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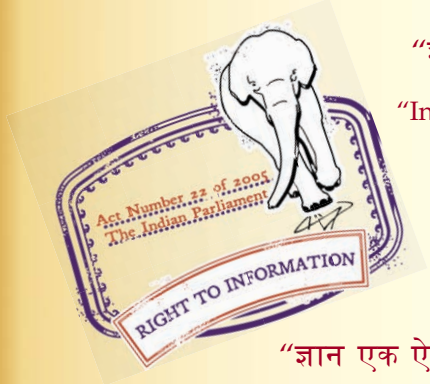

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"Knowledge is such a treasure which cannot be stolen"

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IS : 4701 - 1982
(Reaffirmed 2004)

Indian Standard

CODE OF PRACTICE FOR EARTHWORK ON CANALS

(First Revision)

Second Reprint AUGUST 1991

UDC 626.131.5:006.76

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

Gr 5 *June* 1983

Indian Standard

CODE OF PRACTICE FOR EARTHWORK ON CANALS

(First Revision)

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Indian Standard
CODE OF PRACTICE FOR EARTHWORK ON CANALS
(First Revision)

0. FOREWORD

0.1 This Indian Standard was adopted by the Indian Standards Institution on 31 December 1982, after the draft finalized by the Irrigation Canals and Canal Linings Sectional Committee had been approved by the Civil Engineering Division Council.

0.2 The construction of canals involves a variety of earthwork problems. Because of the great longitudinal extent of the work many different kinds of conditions are encountered which for maximum economy should be treated differently. Moreover, design of a work is based on assumptions regarding the quality of work which will be obtained during construction. These assumptions hold good only if the materials used and the work as actually executed are according to the specifications which are known to give desired results. This standard describes methods for carrying out projects for excavation and construction of embankments on canals. This standard does not, however, cover design of cuttings and embankment slopes for canals.

0.3 This standard was first issued in 1968. The revision of the standard has been taken up in the light of experience gained during the years. Salient changes made in this revision are listed below:

a) Provisions regarding clearing the materials have been slightly modified;

b) Side slopes in cutting in canals to be provided depending on type of soil have been added;

c) Factors to examine sub-grade soil to determine the portion of canal reaches to be lined have been added;

d) Protective measures for lined sections in areas of high ground water table have been indicated;

e) Methods for classification of rock excavation have been stated;

f) Provisions regarding preparation of sub-grade for lined reaches have been modified; and

g) Treatment to repair the settlement in embankment subject to site conditions has been suggested;

h) Provisions regarding requirements for material for the embankment construction have been modified; and

j) Compaction requirements of embankments have also been modified.

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

1. SCOPE

1.1 This standard covers requirements and methods for earthwork on canals covering excavation and construction of embankments.

2. GENERAL

2.1 Effect of Weather Conditions — An earthwork project may be affected by weather conditions which may alter the conditions of the soil to some depth. The earthwork should be as far as possible, so planned that it is carried out during the most favourable season. Rainfall may so affect the exposed surface of cohesive soils as to result in interruption both in the use of excavating plant and in the transport of materials. In wet weather, work may have to be stopped entirely owing to excessive moisture near the surface of soil. In extremely dry weather, it may be necessary to add water to the soil in borrow area or at the fill to fulfil requirements of compaction. It is advisable to compact the soil in its final position in the fill or embankment immediately after it is placed.

2.2 Safety Precautions — Blasting, where required, shall be permitted only when proper precautions have been taken for the protection of persons and property in accordance with IS : 4081-1967†. Blasting shall be carried out only by persons thoroughly conversant with the working methods and precautions to be observed in using explosives. To avoid the danger of injury from flying debris all personnel in a blasting area shall retreat to an adequate distance and take adequate cover. While carrying out excavation adequate precautions in accordance with IS : 3764-1966‡ shall be taken for the safety of workers.

*Rules for rounding off numerical values (*revised*).

†Specification for safety code for blasting and related drilling operations.

‡Specification for safety code for excavation work.

2.2.1 The location and design of magazines for explosives, method of their transport and general precautions to be taken to prevent accidents shall be in accordance with the provisions of Indian Explosives Rules, 1940 and local regulations and regular rules and regulations framed thereunder, if any.

