottom of the bed with heavy duty tarfelt.

iii) Bituminous stabilized soil:

Providing bituminous stabilized soil in a thickness of at least 40 mm.

iv) Geo-composite layer:

Appropriate geo-composite layers are recommended as capillary cut-off.

v) Other stabilized soil layer:

Stabilized soil of adequate thickness may be provided.

8.2.3 For more details about mitigating the adverse effects of high water table, reference may be made to IRC:34 "Recommendations for Road Construction in Waterlogged Areas".

8.3 Placing Soil in Layers

To obtain adequate compaction, the embankment shall be constructed in uniform layers. Successive layers of embankment shall not be placed until the layer under construction has been thoroughly compacted to satisfy the requirements laid down in **Tables 3 and 4.**

8.3.1 The embankment material shall be deposited in layers not exceeding 250 mm in compacted thickness. Provided further, when a sheep foot roller is used, the thickness of the loose layer shall not exceed the length of the tamping feet by more than 50 mm.

8.3.2 Unless otherwise directed, the soil shall be spread uniformly over the entire width of the embankment. The requirements of thickness of the layer and moisture content as laid down shall be satisfied before the rolling is started.

8.3.3 The moisture content of the soil to be excavated for use in embankment shall first be checked and the procedure to bring the moisture content within permissible limits decided.

8.3.4 If the soil has less than the required moisture content, necessary amount of water shall be added to it, either in the borrow pits before excavation is made, or after the soil has been spread loosely on the embankment. Addition of water may be made in the former case through flooding or irrigating the borrow areas, and in the latter case, through sprinkling water either directly from a hose line or from a water browser.

8.3.5 If the soil as delivered to road bed is too wet, it shall be dried by aeration and exposure to the sun, till the moisture content is acceptable for compaction. Should circumstances arise, such as wet weather, the moisture content of certain soils cannot be reduced to the appropriate amount by aeration alone; work on the compaction of these soils shall be suspended.

8.3.6 After adjusting the moisture content (making due allowance for the evaporation losses), the soil shall be processed by means of graders, barrows, rotary mixers or other suitable equipment until the layer is uniformly wet. Clods or hard lumps of earth shall be broken to have maximum size of 75 mm when being placed in the embankment, and maximum size of 50 mm when being placed in the top 500 mm of the embankment. However, if there is to be no processing of soil with the help of mechanical equipment, the clods of earth shall be broken to less than 50 mm size at the site of borrow pits itself before being carried to the site of embankment.

8.3.7 Moisture content at the time of compaction

The moisture content of each layer of soil at the time of compaction shall be between 1 percent above to 2 percent below the optimum moisture content.

8.3.8 Rolling equipment

The soil spread in layers shall be thoroughly compacted by means of suitable compacting plant to densities specified in **Tables 3 and 4**. A general guide to the selection of compaction equipment for different types of soil is provided in Table 6.

Table 6 General Guide to the Selection of Compaction Equipment for Different Types of Soil

Sl. No	Type of material	Suitability of compaction equipment for different types of soil	Remarks
1)	Rock fill (except soft material)	Vibratory roller	
2)	Broken concrete, brick (burnt and un-burnt), colliery shale, fly ash etc.	Vibratory roller, Smooth wheeled roller, Pneumatic-tyred roller	Pneumatic-tyred roller to be used for fly ash only
3)	Coarse - Grained soils	Vibratory roller, Pneumatic-tyred roller, Smooth wheeled roller	
4)	Fine - Grained soils	Sheep foot roller, Smooth wheeled roller, Pneumatic-tyred roller, Vibratory roller, Vibro rammer, Power rammer, Plate compactor	Sheep foot rollers are most suitable for clayey soil.

NOTE: For more details of compaction procedures and equipment, reference may be made to : HRB – Special Report No. 3 "State-of-the-Art : Compaction of Earthwork and Sub-grades"

8.3.9 Density of Compaction: The density of compacted soil shall be as per **Tables 3 and 4**.

8.3.10 Each compacted layer shall be tested in the field for density requirements and acceptance criteria stipulated in Clause **22** before the operations for the next layer are taken in hand.

9 SOIL EROSION AND SEDIMENTATION CONTROL

9.1 Description

This work shall consist of measures as shown on plans or as directed by the Engineer-to-charge control soil erosion, sedimentation and water pollution, through use of berms, sediment basins, fiber mats, mulches, grasses, slope drains and other devices.

