RECOMMENDED PRACTICE
FOR
THE CONSTRUCTION
OF
EARTH EMBANKMENTS
FOR
ROAD WORKS

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RECOMMENDED PRACTICE FOR THE CONSTRUCTION OF EARTH EMBANKMENTS FOR ROAD WORKS

1. INTRODUCTION

1.1. Successful performance of an embankment depends as much on adopting standards of good compaction in construction as on careful preinvestigations leading to the selection of appropriate borrow soil and design features of the bank. Therefore, all the aspects deserve equal attention if the objective is to improve performance and economise on overall costs. In a well-compact ed embankment, subsequent settlements of the fill are negligible, so that the permanent road structure can be placed close at heels of the completion of the earthworks. Subgrades which are well-consolidated possess high strength and resistance to deformation, due to their increased stability a substantial reduction in the overall thickness of the pavement is usually feasible.

1.2. Realising the advantages to be had by going in for improved practices in embankment construction, the Specifications and Standards Committee took on the task of preparing a recommended practice for earthworks in embankments. The ‘Recommended Practice’ finalised by the Specifications and Standards Committee in their meeting held on the 26th & 27th February, 1970 was approved by the Executive Committee and then by the Council at its meeting held at Darjeeling on the 6th & 7th April, 1970 and is now recommended for general adoption in the country.

2. SCOPE

2.1. The Recommended Practice shall apply to the construction of embankments and of miscellaneous backfills with materials obtained either from excavation for road construction, borrowpits, or other selected borrow areas. All embankments shall be constructed in accordance with these clauses and in conformity with the alignment, levels, cross-sections, and dimensions shown on the plans or staked out by the Engineer-in-Charge.

Materials

2.2. The scope of the Recommended Practice is restricted to soil alone being the construction material. For this purpose,
soil will be taken to include gravel and nodular material. The soil used for embankments shall be free from stumps, trees, roots, rubbish, or any other material likely to deteriorate or affect the stability of the embankment. Only material considered suitable by the Engineer-in-Charge shall be employed for the construction and that considered unsuitable shall be disposed of as directed by him.

2.3. The selection of the material to be used in the construction of embankments shall be made after soil surveys and laboratory investigations.

3. SOIL SURVEYS AND LABORATORY INVESTIGATIONS

3.1. The purposes of the soil survey are

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

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

(iii) To provide data to be combined with construction records as a basis for future study of subgrades, road bases and surfaces.

Preliminary Investigations

3.2. After the road alignment and profile have been finalised preliminary investigations shall be carried out to procure the following data:

(i) The suitability for embankment work of material obtainable from excavation for road constructions, or from borrowpits on road land.

(ii) The location of borrow areas, where the embankment cannot be fully made from materials mentioned in (i) above. The investigator shall consider the factors of transport, accessibility to earth moving equipment, initial cost, etc. while making his observations.

(iii) 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.
(iv) 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 any earlier embankments in that area, together with the causes of failure, shall also be gathered from previous records.

(v) Any particular construction problem of the area or any other information likely to be useful.

**Detailed Investigations**

3.3. 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 as given in the following paragraphs.

3.4. Test pits shall be dug in borrow areas from where the embankment material is to be obtained. In the case of borrowpits on or along road land, the test pits shall be dug at intervals of 200 metres. This interval shall be varied as may be required by the Engineer-in-Charge depending on the uniformity or variability of the nature of the soil along the alignment. When embankment material is obtained from selected borrow areas, an 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 borrowpits by more than 15 cm.

3.5. The general character of the material excavated out of the test pits shall be recorded. Representative samples of the soil, typical of the material to be used in the embankment, shall be collected from the test pits for further detailed study in the laboratory. [For sampling procedure, refer to IS: 2720 (relevant part)].