2.3 Planning — Prior to the commencement of a work all relevant data shall be collected and drawings prepared showing the location of the excavation, and embankment reaches separately. On these drawings both the excavation and filling reaches should be distinctively indicated separately and the quantity of material to be excavated and placed in fill stated in these reaches. This information would be useful to ensure economic hauls throughout the work. Where the material to be excavated consists of different types and if the various types have to be used separately in the fill or run to spoil tip, the quantities of each class of material in each area should be shown on drawings.

From the nature of material to be excavated and the method of its disposal, the type of excavation, the length of haul and the amount of compaction necessary, it is possible to select the most suitable type of plant for a particular job.

2.3.1 No earthwork on canals should be started unless proper acquisition and demarcation of land has been finalized and permission of concerned organization obtained. Such land shall be demarcated by fixing permanent boundary stones at intervals of 200 m on both sides on straight reaches and at points where there is change in direction or change in land width. Similar precautions shall be taken for defining the borrow areas also. Such areas will be temporarily acquired and suitably demarcated.

3. SETTING OUT

3.1 Prior to the commencement of work the centre line of the proposed canal shall be marked by stones or pegs each at about 30 m interval. Curves shall be laid out; top and bottom edges of the excavation and toe of all embankments suitably peg marked. Reference pegs should also be driven into ground at a fixed distance outside peg markings. All levels shall be referred to an established bench mark not subject to subsidence or interference.

3.2 Profiles of designed canal section in fill and moderate cut reaches may be marked at intervals of 25 m at curves and 50 m in straight reaches.

4. CLEARING

4.1 The land over which embankments are to be formed and other excavation is to be carried out shall be cleared of all trees, bushes, rubbish, ant hills

and other objectionable matter. The cleared materials shall be suitably disposed off.

4.1.1 All waste materials to be burned shall be piled neatly and when in suitable condition shall be burned completely. Piling for burning shall be done in such manner and in such locations as to cause the least fire risk. All burning shall be so thorough that the materials are reduced to ashes. Necessary precautions shall be taken to prevent fire from spreading to areas beyond the limits of cleared areas and suitable equipment, and supplied for use in preventing and suppressing fires shall be kept available at all times.

4.2 In filling reaches, all holes and hollows whether originally existing or produced by digging up roots shall be filled with suitable earth, well rammed and levelled off.

4.2.1 In filling reaches, the boulders in the top strata shall be removed and filled with suitable material.

4.2.2 Boulders which may interfere with the work should be generally removed after breaking them down, if necessary.

4.3 It is desirable to protect the trees outside the outer edge of the canal embankments. However, the presence of trees in the vicinity of a canal can accentuate variation of moisture content in the sub-stratum. In the case of expansive soils such excessive moisture variation can result in damage to the lining. Such influence is believed to extend to distances equal to twice the height of the tree.

5. EXCAVATION

5.1 Earthwork in Cutting — Canal section shall be excavated as shown on the drawings or as directed by the engineer-in-charge. Both edges of the bank, specially the inner one shall be neatly aligned symmetrically to the centre line of the channel. They shall be absolutely straight in straight reaches and smoothly curved on bends. All gangways, roads and stoppings shall be such that they fall within the canal section so that final dressing of slope will consist of digging only and no filling will be required.

5.1.1 Suitable arrangements for drainage shall be provided to take surface water clear of the excavation during the progress of work. Sumps may be constructed at suitable places and water collected may be pumped out. When cutting on cross sloping ground, it is advisable to cut a catch water drain on the higher side to prevent water from flowing down the cutting slope.

5.1.2 Wherever ground water is met during excavation adequate measures shall be taken to dewater the cutting. The choice of method to be employed and type of equipment to be used would depend on the nature of ground and the volume of water to be dealt with.

5.1.2.1 If there is a continuous flow of water a subdrain with sumps at intervals may be installed. Drainage will be helped by excavating from downstream side to upstream side so that water tends to drain away from the working face. Generally area is drained by providing pilot cut to natural valley so as to drain the subsoil water.

5.1.2.2 In case of lined canals subsoil water shall not be allowed to accumulate in the bottom of the canal and pumping arrangements shall be so organized as to deal with any temporary flood water which may occur. As described above (**5.1.2.1**) the subsoil water should be drained by providing drain or pumping the subsoil water so as to keep the area dry as far as possible.