9.2 Materials

All materials shall meet commercial grade standards and shall be approved by the Engineer-in-charge before being used in the work.

9.3 Construction Operations

Where erosion or sedimentation is likely to be a problem, clearing and grubbing operations should be so scheduled and performed that grading operations and permanent erosion or sedimentation control features can follow immediately thereafter if the project conditions permit; otherwise temporary erosion or sedimentation control measures as per the requirements be taken between successive construction stages. Under no circumstances shall a large surface area of erodible earth material be exposed at one time by clearing and grubbing or excavation. Temporary erosion, sedimentation and pollution control will also include construction work outside the right-of-way where such work is necessary as a result of road construction such as service roads and equipment storage sites.

9.4 Repairing of damages caused by rain/spillage of water: The soil in the affected portion shall be removed in such areas as directed by the Engineer-in-Charge before next layer is laid and refilled in layers and compacted using appropriate mechanical means such as small vibratory roller, plate compactor or power rammer to achieve the required density in accordance with **Tables 3 and 4**. If the cut is not sufficiently wide for use of required mechanical means for compaction, the same shall be widened suitably to permit their use for proper compaction. Tests shall be carried out as directed by the Engineer-in-Charge to ascertain the density requirements of the repaired area. The work of repairing the damages including widening of the cut, if any, shall be carried out by the Contractor at his own cost, including the arranging of machinery/equipment for the purpose.

10 CONSTRUCTION AND MAINTENANCE OF ROAD ON A FLOOD BANK

10.1 River embankment (Levee) is an artificial bank built along a river for the purpose of protecting adjacent land from inundation by flood. Construction of

embankment to control flood is an age old practice and is still being practiced due to its proven suitability. Road construction can be taken up on the top of such river embankments by suitably designing such structures to have adequate right of way on the top of the embankments. Basically these embankments, in addition to providing space for road construction, act as flood protection structures, so it should be ensured that phreatic line is within the embankment. For details refer IRC:89 "Guidelines for Construction of River Training & Control Works for Road Bridges".

10.2 River embankments need to be designed taking into consideration flood records for a period of 25 years in predominately agricultural areas and 50 years frequency for works pertaining to protection of towns, important industrial and other vital installations. These embankments can be designed as either homogeneous embankments (comprising of practically uniform type material with coarser material being placed at the slopes away from river side) and zoned embankments (comprising of a core of impervious material). A side slope of 1V:2H or 1V:3H can be adopted, provided adequate factor of safety is obtained when checked for slope stability analysis. The river side of the embankments should be protected against erosion by providing rip-rap/revet mattress/gabion toe wall, etc to act as energy absorbing armour. Geo-textiles conforming to IRC:SP:59 can be provided below the rip-rap/revet mattress to prevent erosion of fill materials. For more details regarding planning and design of river embankments, IS 12094 and IS 11532 can be referred to. Construction methodology and quality control of construction work for river embankments need to be carried out in a manner similar to other road embankments.

10.3 Borrow Pits on the River Side

All earth for the embankment should be borrowed, as far as possible from the river side. The inner edge of any borrow pit should not be less than 15 m from the toe of the bank, the distance depending upon the magnitude and the duration of the flood to be withstood. The borrow pits should comply also with the requirements of Clause **8.1.3**.

10.4 Borrow Pits on the Rear or Land Side

Ordinarily no borrow pits should be dug on the landside. Where this cannot be avoided, a berm at least 25 m wide should be left between the borrow pit and the toe of the bank. On sloping grounds, borrow pits should be dug on the higher side, as far as possible.

The toe of the bank on the rear side should have a cover of 0.75 m to 1.25 m over the saturation line drawn at a slope of 1V in 6H from the high flood level on the river side, **Fig. 3**. The depth of the cover will depend on the magnitude and duration of the flood to be withstood. Where necessary, rear berms may be provided to give the minimum cover over the saturation line, as shown in Fig. 3. The slope of 1V in 6H would be found suitable in most cases. In special cases, the slope of the saturation line should be determined with reference to the nature of the soil.

