a) In developing rehabilitation scheme, stretches having similar soil characteristics and embankment performance should also be included simultaneously.
b) Cause(s) of unstability of formation should be analysed and accordingly rehabilitation measures formulated. There may be requirement of reprofiling of slope along with laying of blanket.
c) In consultation with RDSO, Geosynthetics may also be used along with laying of blanket, to reduce thickness of blanket if found cost effective.
d) Method of laying of blanket should be appropriate depending upon techno-economical conditions and site requirements.

## 5.0 MATERIALS FOR CONSTRUCTION:

Construction of embankment is to be carried out normally with soil available in nearby area with proper design of slope and desired bearing capacity. However, there are some soils, which are not normally suitable to be used in construction of new lines as detailed below:

### 5.1 Unsuitable Soils for Construction:

**5.1.1** Soils to be normally avoided are :

a) Organic clays, organic silts, peat, chalks, dispersive soils, poorly graded gravel and sand with uniformity coefficient less than 2,
b) Clays and silts of high plasticity (CH & MH) in top 3m of embankment.

**5.1.2** Some typical situations, as given below, may arise when in construction of formation such unsuitable types of soils (para 5.1.1) are not possible to be avoided for economical or any other reason, then Railway may consult RDSO to decide special investigations and other measures to formulate suitable scheme of construction.

a) Cuttings passing through unsuitable soils (para 5.1.1), shales and soft rocks which become muddy after coming into contact with water,
b) Construction of embankment on subsoil of unsuitable types of soils.
c) Use of CH & MH type of soils even in top 3m of embankment.

### 5.2 Use of Mixed Types Soils:

**5.2.1** Different types of fill materials, if used, should be deposited in such a way that all parts of the site receive roughly equal amount of a given material in roughly the same sequence to get approximate homogeneous character of sub-grade.

**5.2.2** In situations where soils for construction of embankment consist of cobbles, boulders, rock or waste fragments etc., largest size of material should normally not be greater than $2/3^{rd}$ of the loose layer thickness. However, it should be ensured that after every one to three meter of such construction, a 30 cm layer of properly compacted soil (other than soil as given in para 5.1) be provided. A detail slope stability analysis also needs to be carried out to ensure stability of such embankments.

**5.2.3** In case cobbles, boulders, etc. i.e., rock materials of bigger size than 2/3rd of the loose layer thickness are only in small quantity, these may be placed on toe of the embankment instead of using as subgrade material.

## 6.0 EXECUTION OF FORMATION EARTHWORK

Before taking up of actual execution of work, detailed drawings need to be prepared for the entire length of the project to give alignment, formation levels, formation width at ground level, cross sections of catch water drains & side drains, cross section & levels of subgrade, blanket levels, etc. to facilitate smooth execution at site. Execution of work has to be carried out in systematic manner so as to construct formations of satisfactory quality which would give trouble free service. The activities and adoption of good practices involved in execution of earthwork are covered under following headings:-

a) Preliminary works
b) General aspects
c) Compaction of earth work
d) Placement of Back-Fills on Bridge Approaches and Similar Locations
e) Drainage Arrangement in Bank/Cutting
f) Erosion control of slopes on banks & cuttings
g) Other aspects

### 6.1 Preliminary Works:

### 6.1.1 Preparation of Natural Ground:

Preparation of natural ground surface may be carried out as follows:

**6.1.1.1 Site clearances:** Full formation width at ground level plus additional extra width of 1 m on both sides should be cleared of all obstructions viz. vegetation, trees, bushes, building, fences, abandoned structures etc. and thereafter it should be dressed and leveled. Depressions if any, should be filled with suitable soil duly compacted. Finally, leveled surface should be properly compacted by mechanical means to get leveled and uniform ground surface.

**6.1.1.2 When Bank is Constructed On Ground Having Steep Slope** then the ground surface should be suitably benched so that new material of bank gets well bonded with the existing ground surface.