5.1.3 Excavation may be carried out by manual labour or by excavating machines. The choice of type of excavating machine to be used will depend on the nature and quantity of materials to be excavated and also on the leads and lifts involved.

5.1.3.1 Side slopes for canals should be provided depending on type of soil through which the canal is laid. Generally the following slopes are provided for unlined canals :

Sl No.	*Type of Soil*	*Side Slopes* (H_{or} : *vert*)
1.	Very light loose sand to average sandy soil	1·5 : 1 to 2 : 1 (in cutting) 2 : 1 to 3 : 1 (in embankment)
2.	Sandy loam	1 : 1 to 2 : 1 (in cutting) 1·5 : 1 to 2 : 1 (in embankment)
3. a)	Sandy soil or gravel	1 : 1 to 1·5 : 1 (in cutting)
b)	Muram, gravel mixed soil	1·5 : 1 to 2 : 1 (in filling)
4.	Black cotton	1·5 : 1 to 2·5 : 1 (in cutting) 2·5 : 1 to 3·5 : 1 (in embankment)
5.	Clayey soils	1 : 1 to 2·5 : 1 (in cutting) 1·5 : 1 to 3 : 1 (in embankment)
6.	Rock	0·25 : 1 to 0·5 : 1 (in cutting)

NOTE 1 — The above slopes are for general guidance for height of embankment up to 6 m. For heights in excess of the above special studies for the stability of slope are recommended.

NOTE 2 — In case of rocky areas above recommended side slopes may require change due to any adverse jointing pattern.

5.1.4 Exploratory holes and type of soil shall be determined before excavation. The permeability characteristics of the soil encountered should be assessed by making use of in place permeability tests as required. Canal sub-grade soil on the slopes and bottom with respect to probable future seepage and erosion should be examined. In case of high seepage

losses are anticipated, or if the soils are fine and lacking in cohesion and could erode badly under the proposed operating conditions, suitable measures such as lining, etc, should be planned.

5.1.5 Above the lining in case of lined sections and above the proposed water level in case of unlined sections the rock may be allowed to stand at its steepest safe angle and no finishing is required other than removal of rock masses which are loose and are liable to fall.

5.1.5.1 Lined sections in areas of high ground water shall be protected against uplift by drainage system as per IS : 4558-1968*. If fine grain soils (sand) are to be placed as sub-grade below concrete or membrane lining, this should be without organic matter, gravel, pebbles, etc. Natural sub-grade should be inspected and organic material, gravels, pebbles, protruding should be removed from sub-grade. Filter blankets should be provided beneath lining as per IS : 4558-1968* to release uplift pressure. All washable materials and any soil which generally becomes unstable on saturation such as organic soil, loose, silts, expansive clays are generally removed or properly treated for embankment and canal linings so as to provide safe and stable sub-grade under operating conditions.

5.2 Rock Excavation — Rock may be excavated by the following methods :

a) Quarrying out by hand with suitable rock wedges and hammers, steel bars, picks, etc, and breakings with rock hammers;

b) Loosening by use of pneumatic paving breakers;

c) Drilling suitable holes by hand with jumpers or pneumatic drilling machines, and breaking up rock with plugs and features;

d) Drilling holes by hand jumpers or pneumatic drilling machines as above, but breaking the rock with suitable commercial explosives, or blasting devices; and

e) Ripping with suitable heavy duty tractors where the rock formation falls within the range of ripability of commercially available units.

5.2.1 Classification of rock could be done as below:

a) Disintegrated rock removable by crow bars and pick axes;

b) Fissured and fractured rocks jointed at less than 450 mm apart;

c) Hard rock boulders of size greater than 300 mm in any dimension up to 3 m^3 ;

d) Solid and sheet rock boulders of size greater than 3 m^3; and

e) Generally hard soil, hard muram, stoney earth and earth/sand mixed with stone and boulders not exceeding 300 mm in any direction.

*Code of practice for under-drainage of lined canals.

5.2.2 Excavation of rock is usually done by loosening and removing the rock by forming a slightly sloping open face across the cut and working towards this open face. The depth and width of this face will vary according to the nature of rock and method adopted. Several faces may be worked simultaneously, one behind the other, with benches between each face; the space between the faces and the length of each bench varying according to the conditions prevailing and the methods adopted for removing the rock. Provided that proper equipment and technique are adopted, drilling and blasting is the most speedy and economical method for excavating hard rock. For soft rocks ripping may loosen the rock at greater speed and at much less cost.