3.6. Along the alignment of the road where unstable strata or soft material may have been met with at the foundation level, and particularly where the height of the fill will be considerable, the soil profile shall be drawn after determining through borings the type of soil at different levels. The borings may be at intervals of 100 to 200 m, the depth being normally 1.25 to 1.5 m below existing ground level. In the case of high embankments and problematic substrata, the borings should taken down to a depth equal to twice the height of the embankment. 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.
3.7. 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 poses particular difficulty on account of the terrain being rigorous, this information might be ascertained through local enquiries [vide para 3.2 (iii)].

3.8. Samples of soil intended to be used in embankment work shall be tested in the laboratory as a routine for the following properties:

(i) Sieve analysis or particle size distribution.
(ii) Liquid limit.
(iii) Plastic limit.
(iv) Moisture content-dry density relationship using light compaction, i.e. determination of the standard Proctor density and corresponding optimum moisture content.
(v) Deleterious constituents.

However, in cases of high fills or embankments laid on soft foundations the substrata and fill soil may have also be subjected to quality tests like shear and consolidation if considered necessary and directed so by the designer.

3.9. The routine tests mentioned above shall be carried out in accordance with the procedure laid down in IS: 2720 (relevant parts) “Methods of Test for Soils”, except that the mechanical analysis test shall be performed only with three sieve sizes viz. I.S. sieve Nos. 2 mm, 425 microns and 75 microns (which correspond to B.S. sieve Nos. 8, 36 and 200 and A.S.T.M. sieve Nos. 10, 40 and 200); provided further that to determine the amount of material finer than 75 microns (which corresponds to B.S. sieve No. 200), ‘wet’ sieving as described in IS:2720 (Part IV)—1965 shall be resorted to.

3.10. After carrying out the laboratory tests, each soil sample shall be classified according to the P.R.A. classification (see Table 1), or the Indian Standard system of soil classification (vide IS: 1498—1959) if so desired.

3.11. The results of laboratory investigations shall be presented in a concise form. The sample proforma given in Table 2 may be used for this purpose where classification is to be done according to

*Only in salt-infested areas or where presence of salts is suspected.
### Table 1
Revised U. S. Public Roads Administration (P. R. A.) System (1945) Classification into Groups.

<table>
<thead>
<tr>
<th>General Classification</th>
<th>Granular Materials (35 per cent or less passing No. 200 B. S. Sieve)</th>
<th>Silt clay materials (more than 35 per cent passing No. 200 B. S. Sieve)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group Classification</td>
<td>A-1</td>
<td>A-3*</td>
</tr>
<tr>
<td>Sieve analysis, percentage passing No. 10 A.S.T.M. (or No. 8 B.S. or 2.00 mm I.S.)</td>
<td>50 max.</td>
<td>51 min.</td>
</tr>
<tr>
<td>No. 40 -do- (or No. 36 B.S. or 425 microns I.S.)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>No. 200 -do- (or No. 200 B.S. or 75 microns I.S.)</td>
<td>25 max.</td>
<td>10 max.</td>
</tr>
<tr>
<td>Characteristics of fraction passing No. 40 sieve Liquid limit (per cent)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Plasticity index (per cent)</td>
<td>6 max.</td>
<td>N. P.</td>
</tr>
<tr>
<td>Group index</td>
<td>4 max.</td>
<td>8 max.</td>
</tr>
<tr>
<td>Usual types of significant constituent materials</td>
<td>Stone fragments, gravel and sand</td>
<td>Fine sand</td>
</tr>
<tr>
<td>General rating as a subgrade</td>
<td>Excellent to good</td>
<td></td>
</tr>
</tbody>
</table>

**Classification Procedure:** With required test data available, proceed from left to right on above chart and correct group will be found by process of elimination. The first group from the left into which the test data will fit is the correct classification. (Note: All limiting test values are shown as whole numbers. If fractional numbers appear on test reports, convert to nearest whole number for purposes of classification).