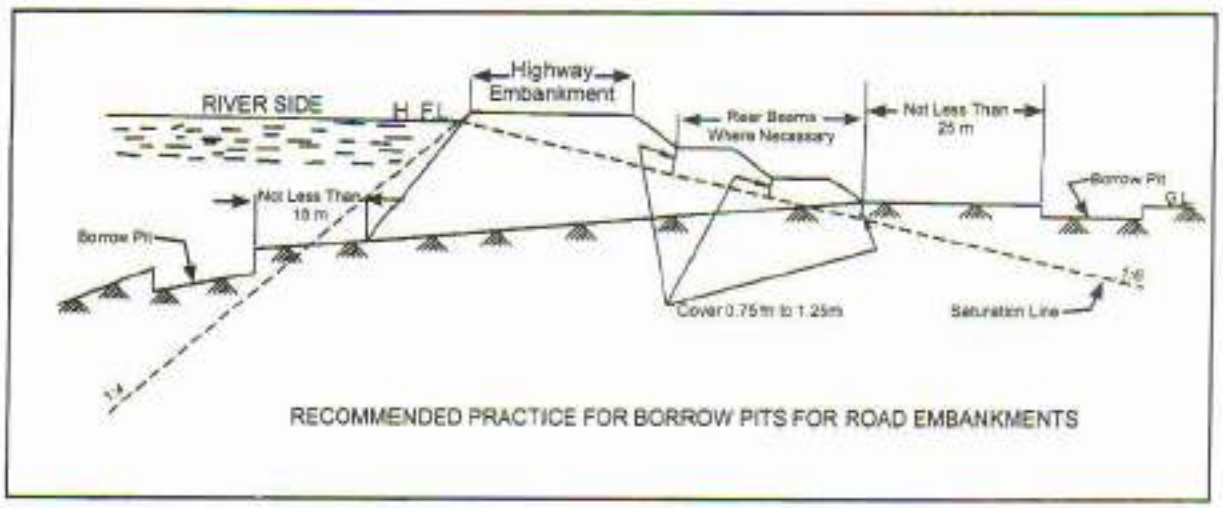

Fig. 3 Construction of Embankment as Flood Bank

11 EMBANKMENTS AROUND STRUCTURES

11.1 The filling around and over culverts and other structures in the embankment area shall be carried out independently of the work on the main embankment. The embankment shall be brought up simultaneously in equal layers on each side of the structure so as to avoid displacement and unequal pressure. Filling behind abutments and wing walls for all structures shall conform to the general guidelines given in Appendix 6 of IRC:78 "Standard Specifications and Code of Practice for Road and Bridges, Section VII Foundation and Substructure" in respect of the type of the material, the extent of backfill, its laying and compaction etc.

11.2 The soil in such cases shall be deposited in layers not exceeding 150 mm in loose thickness and compacted thoroughly to the requirements of **Tables 3 and 4** and the satisfaction of the Engineer-in-Charge. Where it may be impracticable to use power rollers or other heavy equipment, the compaction shall be carried out by mechanical tampers or by other approved methods.

12 WIDENING OF EXISTING EMBANKMENTS

12.1 When an existing embankment is to be widened, and its slopes are steeper than 1V:4H, horizontal benches of upto 0.3 m width shall be cut into the old slope for ensuring adequate bond with the fresh embankment material to be added. The material obtained from cutting of benches could be utilized in widening of the embankment. However, when the existing slope against which the fresh material is to be placed is flatter than 1V:4H, only the sloping surface may be ploughed or scarified instead of resorting to benching.

12.2 The layers of the widened embankment shall be compacted to the requirements of **Tables 3 and** 4. In cases where the width of the widened portion is insufficient to permit the use of usual wider rollers, compaction may be carried out with the help of light vibratory roller, vibratory plate compactor, vibratory tamper or other approved means. End dumping of earth from trucks for widening operations shall not be allowed except in difficult circumstances when the extra width is too narrow to permit the movement of any other type of hauling equipment.