5.2.3 Blasting in a manner as to produce over breakage which in the opinion of engineer-in-charge is excessive shall not be permitted. Special care shall be taken to prevent over-breakage or loosening of material on bottoms and side slope against which rigid lining is to be placed.

5.2.3.1 Final cutting for 45-60 cm in hard rock shall be carried out by controlled blasting or trimming or with the help of pneumatic paving breakers.

5.3 Preparation of Subgrade — Where the canal is to be lined the excavation and preparation of subgrade shall be done in accordance with IS : 3837-1978*. Where the canal is not to be lined, excavation shall be done to full depth and width required and shall be finished to prescribed lines and grades. Where the original ground surface is below the grade of the canal the bottom of the canal shall be filled to the grade in a manner prescribed for the construction of canal embankments (*see* **6.6.2**). In so far as practicable the finishing operation required on canal sections shall be performed simultaneously with canal excavation.

5.3.1 The sub-grade and embankment for a canal may comprise of rock or soil. Canal sections excavated in rock should be inspected to examine whether joints or fissures exist which will cause excessive seepage or piping. In case this is so, rock will require grouting or the section may require lining. Rock surfaces on which compacted earth is to be placed should be moistened before placing the first layer of earth but standing water should not be allowed. The minimum soil cover over rock should be 225 mm.

6. EMBANKMENT CONSTRUCTION

6.1 Before commencing the work, the toe of the slope on each side of the banks shall be lock-spitted (Dag-Belled) and marked by pegs, firmly driven into the ground at intervals of about 20 m. Profiles made by bamboos, earth or other convenient materials and strings shall be set up for the guidance of the workmen at about 50 m apart over straight reaches and

*Code of practice for lining-in-situ cement concrete lining on canals (*first revision*).

about 25 m apart at curves. In setting up the profile for an embankment a suitable allowance shall be made for settlement (*see* **6.2.2.1**).

6.1.1 Masonry blocks shall be constructed at each profile to indicate the centre line as also the bed level of the canal before starting the entire earthwork.

6.2 General Requirements — Embankments shall be built to the height and slope as shown on the drawings. All the edges of the embankment shall be neatly aligned symmetrical to the centre line of the channel. They shall be absolutely straight in reaches and smoothly curved at bends.

6.2.1 The top of each embankment shall be levelled and finished so as to be suitable for roadway and given a cross outward slope to drain away rain waters. The bank carrying inspection road shall be given a suitable cross slope.

6.2.2 For embankment in which controlled compaction has not to be carried out (**6.6.1**), suitable allowance shall be made for settlement.

6.2.2.1 An allowance of about 10 percent for settlement is recommended for embankments in which controlled compaction has not been carried out (*see* **6.6.1**).

6.3 Methods of Construction — Embankments may be built by manual labour or by machinery depositing the materials directly from excavation. The choice of type of excavating plant will depend on many factors. Where boulders which may interfere with the work are encountered they shall be dealt with in accordance with **4.2.2.**

6.3.1 *General Drainage* — Under ordinary circumstances no special drainage works are necessary in embankments but where required ditches may be dug at a distance not less than 3 m from the toe of the slope. The necessity for any drain so provided will depend on the topography of the ground on which the embankment is constructed, having regard to the desirability of preventing an accumulation of water at the base of the embankment.

6.3.2 In case any settlement takes place in the embankment after its completion it would also induce cracks in the embankment in addition to causing damage to lining. The following treatment is suggested to repair the settlement subject to site conditions.

A trench of minimum required width shall be dug along the crack in the embankment for a depth to which the crack has extended plus minimum 0·25 m or to a depth of 1 m whichever is more. The width of the trench shall, however, not be less than 0·5 m. This trench shall be filled back with a thorough mixture of clay and fine sand having plasticity index of 10 or less, and should be placed in 150 mm thick layers and thoroughly compacted.

6.4 Requirements for Material — Where the embankment is constructed by taking material from borrow pits care shall be exercised that all large clods are broken and no clod bigger than human fist, say 8 to 10 cm, roots, grass and other rubbish are burried in the banks. Before procuring materials from borrow pits all perishable material shall be stripped off from the top surface as specified in **6.5.1.** Unless otherwise directed by the engineer-in-charge all materials shall be deposited in embankments so that cobbles, gravel and boulders are well distributed through other material and not rested in any position within or under the embankment.