*The placing of A-3 before A-2 is necessary in the left-to-right elimination process and does not indicate superiority of A-3 over A-2.*
| **Reference**  
(Data concerning location of sample etc.) |  |  |  |
| --- | --- | --- | --- |
| **Test information**  
(Origin of soil sample etc.) |  |  |  |
| No. of Samples tested |  |  |  |
| Particle size distribution |  |  |  |
| Passing No. 10 A.S.T.M. Sieve (≈ No. 8 B.S. Sieve or 2.00 mm I.S. Sieve) |  |  |  |
| Passing No. 40 A.S.T.M. Sieve (≈ No. 36 B.S. Sieve or 425 micron I.S. Sieve) |  |  |  |
| Passing No. 200 A.S.T.M. Sieve (≈ No. 200 B.S. Sieve or 75 micron I.S. Sieve) |  |  |  |
| Liquid Limit |  |  |  |
| Plastic Limit |  |  |  |
| Plasticity Index |  |  |  |
| Maximum Dry Density (Proctor's test) |  |  |  |
| Optimum Moisture Content |  |  |  |
| Group Index |  |  |  |
| Soil Classification (P.R.A.) |  |  |  |
| General Remarks  
(i.e. suitability of embankment material, safe side slopes etc.) |  |  |  |
P.R.A. system. Where it is to be done according to Indian Standard system, reference may be made to IS:1498-1959.

3.12. In addition to the tests prescribed in para 3.8, samples of soil to be used in the top 50 cm of the embankment shall be tested in the laboratory for the determination of C.B.R. value at 100 per cent standard Proctor density and optimum moisture content, after soaking the samples in water for four days where applicable. The results of these tests shall be used for the design of the pavement*.

3.13. A general guide to the selection of soils classified on the P.R.A. system on the basis of anticipated embankment performance is given in Table 3. Comparable soil groups in the Indian Standard

<table>
<thead>
<tr>
<th>P.R.A. Classification</th>
<th>Comparable soil groups in Indian Standard Soil Classification System</th>
<th>Visual description</th>
<th>Max. dry density range gm per c.c.</th>
<th>Optimum moisture content range percent</th>
<th>Anticipated embankment performance</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Most probable Possible</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
</tr>
<tr>
<td>2</td>
<td>3</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A-1</td>
<td>GW, GP, GB, GM, SW, SP, SB, SM</td>
<td>—</td>
<td>Granular materials</td>
<td>1.84-2.28 (115-142)</td>
<td>7-15</td>
</tr>
<tr>
<td>A-2</td>
<td>GM, GC, SM, SC</td>
<td>—</td>
<td>Granular materials with soil</td>
<td>1.76-2.16 (110-135)</td>
<td>9-18</td>
</tr>
<tr>
<td>A-3</td>
<td>SP</td>
<td>—</td>
<td>Sand</td>
<td>1.76-1.84 (110-115)</td>
<td>9-15</td>
</tr>
<tr>
<td>A-4</td>
<td>ML, MH, OL, OH</td>
<td>CL, SM, SB, SC</td>
<td>Sandy silts and silts</td>
<td>1.52-2.08 (95-130)</td>
<td>10-20</td>
</tr>
<tr>
<td>A-5</td>
<td>MH, OH</td>
<td>—</td>
<td>Elastic silts and silts</td>
<td>1.36-1.60 (85-100)</td>
<td>20-35</td>
</tr>
<tr>
<td>A-6</td>
<td>CL, CI</td>
<td>MH, OH, SC</td>
<td>Silt clay</td>
<td>1.52-1.92 (95-120)</td>
<td>10-30</td>
</tr>
<tr>
<td>A-7</td>
<td>MH, CI, CH, OH</td>
<td>SC</td>
<td>Clay</td>
<td>1.36-1.84 (85-115)</td>
<td>15-35</td>
</tr>
</tbody>
</table>

*For guidance in this respect see Standard No. IRC: 37—1970 “Guidelines for the Design of Flexible Pavements”.
soil classification system (IS:1498—1959) corresponding to the P.R.A. soil classification groups, are also indicated in this Table for guidance.