### 6.1.2 Setting out of Construction Limits:

Centreline of the alignment (@ 200 m c/c or so) and full construction width should be demarcated with reference pegs/dug belling about 90 cm away from proposed toe of the bank. Care should be taken not to disturbed the pegs during construction. Pegs should be preferably painted for identification.

Content). If natural moisture content of the soil is less than the OMC, calculated amount of water should be added with sprinkler attached to water tanker and mixed with soil by motor grader for uniform moisture content. When soil is too wet it is required to be dried by aeration to reach up to OMC.

**(c)** **Soil Type:** Type of soil has a great influence on its compaction characteristics. Normally, heavy clays, clays and silts offer higher resistance to compaction, whereas, sandy soils and coarse grained or gravelly soils are amenable for easy compaction. Coarse-grained soils yield higher densities in comparison to clay. A well-graded soil can be compacted to higher density.

**(d)** **Thickness of Layer:** Suitable thickness of soil of each layer is necessary to achieve uniform compaction. Layer thickness depends upon type of soil involved and type of roller its weight and contact pressure of its drums. Normally, 200 – 300 mm layer thickness is optimum in the field for achieving homogenous compaction.

**(e)** **Number of Passes:** Density of soil will increase with the number of passes of roller but after optimum number of passes, further increase in density is insignificant for additional number of passes. For determination of optimum number of passes for given type of roller and optimum thickness of layer at a predetermined moisture content, a field trial for compaction is necessary as explained in Annexure -IV.

### 6.3.3 Compaction Procedures for Different Soils:

The embankments are constructed with locally available soils provided it fulfils the specified requirements. Procedure of compaction to be adopted will depend on the type of soil being used in construction. General guidelines to deal with compaction of various types of soils for attaining optimum dry density/relative density at minimum effort, have been briefly given as under:

#### 6.3.3.1 Compaction of Cohesion Less Gravely and Sandy Soil:

i) Sandy & gravely soils should be compacted with vibratory rollers. If fines are less in these types of soils, it can be compacted with minimum number of passes of vibratory rollers without strict control of moisture to achieve desired Relative Density. With higher percentage fines, sandy and gravely soils need to be brought to OMC level to get effective compaction. Uniformly graded sand and gravel are difficult to be compacted. Top layer of sand and gravel remains loose in vibrating compaction. Therefore, in final pass the roller should move smoothly without vibration. Dry densities attained in field trails normally should be around MDD/ specified Relative Density as obtained from laboratory tests and should form the basis for specification and quality control.

ii) Poorly graded sand and gravel with $Cu < 2.0$, should not be used in earthwork for the banks to safeguard against liquefaction under moving loads or especially due to earthquake tremor. Generally, fine sand is prone to liquefaction. Materials having gradation as per sketch 'D' should be specifically examined and designed to prevent possibility of any liquefaction.

**6.3.3.2 Compaction of Silty - Clayey Soils:**

Silty soil is a fine-grained soil. These can be plastic or non-plastic depending upon the clay content in it. Silts and fine sands with high water content have a tendency to undergo liquefaction under vibrating rolling due to the pore water pressure generated by mechanical work. Silty soils can be compacted satisfactorily near about OMC either with smooth rollers or vibratory rollers. Vibratory roller will give high degree of compaction and higher lift. Compaction of silty clays will have to be handled in a manner similar to clays.

**6.3.3.3 Compaction of Clays:**

i) Water content plays very important role in compaction of clays. Main objective of compacting predominantly clays is to achieve uniform mass of soil with no voids between the lumps of clays. If moisture content is too high, roller tends to sink into the soil and if too low the chunks would not yield to rolling by rollers. Appropriate water content i.e. OMC of the soil is in the range of about plastic limit plus two percent. Sheepsfoot rollers are most effective in breaking the clods and filling large spaces.

ii) Thickness of layer should not be more than depth of feet of roller plus 50 mm. Pad foot vibratory roller with drum module weight of 7tonne( total static weight of 11 tons) for a lift thickness of 30 cm is found quite effective for compaction of clays. For better results, initial rolling with static pad foot roller followed by 15 tons vibratory roller can be tried.