6.4.1 In areas where gravel and stone is mixed with earth, these should be removed as far as possible. But the areas where all gravel material cannot be economically removed, cobbles, stones of size greater than 40 mm should be removed to ensure proper compaction. This is very important for lined sections where plastic membrane is provided to reduce seepage. The existence of nest of cobbles may result in more seepage and piping. In view of this measure to remove cobbles of larger size should be taken at the excavation area itself.

6.5 Preparation of Ground Surface for Embankment — Before beginning the construction of embankments the surface area of ground to be occupied shall be cleared of all roots and vegetable matter of any kind and stripped to a suitable depth.

6.5.1 The depth to which top soil is removed shall be adequate to remove all perishable material and any soil which may become unstable on saturation or may interfere with development of proper bond between the foundation and embankment. It is not necessary to remove all the soil containing fine hair like roots but only the rather heavy mat. Table 1 may serve as a guide for fixing the depth of stripping.

TABLE 1 DEPTH OF STRIPPING

TYPE OF VEGETABLE COVER ON THE SOIL	DEPTH OF STRIPPING
Soil containing light grass cover	5·0 to 7·5 cm
Agricultural land	To the bottom of ploughed zone usually 15·0 to 22·5 cm

6.5.2 The ground surface under all canal embankments (excepting rock surfaces) where it is below the maximum water level in the canal, shall be scarified making open furrows not less than 20 cm deep below natural ground surface at intervals of not more than 1 m. However, where the ground surface is below the bed level of the canal the entire surface of the foundations for embankments shall be stripped to a depth of not less than 20 cm.

6.6 Compaction Requirement — Embankments shall be compacted, as shown on the drawings, to achieve the requirements laid down in **6.6.1** and **6.6.2**. General methods of compaction of embankments are given in **7**.

6.6.1 *Embankments Without Controlled Compaction* — Where the natural ground surface is above the maximum water level in the canal but below the top of the embankment, the embankment shall be built in layers not exceeding 30 cm in thickness and to the full width of the embankment. Each layer shall be commenced from the edge farthest from the excavation. Top of each layer shall be kept slightly depressed in the centre. The excavating and hauling equipment shall travel over the embankment to evenly distribute the material and compacting effort over whole surface. If the embankment is to carry a highway it shall be constructed in accordance with **6.6.2**, **6.6.3.1**, **6.6.4**, **6.6.4.1** and **6.6.5**.

6.6.2 *Embankments With Controlled Compaction* — Where the natural ground is below the maximum water level in the canal the portion of the embankment up to the maximum water level or where rigid lining is to be laid, the portion of embankment up to the upper level of the lining, shall be built according to the requirements given in **6.6.3.1**, **6.6.4** and **6.6.5**.

6.6.2.1 Embankment shall be built in layers generally not exceeding 25 cm in thickness (loose layer) and to full width of the embankment. Each layer shall be commenced from the edge farthest from excavation. Top of each layer shall be kept slightly depressed in the centre.

6.6.3 Generally blending of two or more materials are recommended to obtain suitable soil for earth lining. Fine soil from borrow areas is generally added to coarse soil to improve impermeability. But coarse soils are added to fine soils to improve erosion resistance. The proportions for blending should be ascertained by laboratory test.

6.6.3.1 *Impervious zone* — The impervious zone wherever shown on the drawings shall be built of material having sufficient percentage of clay so that it can be compacted at optimum moisture content by suitable compacting equipment to the maximum dry density. The material shall be compacted to a density as specified in **6.6.5**. The water tightness of material should be checked by carrying out permeability test. The coefficient of permeability of impervious material should not be greater than 30 cm per year. The impervious material should preferably be free from large size particles. If this is not possible the maximum size and percentage of gravels to be permitted is 40 mm and 20 percent respectively. When the above relaxation is allowed the engineer-in-charge should ensure that relative standards set for dry density and permeability are fulfilled.