4. STRUCTURAL FEATURES OF THE EMBANKMENT

4.1. The structural features and other details regarding the construction work shall be decided upon 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 super-imposed load of the embankment, it shall be necessary to specially design it and adopt remedial measures. Cases of high embankments in all soils when the height is over 8 m or when the fill material consists of a heavy clay or another problematic soil in embankments more than 3 m high and subject to inundation, or when the embankment is liable to rapid drawdown conditions, shall also be dealt with in the same way and the embankment designed on a rational basis according to principles of soil mechanics.

Side Slopes

4.2. Where possible, the embankment shall be built to side slopes as illustrated in Fig. 1. These slopes are recommended mainly from the consideration of safety of traffic. However, where costs of construction forbid going in for such liberal slopes, the slope angle may be selected depending upon the type of the soil. Ordinarily the safe slope will range from \( 1\frac{1}{4}:1 \) to 2:1 in uninundated conditions and from 2:1 to 3:1 in inundated conditions.

5. SETTING OUT OF CONSTRUCTION LIMITS

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

Centre-line and Reference Pegs

5.2. On long tangent sections, points on transit shall be fixed at least every 500 metres in plain terrain and 250 metres 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 of the road on either side at a distance of 20 to 25 metres from 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

![Diagram of side slopes for road embankments]

**Fig. 1** Side slopes for road embankments

**Notes:**

1. Both the upper and lower ends of the side slopes should be rounded off to improve appearance.

2. The side slopes recommended above are mainly from the point of view of traffic safety. However, where economically not feasible, slopes as mentioned in para 4.2 may be adopted.

3. Embankments needing careful attention (as identified in para 4.1) should be designed on a rational basis according to principles of soil mechanics.
irons embedded in concrete or permanent bench mark pillars of design approved by the Engineer-in-Charge.

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

Intermediate Pegs

5.4. Intermediate pegs shall be fixed along the centre-line of the road once the points of transit have been established. The interval between intermediate pegs may be 50 metres on straight sections and 20 metres on curves and transition spirals, in case of roads situated in the plain or rolling terrain. In hilly terrain, the interval between intermediate pegs should be reduced to 20 metres on straight sections and 10 metres on curves. These pegs may consist simply of stakes driven in the ground.

Batter Pegs

5.5. After intermediate pegs have been established, batter pegs marking the limits of the embankment shall be fixed on the both sides. Batter pegs are meant as guides for the plant when commencing the earthworks. To ensure their safety, it will be desirable to fix the pegs about 0.5 metre back from the actual limit of the fill and to paint them in a distinctive colour.

5.6. Sketches explaining the setting out of control pegs for embankment construction are given in Fig. 2.

6. CONSTRUCTION—PRELIMINARY OPERATIONS

Clearing and Grubbing

6.1. Prior to the commencement of earthworks 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 stakes (see Fig. 2). Except where it may be desirable to retain the vegetation for 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:

(i) To provide adequate sight distance for safe travel;

(ii) To improve the landscape and afford opportunity to view scenic attractions;
Fig. 2. Sketches explaining the setting out of control pegs for embankment construction operations

(iii) To remove decayed or dead trees which might otherwise fall on the highway;
(iv) To remove obstructions to drainage;
(v) To permit access to and use of borrowpits and other sources of materials.

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

6.2. All stumps must be cut down to below ground level. This applies especially to the areas, to be cleared beyond the embankment or earthwork limits so that appearance may not be unsightly.

6.3. Materials possessing any salvage value among the removed brush 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 as directed and preferably burnt in locations away from the road side.

6.4. 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 construction.

Stripping and Storing of Top Soil

6.5 In localities where most of the embankment materials are not conducive to plant growth, or when so directed by the Engineer, the top soil suitable for plant growth existing over the embankment foundation areas or borrowpits shall be stripped and stored for covering embankment slopes, cut slopes or other disturbed areas where revegetation is desired.