13 EARTHWORK OVER EXISTING ROAD SURFACE

13.1 Where the embankment is to be placed over an existing road surface, the work shall be carried out as indicated below:

a) If the existing road surface is of granular type and lies within 1 m of the new sub-grade level. The existing granular base/sub-base, as the case may be, shall be scarified to a depth of 50 mm or as directed so as to provide ample bond between the old and new material ensuring that at least 500 mm portion below the top of new sub-grade level is compacted to the required density as per **Tables 3** and 4.

b) If the existing road surface is of bituminous type and lies within 1 m of the new sub-grade level, the bituminous layer shall be removed completely, so as to avoid presence of impermeable layer beneath the new thin earthen layer and also provide ample bond between the old and new material ensuring that the embankment and subgrade portions are compacted to the required density as per **Tables 3 and** 4.

c) If the existing road surface is of cement concrete type and lies within 1 m of the new sub-grade level, the same shall be removed completely.

d) If the level difference between the existing road surface and the new formation level is more than 1 m, the existing surface shall be permitted to stay in place without any modification.

14 EMBANKMENT CONSTRUCTION UNDER SUBMERGED CONDITION

14.1 Where filling or backfilling is to be placed under water, only acceptable granular material or rock shall be used unless otherwise approved by the Engineer-in-Charge. Acceptable granular material shall be of GW, SW, GP, SP as per **Table 1** and consist of graded, hard durable particles with maximum particle size not exceeding 75 mm. The material should be non-plastic having uniformity coefficient of not less than 10. The material placed in open water shall be deposited by end tipping without compaction.

14.2 Coarse sand blanket layer, in accordance with the provisions of IRC:34, shall be provided for construction of embankment in water logged and marshy areas.

15 CONSTRUCTION OF EARTHEN SHOULDERS

15.1 Where earth shoulders are specified, these shall be constructed of the same material as specified for the subgrade i.e. top 500 mm portion of the embankment and compacted to the same density requirement as set forth in **Tables 3 and 4**. Construction of shoulders should be so organized as to keep pace with the construction of different layers of the pavement.

16 FLYASH EMBANKMENT CONSTRUCTION

16.1 For the purpose of embankment construction either pond ash, bottom ash or mound ash can be used. Flyash being a very fine material is not recommended for embankment construction. However, it may be noted that the term "flyash" is commonly used as a generic term to denote any type of coal ash. For the purpose of this code, the term flyash would denote Pond Ash/Bottom Ash/Mound Ash, which are to be used for embankment construction.

For flyash embankment, IRC:SP:58 'Guidelines for Use of Flyash in Road Embankments" including amendments should be referred to. Flyash for Road embankments, wherever it is available from a nearby thermal power plant can be used with an appropriate soil cover, in accordance with the lines, grades and cross sections as approved by the Engineer-in-charge and shown on the drawings. The following information on the flyash to be used in embankment construction shall be made available for the approval of Engineer in-charge:

a) Particle size analysis of the material (wet sieve analysis)

b) Maximum Dry Density and Optimum Moisture Content as per IS 2720 (Part 8) which shall form the basis for compaction.

The soil to be used as soil cover to the flyash embankment shall satisfy all the requirement as specified in **Tables 3 and 4**.

16.2 The side soil cover, of required width shall be provided, along with the flyash core and mechanicall, compacted as the embankment progresses upwards. The addition of side cover subsequent to the construction of the flyash core shall not be permitted. The fill material shall preferably be spread by mechanical means, finished by the motor grader, so as to achieve the specified slope and grade.

16.3 The moisture content of the fill material shall be checked at the site of placement prior to the commencement of compaction. Normally, the moisture content of flyash laid for compaction shall be within +1 percent to -2 percent of the Optimum Moisture Content when determined as per IS 2720 (Part 2). Moisture content of the cover soil shall also be maintained at its Optimum Moisture Content.

16.4 Flyash shall be compacted using static, pneumatic or vibratory rollers, as directed by the Engineer-in-Charge. Regardless of the equipment, flyash must be compacted as early as possible after spreading. The compaction of flyash core and earth cover on the sides shall proceed simultaneously. Each compacted layer shall be finished parallel to the final cross-section of the embankment. The end product specifications for the construction of flyash embankments shall be as under:

Minimum dry density after compaction as percentage of maximum dry density determined as per IS 2720 (relevant part) shall be 95 percent.

Subsequent layers shall be placed only after the finished layer has been tested for its density requirements.

16.5 On the top of the flyash embankment, atleast 500 mm thick earth as subgrade shall be provided.

17 FINISHING OPERATIONS

17.1 The embankment shall be finished in conformity with the alignment, levels, cross-sections and dimensions shown on the plans. Where the alignment of the road is curved, the top of the embankment shall be formed with the super elevation and the increased widths shown on the drawings or as the Engineer-in-Charge may direct.