6.6.3.2 The rest of the compacted zone may consist of any suitable support for the impervious core under various conditions of saturation and draw down. If silty or sandy material is used for this portion, such a material will not be amenable to compaction by the usual compaction

procedure using sheep foot rollers. For such materials proper machinery utilising the principle of vibro-compaction should be used. The minimum relative density of the compacted material shall not be less than 70 percent. The distribution of material shall be such that the compacted material will be homogeneous and free from lenses, pockets or other imperfections. The maximum dimensions of stones placed in the embankment shall be not more than 10 cm. The excavating and placing operations shall be such that the materials when compacted will be blended sufficiently to secure the best practicable degree of compaction, impermeability and stability.

6.6.4 *Moisture Content* — Prior to and during compaction operations the embankment shall have optimum moisture content required for the purpose of compaction and this moisture content shall be fairly uniform throughout the layer. In so far as practicable the moistening of the material shall be performed at the site of excavation but such moistening shall be supplemented as required by sprinkling water at the site of compaction, if necessary.

6.6.4.1 If the moisture content is greater than optimum for compaction, the compaction operation shall be delayed until such time as the material has dried to the optimum moisture content.

6.6.5 *Dry Bulk Density After Compaction* — The dry bulk density of the soil fraction in compacted embankment material shall be not less than 95 percent of the maximum dry bulk density at optimum moisture content obtained in accordance with IS : 2720 (Part VII)-1980*, or as specified.

7. COMPACTION METHODS AND FIELD CONTROL

7.1 Methods of Compaction — To obtain the required amount of compaction by most economic means it is necessary to employ systematic field control. For a particular job the following items should be decided:

a) Dry density of the soil required with regard to the soil type;

b) The most suitable moisture content at which to work and the effect of probable moisture content variation;

c) The type or types of compaction equipment most suitable for compacting the soil having due regard to relative costs; and

d) The thickness of loose layers.

7.1.1 Average performances of compaction plant for various types of soils are given in Appendix A. Whilst exact details of the procedure for compacting every type of soil and materials are not given in Appendix A, the information contained in it may be used as a reasonable guide.

*Method of test for soils: Part VII Determination of moisture content dry density relations using light compaction (*second revision*).

7.1.2 Where the magnitude of work justifies it, the procedure described in **7.1.2.1** to **7.1.2.3** is recommended to determine the required compaction method. In deciding the method to be employed, economic considerations should be kept in view. For example, it may have to be decided whether it is more economical to compact in layers of less thickness with a light roller or thick layers with heavy rollers; again, consideration may have to be given to the number of passes required with smooth and sheepfoot rollers to produce specified density. Often it may be found that a combination of two or more types of equipment would give best results.

7.1.2.1 Standard compaction tests shall be made on available materials. The tests will indicate broadly which are the most suitable and give a rough idea of the best type of equipment to be used and the moisture content at which compaction should be undertaken. This method would help in classsifying a material according to its compaction characteristics.

7.1.2.2 Having decided on the filling material to be used, field compaction trials should, where possible, be made with the compaction equipment expected to be used under conditions which are likely to obtain during construction to determine the effects of soil moisture content, thickness of layer, and number of passes.

7.1.2.3 In deciding on the range of moisture contents, day-to-day variations in moisture content should be taken into consideration, particularly in the case of cohesive soils. Refer **6.6.4**. Having decided on the thickness of layers and range of moisture contents, tests should be made with the different types of equipment available, and the required number of passes should also be determined. In all this work the state of compaction should be measured in terms of dry bulk density.

7.1.3 During the actual construction of any earthwork, maximum use should be made of constructional plant and routing of the plant should be carefully controlled to obtain uniform compaction over as wide an area as possible. Care should also be taken during the compaction operation to shape the surface of the works to facilitate the shedding and to minimize the absorption of rainwater, particular attention being given to the prevention of ponding. It is advisable to do this at the end of each day's work.

7.1.4 Where, in the construction of an embankment, it is necessary to construct a culvert over which the filling has to be placed, it is essential that the filling and subsequent compaction should be carried out in such a manner as to avoid an unbalanced thrust on the culvert, which might displace or damage it.

7.2 Tests for Compaction of Earthworks — The following tests shall be carried out for determining compaction:

a) Density moisture relationship of the soil;

b) Density of the soil in field; and

c) Moisture content.

7.2.1 Density moisture relationship of the soil shall be determined in accordance with IS : 2720 (Part VII)-1980* and IS : 2720 (Part VIII)-1974†.

7.2.2 Density of soil in field shall be determined in accordance with IS : 2720 (Part XXVIII)-1974‡ or IS : 2720 (Part XXIX)-1975§.