Compacting Original Ground

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

6.7. Normally the height of the road embankment shall not be less than 0.6 metre. Where, however, this is not feasible and the original ground has a relative compaction of less than 90 per cent of standard Proctor density, the original ground should be brought to a relative compaction of at least 100 per cent Proctor density by loosening, watering and rolling in layers of 25 cm loose thickness up to a depth of at least 50 cm below the top of the subgrade and for a width equal to the proposed width of pavement plus 1 m on each side thereof. If the next 15 cm depth of the original ground below this excavation does not have a relative compaction of at least 90 per cent, it shall be compacted until not less than 95 per cent Proctor density is obtained.

6.8. Where so directed by the Engineer-in-Charge any unsuitable materials occurring in the embankment foundations shall be removed and replaced by approved materials.

6.9. 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 material will bond with the existing surface.
6.10. Embankment work shall not proceed until the foundations have been inspected by the Engineer-in-Charge for satisfactory condition and approved.

7. CONSTRUCTION—PLACING OF EMBANKMENT

Materials

7.1. Only approved materials shall be utilised in the embankment. Where earth is borrowed from land close to the embankment, principles regarding the location, depth and drainage of borrowpits as enunciated in the I.R.C. "Recommended Practice for Borrowpits for Road Embankments constructed by Manual Operation" shall be kept in view so that the bad effects of borrowpits are kept down to the minimum. 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.

7.2. Soils having laboratory maximum dry density of less than 1.44 gm per c.c. are ordinarily considered unsuitable and shall be avoided for use in embankments.

Soils having laboratory maximum dry density of less than 1.52 gm per c.c. are ordinarily considered unsuitable for use in embankments exceeding 3 m in height or in embankments of any height subject to long periods of inundation.

The top 0.5 m of the embankment (or subgrade) should preferably be made up of materials having a laboratory maximum dry density of at least 1.65 gm per c.c.

However, cases where there is very little choice and soil available within an economical lead has maximum dry density less than 1.44/1.52 gm per c.c. (with reference to recommendations above), or where foundation conditions are such that use of light weight material, e.g., ash or cinder in fill is necessary from stability considerations, should be treated as special cases needing individual attention and design.

7.3. Highly expansive clays, exhibiting marked swell and shrinkage properties, shall be deposited at the bottom of the embankment and no such material shall be placed nor permitted to remain in the top 50 cm portion of the embankment below the subgrade.

Capillary Cutoff

7.4. 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 cutoff, 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 cutoff, when provided, shall extend across the full width of the embankment. Further guidance about the suitable types of capillary cutoffs, and their provision, may be had from the I.R.C. Standard “Recommendations for Road Construction in Waterlogged Areas” separately published.

Placing Soil in Layers

7.5. 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 hereafter.

7.6. The embankment material shall be deposited in layers not exceeding 25 cm in loose thickness. Provided further, that when a sheepfoot roller is used, the thickness of the loose layer shall not exceed the length of the tamping feet by more than 5 cm.

7.7. 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 in paras 7.6 and 7.12 shall be satisfied before the rolling is started.

7.8. 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.

7.9. If the soil has less than the required moisture content, necessary amount of water shall be added to it, either in the borrowpits 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 the water either directly from a hose line or from a truck-mounted water tank.

7.10. If the soil as delivered to roadbed 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 where owing to 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.

7.11. After adjusting the moisture content (making due allowance for the evaporation losses), the soil shall be processed by
means of graders, harrows, 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 15 cm when being placed in the embankment, and a maximum size of 6 cm when being placed in the top 50 cm 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 5 cm size at the site of borrowpits itself before being carried to the site of embankment.

Moisture Content at the time of Compaction

7.12. The moisture content of each layer of soil at the time of compaction should be from 1 per cent above to 2 per cent below the optimum moisture content (also see para 7.16).