17.2 Finishing operations shall include the work of shaping and dressing the shoulders, roadbed and the side slopes to conform to the typical cross-section shown on the plans. Both the upper and lower ends of the side slopes shall be rounded off to improve appearance and to merge the embankment with the adjacent terrain.

17.3 Where the top soil has been removed and conserved (Clause **7.5**), it shall be spread over the fill slopes to facilitate the growth of vegetation. Slopes may be roughened and wetted slightly prior to the application of the top soil in order to achieve satisfactory bond, the usual thickness being between 75 mm to 150 mm. After the top soil has been spread, grass or small shrubs shall be planted on the slopes as instructed by the Engineer-in-charge in order to protect the slopes against erosion and for aesthetic purposes.

17.4 When the earthwork operations have been substantially completed, the roadway area shall be cleared of all the debris and ugly scars existing near the camping areas, etc. Every effort shall be made to obviate objectionable appearance.

18 DRAINAGE

18.1 The main objective of drainage is to prevent early damage of the embankment/subgrade of the pavement due to entry of excess water and preventing saturation upto a depth of 1 m below the top of the subgrade. An adequate drainage is required for maintaining the structural and functional adequacy of the embankment/ subgrade of the road. The surface of the embankment/subgrade at all times during construction shall be maintained at such a crossfall (not flatter than that required for effective drainage of an earthen surface) as will shed water and prevent ponding.

18.2 Particular attention shall be paid to drainage for roads built on sloping ground, by the provision of side drains designed to carry the maximum flow ever likely to be required of them. Drainage of high embankments also merits close attention and appropriate measures shall be taken as recommended by the designer. When a high embankment is made up of sandy soil, one of the possible measures against erosion is to have a blanket cover of cohesive soil over the sandy core.

18.3 The drainage works may be broadly classified as under:

a) Drainage of surface water.

b) Drainage of sub-surface water.

For guidance following codes shall be referred to:

i) IRC:SP:42 "Guidelines on Road Drainage".

ii) IRC:SP:50 "Guidelines on Urban Drainage".

19 ALLOWANCE FOR SETTLEMENT

19.1 To allow for subsequent settlement for embankment compacted as described herein, the finished level of the road should be set higher than the specified level by

1 to 2 percent of the height of the bank. This rule should, however, not be applied for high approaches to structures where stricter control during compaction will usually ensure the settlement of the bank to be minimal. Any allowance for the settlement of foundations due to the compression of sub-soil strata should be over and above the provision referred to here.

19.2 In case of high embankments, water logged areas or near structures, magnetic settlement gauge, piezometer, inclinometer etc may be used as detailed in IRC:75 "Guidelines for the Design of High Embankments".

20 COMPACTION CONTROL

20.1 Preliminary investigations are made to determine the most economical procedure to be adopted to obtain the specified degree of compaction and the necessary field controls. As a result of the suggested investigations, it is generally found that it is sufficient to ensure that the soil is laid in layers of the specified thickness, with the specified moisture, and is rolled with the number of passes of the compaction equipment which are found to produce the specified degree of compaction.

20.2 A test area about 20 m long and 5 m wide is prepared after removing the top soil. The fill material to be used is spread over this area, the depth of the loose material being 250 mm, the moisture content of the soil should be from 1 percent above to 2 percent below the optimum moisture content for the soil.

20.3 The test layer is then compacted with the compaction plant, which has been decided to be used and the mean dry density to the full depth determined after 4, 6 and 8 passes of a smooth wheel roller/vibratory roller/vibratory tandem roller/ pneumatic tyre roller or a suitable number of passes if other compaction equipment is used. In case of sheep foot roller, these measurements may be made after 4, 8 and 16 passes. The dry density should be determined by the sand replacement method and the mean of five determinations should be obtained for each soil condition. Thus, the number of passes of the compaction equipment required to obtain the specified dry density is determined.

20.4 Normally, control on compaction in the field shall be exercised through frequent moisture content and density determinations. A systematic record of these determinations shall be maintained. The control of compaction through checks on compacting effort alone (i.e. by the number of passes of compacting equipment) shall not be accepted as a substitute for the control of compaction by moisture content and density determinations.