7.2.3 Moisture content of soil shall be in accordance with IS : 2720 (Part II)-1973‖.

8. DISPOSAL OF MATERIALS

8.1 All excavated materials within economic lead, suitable for construction of canal embankment should be used in its construction. Where the canal is aligned on sloping ground excavated material not required for the construction of embankment on the higher side shall be deposited on the lower side. Where canal is on level or nearly level ground the material from excavation shall be deposited on embankments on both sides of the canal. If there is excess of material from the excavation than needed for construction of embankments of canals, it should be deposited outside the embankments on either side of the canal in the form of spoil banks leaving a suitable berm and cross drains as directed by the engineer-in-charge.

8.2 A gap 3 m wide at toe may be left in spoil banks at 150 m intervals for the purpose of drainage.

9. BORROW PITS

9.1 Where canal excavation does not furnish sufficient suitable material for embankments, additional material required may be procured from the borrow pits. The location of borrow pits will depend on the material that is being sought which in turn depends on the design consideration. It may be necessary to survey the soil by means of auger borings or trial pits to determine the extent and nature of the deposits in the borrow area.

9.2 No borrow pits shall be dug within 5 m of the toe of embankment, if their depth is less than 0·5 m, and 10 m, if their depth is more than 0·5 m;

*Methods of test for soils : Part VII Determination of moisture content dry density relations using light compaction (*second revision*).

†Methods of test for soils : Part VIII Determination of moisture content dry density relations using heavy compaction (*first revision*).

‡Methods of test for soils : Part XXVIII Determination of dry density of soils, in place, by the sand replacement method (*first revision*).

§Methods of test for soils : Part XXIX Determination of dry density of soils, in place, by the core cutter method (*first revision*).

‖Methods of test for soils : Part II Determination of moisture conten t(*second revision*).

or within such a distance from the toe of the bank where a 4 : 1 hydraulic gradient line cuts the ground surface, whichever is more. Borrow pits shall not be more than 1 m in depth and 25 m in length. A clear distance of 1 m shall be left between the pits. The bed of borrow pits shall be left reasonably smooth and even.

9.3 Borrow pits shall be drained to avoid stagnation of water. The bottom level of borrow pits should be fixed with reference to the prevailing ground slope towards the nearest natural drainage course. The pits shall be connected together by a drain about 0·5 m wide. The bottom level of connecting drain should suit the bed level of the pits it connects.

10. TURFING

10.1 Principles Underlying the Use of Grass on Earth Slopes — Surface stabilization of slopes and the prevention of soil erosion and weathering may be accomplished by the establishment of grass or other herbage. The living grass roots mechanically reinforce the soil, and the decaying organic matter improves soils structure. The grass leaves, living or dead, protect the surface against rain and wind. The combination of improved soil structure and protection gives stability against erosion.

Virgin clays and other subsoils are usually deficient in those bacterial organisms which promote healthy growth. The application of top soil to any new slope is usually a pre-requisite for the successful establishment of grass.

10.2 Topsoiling — The depth of topsoil required will vary according to the nature of the subsoil and a depth of about 15 cm of good quality soil overlying the subsoil is usually sufficient to sustain plant growth.

10.3 Sodding — The sods used shall be cut in rectangular shape 8 to 10 cm thick and laid so that their edges are in close contact and then welded by being gently rammed till they form a level and compact mat. When old surfaces are to be turfed, they shall be picked up to a depth of about 4 cm to give a hold to the sods. For sodding any grass which forms a thick short turf shall be used.

10.4 Turfing — It is difficult to generalize on the type of grass to be used since each particular soil type required a specific grass. To ensure a satisfactory result it is desirable to consult agriculture department, who would make any necessary analysis of the soil before specifying the type of grass. It would also be a help to study the grasses growing in the neighbourhood and to include the varieties that appear to be most suitable; this, of course, largely depends on the top soil being obtained from the same vicinity.