Rolling Equipment

7.13. The soil spread in layers shall be thoroughly compacted by means of suitable compacting plant to densities specified in para 7.14. A general guide to the selection of compaction plant for different types of soil is provided in Table 4.

Density of Compaction

7.14. Densities to be aimed at in compaction shall be chosen with due regard to factors such as the soil type, height of embankment, drainage conditions, position of the individual layers and type of plant available for compaction. Tables 5 and 6 shall be used as guides in this connection. However in soils such as silts where a higher state of compaction is physically difficult to attain in the field, or at sites where a very sophisticated control is neither feasible nor considered necessary, the simple rule of achieving 100 per cent of standard Proctor density in the subgrade portion i.e. top 50 cm of the embankment and 95 per cent of standard Proctor density in the lower layers, may be followed as an alternative (also see para 7.16).

7.15. Each compacted layer shall be tested in the field for density (see para 14.4) and accepted before the operations for next layer are begun.

Compaction of Expansive Soils

7.16. Highly expansive clays (such as black cotton soil) possessing a marked tendency for volume change should be compacted at a moisture content of 3 to 4 per cent above the optimum to a density not exceeding 90 per cent of the laboratory standard Proctor dry density.
<table>
<thead>
<tr>
<th>Type of compaction plant</th>
<th>Cohesive soil</th>
<th>Well-graded granular and dry cohesive soils</th>
<th>Uniformly-graded materials</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>1. Smooth-wheeled roller</td>
<td>Suitable</td>
<td>Suitable</td>
<td>Suitable only if the roller is towed by tractors and the load per cm width of the roller is less than 55 kg</td>
<td></td>
</tr>
<tr>
<td>2. Pneumatic-tyred roller</td>
<td>Suitable</td>
<td>Suitable when load on each wheel is more than 2 tonnes (tons)</td>
<td>Suitable only if the roller is towed by tractors and the load on each wheel is less than 1 1/2 tonnes (tons)</td>
<td></td>
</tr>
<tr>
<td>3. Vibratory roller</td>
<td>Suitable only when the static load per cm width of the vibratory roller is more than 7 kg</td>
<td>Suitable</td>
<td>Suitable; but when the static load per cm width of the vibratory roller is more than 12 kg, the roller should be towed by tractors.</td>
<td></td>
</tr>
<tr>
<td>4. Sheepsfoot roller</td>
<td>Suitable</td>
<td>Unsuitable</td>
<td>Unsuitable</td>
<td></td>
</tr>
<tr>
<td>Power rammer*</td>
<td>Suitable</td>
<td>Suitable</td>
<td>Unsuitable</td>
<td></td>
</tr>
<tr>
<td>--------------</td>
<td>----------</td>
<td>----------</td>
<td>------------</td>
<td></td>
</tr>
</tbody>
</table>

*Normally used only when space is restricted such as behind abutments.

Note:—For the purpose of this table, soils are grouped as follows:

(i) 'Cohesive soil' includes clays with up to 20 per cent of gravel and having a moisture content not less than the value of the plastic limit minus 4;

(ii) 'Well-graded granular and dry cohesive soils' include clays containing more than 20 per cent of gravel and/or having a moisture content less than the value of the plastic limit minus 4; well graded sands and gravels with a uniformity coefficient exceeding 10 and all shales and clinker-ash.

(iii) 'Uniformly-graded material includes sands and gravels with a uniformity coefficient of 10 or less and all silts and pulverised fuel ashes. Any soil containing 80 per cent or more of material in the particle size range 0.06-0.002 mm will be regarded as silt for this purpose.
### Table 5