20.5 Moisture content determination is necessary to control the moisture at which soil is compacted so as to attain maximum compaction of the soil and for the purpose of finding out the above parameters, the procedure as laid down in IS 2720 (Part 2) shall be employed.

20.6 The density of the compacted soil shall be measured in the field by sand-replacement method and or Nuclear Densometer, as specified in IS 2720 (Part 8 and Part 7). If during checking of compaction of a particular stretch, requisite density as specified in Tables 3 and 4 and Clause **22.1**, if not achieved, the entire stretch will be loosened upto the full layer depth by suitable means preferably by motor grader, brought to optimum moisture content and re-compacted to achieve the requisite density.

21 QUALITY CONTROL

21.1 Quality of compacted material shall be controlled through exercise of checks on the borrow material, the compaction process, or the end-product, singly or in combination as directed. However, in every case, the end-product must conform to the construction specifications.

21.2 Various tests required to be conducted on the borrow material, with their recommended frequency, are indicated below. All the tests need not be stipulated on every project. Depending upon site conditions etc, only some may be found necessary for a particular project. The frequency of testing indicated refers generally to the minimum number of tests to be conducted. The rate of testing must be stepped up as found necessary, depending upon the variability of the materials and compaction methods employed on a project. Tests are to be conducted as per provisions contained in IS 2720.

a) Gradation
At least one test for each kind of soil. Usual rate of testing 2 tests per 3,000 cu.m of soil.

b) Plasticity index and liquid limit
At least one test for each kind of soil. Usual rate of testing 2 tests per 3,000 cu.m of soil.

c) Proctor Density Test
At least one test for each kind of soil. At the rate of 2 tests per 3,000 cu.m of soil.

d) Deleterious Contents
As and when required by the Engineer-in-charge.

e) Moisture Content
One test for every 250 cu.m of soil.

f) CBR

At least one test for each kind of soil. At least one test per 3000 cu.m of soil.

g) Free Swelling Index

At least one test for each kind of soil. At least one test per 3000 cu.m of soil.

22 ANALYSIS AND ACCEPTANCE OF DENSITY RESULTS

22.1 Except when otherwise directed, at least one measurement of density shall be made for each 1000 sq.m of compacted area for embankment and 500 sq.m for subgrade. Test locations shall be chosen only through predetermined random sampling techniques. Control shall not be based on the result of any one test but on the mean value of 5-10 density determinations. The number of tests in one set of measurements shall be 5 as long as it is felt that sufficient control over borrow material and the method of compaction are being exercised. But if there is any doubt about this control, or considerable variations are observed between individual density results, the minimum number of tests in one set of measurements shall forthwith be increased to 10. The acceptance criteria shall be subject to the condition that the mean density is not less than the specified density plus

$$\left[1.65 - \frac{1.65}{(\text{No. of samples})^{0.5}}\right] \text{ times the standard deviation}$$

22.2 In general, the control of density at top subgrade layers of the formation shall be more strict, with density measurements being done, than stated above, at the rate of 1 test per 500 sq.m of compacted area. Further, for the determination of mean density and standard deviation, the number of tests in one set of measurements shall not be less than 10. In other respects, the control will be similar to as spelt out in the Clause **22.1**.

22.3 If for any reason, it has not been found possible to conduct the minimum number of tests mentioned above, the test values obtained from fewer tests shall be used only as an aid to judgment and not as a proof of the quality of work.

22.4 The value of the standard deviation shall be calculated from the formula:

$$\sigma = \sqrt{\frac{\sum_{i=1}^{n}(x_i - \bar{x})^2}{n-1}}$$

where

σ = standard deviation in g/cc.

n = total number of density measurements; and

x_i = value of dry density in g/cc.

x = mean density

23 SOFT AREAS

23.1 When density measurements reveal any soft areas in the embankment, the Engineer-in-Charge shall direct that these be compacted further. If in spite of that, the specified compaction is not achieved, the material in the soft areas shall be removed and replaced by approved material, compacted to the satisfaction of the Engineer-in-Charge.

(The Official amendments to this document would be published by the IRC in its periodical, 'Indian Highways' which shall be considered as effective and as part of the code/guidelines/manual, etc. from the date specified therein)