APPENDIX A

(*Clause* 7.1.1)

COMPACTION CHARACTERISTICS FOR SOILS AND OTHER MATERIALS USED IN EARTHWORK CONSTRUCTION

(The information given should be taken only as an approximate guide)

Material	Major Divisions	Sub-groups	Suitable Type of Compacting Equipment	No. of Passes for Satisfactory Compaction, *Min*	Thickness of Loose Layer (Actual Thickness Depends on Plant Used), *Max* cm	Remarks
(1)	(2)	(3)	(4)	(5)	(6)	(7)
Coarse grained soils and other materials	Boulders and cobbles	Boulder gravels	Heavy earth-moving equipment		30	Maximum size of material will govern the minimum thickness of layer
	Other materials	*Hard* : Hard broken rock, hardcore, etc (no soil binder)	Heavy smooth-wheel roller	8	30	As for boulders and cobbles
			Frog-rammer	4	37·5	
			Heavy vibrating plate	2	30	
		Soft: Chalk, soft rocks rubble	Track laying tractor and heavy smooth-wheel roller	4	20	Best compaction is obtained by spreading the material with a doser and compacting with four passses of the roller. In wet weather a smooth-wheel roller may prove impracticable due to skidding. In this case adequate compaction can be obtained by using a heavy tractor and thinner layer
			Frog-rammer	4*	37·5	
	Gravel and gravelly soils	Well-graded gravel, gravels and mixtures, little or no fines				A concrete vibrator may be used when these soils are used as subgrade materials. For effective use of a vibrator the soil should be in relatively dry condition
		Well-graded gravel sand mixtures with excellent clay inder				Close moisture content control is essential
		Uniform gravel with little or no fines				
		Poorly-graded gravel and gravel sand mixtures, little or no fines				As for well-graded gravel, gravel sand mixtures, little or no fines
		Gravel with fines, silty gravel, clayey gravel, poorly-graded gravel-sand-clay mixtures	Smooth-wheel roller	6	20	Close moisture content control is essential
			Pneumatic-tyred roller	6	20	
			Vibrating smooth-wheel roller	6	20	

*Where one pass is equivalent to 6 to 8 blows per unit area.

(*Continued*)

Material	Major Divisions	Sub-groups	Suitable Type Compacting Equipment	No. of Passes for Satisfactory Compaction, *Min*	Thickness of Loose Layer (Actual Thickness Depends on Plant Used) *Max*, cm	Remarks
(1)	(2)	(3)	(4)	(5)	(6)	(7)
Coarse grained soils and other materials	Sands and sandy soils	Well-graded sands and gravelly sands, little or no fines	Heavy vibrating plate		37·5	Vibrating rollers or vibrators will be very satisfactory if the moiture content of the soil is low, but may be uneconomical
			Frog-rammer	2*	37·5	
			Power-rammer	3†	20	
		Well-graded sand with excellent clay-binder				Close moisture content control is essential, when the moisture content is relatively high it is preferable to use a pneumatic-tyred roller
		Uniform sands with little or no fines				—
		Poorly-graded sands, little or no fines				As for well-graded sands and gravelly sands, little or no fines
		Sands with fines, silty sands, clayey sands, poorly-graded sand-caly mixtures				As for well-graded sand with excellent clay binder
Fine grained soils	Soils having low compressibility	Silts (inorganic) and very fine sands, rock flour, silty or clayey fine sands, with slight plasticity				—
		Clayey silts(inorganic)				—
	Soils having medium compressibility	Organic silts of low plasticity				These soils are difficult to compact and the effect of varying the contact pressure should be tried. Close moisture content control should be maintained
		Silty and sandy clays (inorganic) of medium plasticity	Smooth-wheel roller	4	20	—
			Pneumatic tyred roller	—	—	
		Clays (inorganic) of medium plasticity	Track-laying tractor	10	15	—
			Sheeps - foot roller‡	30	15	
		Organic clays of medium plasticity	Frog-rammer	2*	37·5	—
			Power-rammer	2†	20	
	Soils having high compressibility	Micaceous or distomaceous fine sandy and silty soils, elastic silts				These soils are considered very undesirable for use in earthwork and should not be employed if they are highly compressible
		Clays (inorganic) of high plasticity, fat clays				It is advisable to compact these soils at the moisture content at which no change will occur subsequently
		Organic clays of high plasticity				As for micaceous or distomaceous fine sandy and silty soils
Fibrous organic soils with very high compressibility		Pest and other highly organic swamp soils	—	—	—	These soils are entirely unsuitable for earthwork construction

*Where one pass is equivalent to 6 to 8 blows per unit area.

†Where one pass is equivalent to 2 to 3 blows per unit area.

‡For use in dry climates.

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