**Specification Requirements for Embankment Soil Compaction**

<table>
<thead>
<tr>
<th>Condition I</th>
<th>Condition II</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fills 3 m or less in height and not subject to extensive floods</td>
<td>Fills exceeding 3 m in height or fills of any height subject to long periods of flooding</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Laboratory max. dry density, gm per c.c.</th>
<th>Min. field compaction requirements, per cent laboratory max. dry density</th>
<th>Max. laboratory dry density gm per c.c.</th>
<th>Min. field compaction requirements per cent laboratory max. dry density</th>
</tr>
</thead>
<tbody>
<tr>
<td>Less than 1.44 (90.0)</td>
<td>Φ</td>
<td>Less than 1.52 (95.0)</td>
<td>(cf)</td>
</tr>
<tr>
<td>1.44 to 1.64 (90.0—102.9)</td>
<td>100</td>
<td>1.52 to 1.64 (95.0—102.9)</td>
<td>102*</td>
</tr>
<tr>
<td>1.65 to 1.75 (103.0—109.9)</td>
<td>98</td>
<td>1.65 to 1.75 (103.0—109.9)</td>
<td>100</td>
</tr>
<tr>
<td>1.76 to 1.91 (110.0—119.9)</td>
<td>96</td>
<td>1.76 to 1.91 (110.0—119.9)</td>
<td>98</td>
</tr>
<tr>
<td>1.92 (120.0) and more</td>
<td>95</td>
<td>1.92 (120.0) and more</td>
<td>96</td>
</tr>
</tbody>
</table>

Φ Soils having maximum dry densities of less than 1.44 gm per c.c. are ordinarily considered unsuitable and shall not be used in embankments as far as possible.

(cf) Soils having maximum dry densities of less than 1.52 gm per c.c. are ordinarily considered unsuitable and shall not be used in embankments under condition 2 requirements.

*If not attainable in any soil, then at least 100 per cent.

### Table 6

**Specification Requirements for Minimum Subgrade Soil Compaction**

<table>
<thead>
<tr>
<th>Laboratory Max. Dry Density, gm per c.c.</th>
<th>Min. Subgrade Compaction Requirements, (per cent of Laboratory Max. Dry Density)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Less than 1.65 (103.0*)</td>
<td>102**</td>
</tr>
<tr>
<td>1.65 to 1.74 (103—109.0)</td>
<td>102**</td>
</tr>
<tr>
<td>1.76 to 1.90 (110—119.0)</td>
<td>100</td>
</tr>
<tr>
<td>1.92 (120.0) and more</td>
<td>98</td>
</tr>
</tbody>
</table>

*Soils with a maximum dry density of less than 1.65 gm per c.c. are considered unsuitable for use in the top 50 cm soil layer immediately below the surface of the subgrade and shall be replaced with suitable soil or granular material.

**If not attainable in any soil, then at least 100 per cent.
Drainage

7.17. At all times during construction, the top of the embankment shall be maintained at such a crossfall as will shed water and prevent ponding.

8. EMBANKMENTS AROUND STRUCTURES

8.1. 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.

8.2. The soil in such cases shall be deposited in layers not exceeding 15 cm in loose thickness and compacted thoroughly to the requirements of para 7.14 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.

9. WIDENING OF EXISTING EMBANKMENTS

9.1. When an existing embankment is to be widened, and its slopes are steeper than 4:1, horizontal benches of up to 0.6 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 utilised in the widening of the embankment. However, when the existing slope against which the fresh material is to be placed is flatter than 4:1, the slope surface may only be ploughed or scarified instead of resorting to benching.

9.2. The layers of the widened embankment shall be compacted to requirements of paras 7.12 and 7.14. In such 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 tandem/sheeps-foot rollers or other approved plant. End dumping of earth from trucks for widening operations should be avoided except in difficult circumstances when the extra width is too narrow to permit the movement of any other type of hauling equipment.

10. CONSTRUCTION OF EARTH SHOULDERS

Where earth shoulders are specified, these shall be constructed of the same material as specified for the subgrade i.e. top 50 cm
portion of the embankment and compacted to the same density requirements as set forth in para 7.14. Shoulder construction should be so organised as to keep pace with the construction of different layers of the pavement.

II. FINISHING OPERATIONS

11.1. 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 superelevations and the increased widths shown on the drawings or as the Engineer-in-Charge may direct.

11.2. 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 appearances and to merge the embankment with the adjacent terrain.

11.3. Where the top soil has been removed and conserved (para 6.5), 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 affect satisfactory bond. The depth of the top soil shall be sufficient to sustain plant growth, the usual thickness being from 7.5 to 15 cm.

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.

11.4. 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 reasonable effort shall be made to obviate objectionable appearance.

12. DRAINAGE

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.
13. ALLOWANCE FOR SETTLEMENT

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 per cent of the height of the bank. This rule should, however, not be applied at high approaches to structures where stricter control during compaction (vide para 8) 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.

14. COMPACTION CONTROL—PRELIMINARY INVESTIGATIONS

14.1. 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.

Procedure of the Preliminary Investigations

14.2. A test area of 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 25 cm. The moisture content of the soil should be from 1 per cent above to 2 per cent below the optimum moisture content for the soil.

14.3. 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 or a suitable number of passes if other compaction equipment is used. In case of sheepfoot 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.

Compaction Control—Moisture Content and Density Determinations

14.4. Normally, control on compaction in the field shall be exercised through frequent moisture content and density determina-
tions. A systematic record of these determinations shall be main-
tained. The control of compaction through checks on compactive
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.

14.5. Moisture content determination is necessary to control
the moisture at which soil is compacted (para 7.12) and to find out
the dry density of the compacted soil (para 7.14). For this purpose,
the procedure as laid down in IS: 2720 (relevant part) shall be
employed, except that the soil may also be dried through:

(i) application of heat from a portable stove in an open pan;

or

(ii) dispersal in a volatile liquid, such as alcohol or spirit,
and burning the fluid to evaporate the moisture (three
applications will normally be necessary).

14.6. The density of the compacted soil shall be measured in
the field by sand-replacement method, as specified in IS: 2720
(relevant part) except for the deviation that the moisture content
may alternatively be determined as described in para 14.5 above.

15. QUALITY CONTROL OF WORK

15.1. 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.

Control Tests on Borrow Material

15.2. 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 at a
particular project. The frequency of testing indicated refers
generally to the minimum number of test to be conducted. The
rate of testing must be stepped up as found necessary, depending
upon the variability of the materials and compaction methods em-
ployed at a project.

(a) Gradation

At least one test for each kind of soil. Usual rate of testing
1-2 tests per 8,000 m³ of soil.
(b) **Plasticity**

At least one test for each kind of soil. Usual rate of testing 1-2 tests per 8,000 m$^3$ of soil.

(c) **Proctor Test**

At the rate of 1-2 per every 8,000 m$^3$ of soil.

(d) **Deleterious Contents**

As required.

(e) **Moisture Content**

One test for every 250 m$^3$ of soil.

**Analysis and Acceptance of Density Results**

15.3. Except when otherwise directed, at least one measurement of density shall be made for each 1000 m$^3$ of compacted area. 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 was felt that sufficient control over borrow material and the method of compaction was being exercised. But if there was any doubt about this control, or considerable variations were observed between individual density results, the minimum number of tests in one set of measurement shall forthwith be increased to 10. The acceptance of results shall be subject to the condition that the mean dry density equals or exceeds the specified density and the standard deviation for any set of results is below 0.08 gm per cc.

15.4. In general the control 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 500-1000 m$^3$ 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 spelled out in the previous para.

15.5. 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 judgement and not as a proof of the quality of work.
15.6. The value of the 'standard deviation' shall be calculated from the formula:

\[ \sigma = \frac{1}{n} \sqrt{\frac{1}{n} \sum X^2 - (\sum X)^2} \]

where

\( \sigma \) = standard deviation in gm/cc.

\( n \) = total number of density measurements; and

\( X \) = value of dry density in gm per cc.

16. REMOVAL OF SOFT AREAS

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.