**6.3.4** In case of such soils, the MDD and OMC, as determined in the Laboratory my not be very relevant and therefore achievable MDD and practicable moisture content at which such soils can be compacted effectively should be determined by conducting field trials.

**6.3.5 Selection of Compacting Equipment:**

The performance of roller is dependent mainly on type of soil used in construction. Guidelines on selection of compacting equipment are given in Annexure V. Vibratory rollers which can be used in static as well as dynamic mode with plain & pad drum, are now being manufactured by reputed Indian Companies also. Salient features of some of models are given in Annexure- VIII.

## 6.4 Placement of Back-Fills on Bridge Approaches and Similar Locations:

**6.4.1** The back fills resting on natural ground may settle in spite of heavy compaction and may cause differential settlements, vis-a-vis, abutments, which rest on comparatively much stiffer base. To avoid such differential settlements, while on one hand it is essential to compact the back fill in the properly laid layers of soil, on the other hand, the back fill should be designed carefully to keep;

i) Settlements within tolerable limits.
ii) Coefficient of subgrade reaction should have gradual change from approach to the bridge.

**6.4.2** Back-fills on bridge approaches shall be placed in accordance to para 605 of Indian Railways Bridge Manual 1998. Details given at Fig I.

**6.4.3** Fill material being granular and sandy type soil, therefore need to be placed in 150mm or lesser thick layers and compacted with vibratory plate compactors.

**6.4.4** While placing backfill material benching should be made in approach embankment to provided proper bonding.

## 6.5 Drainage Arrangement in Banks and Cuttings:

Drainage is the most important factor in the stability of bank/cutting in railway construction. Effective drainage of the rainwater in the monsoon season is very important to safe guard bank/cutting from failure. Railway formation is designed for fully saturated condition of soil. However, flow of water should not be allowed along the track as it not only contaminates ballast but also erodes formation. Stagnation of water for long time on formation is not desirable. Therefore, drainage system should be efficient enough to prevent stagnation and allow quick flow of water. Some guidelines on this aspect are given as follows:

**6.5.1 Drainage of Embankment:** In bank cross slope is provided from center towards end to drain out surface water. Therefore, normally there is no need of side drains in case of embankment. However, there are situations where height of bank is such that blanket layer goes below normal ground level. In such cases, side drains may require to be constructed along the track at suitable distance so that track alignment does not become channel for flow of ground surface water.

In case of double line construction, central drain between the tracks should be avoided to extent possible (even if it means resorting to additional earthwork to facilitate flow of water) as it is not only difficult to construct but also difficult to maintain for continuous vibrations caused by moving traffic, problem in proper curing of concrete etc. Only in very rare situations, when drainage of water is not possible without construction of drain, suitable arrangements for construction of drain with pre-cast concrete channel/ subsoil drains alongwith proper outfall should be made. If distance between adjacent tracks is large enough, suitable slope should be provided in ground to make rain water flow in natural manner. Wherever, there is level difference between two adjacent tracks, suitable non-load bearing dwarf wall may be constructed to retain earth.

### 6.5.2 Drainage in Cuttings:

**6.5.2.1 Side Drains**: In case of cuttings, properly designed side drains of required water carrying capacity are to be provided. If height of the cutting is less (say, up to

4m), normally only side drains on both sides of the track are to be provided. In case of deep cuttings, catch water drains of adequate water carrying capacity are also required along with side drains. A typical sketch of side drain and catch water drain has been given in Sketch - E. It is to be noted that blanket material is to be placed like fill/embankment and top of side drains has to remain below the bottom of blanket material.

**6.5.2.2 Catch Water Drains**: Surface water flowing from top of hill slope towards the track in huge quantity needs to be controlled on safety consideration. It is also not possible to allow water from the hillside to flow into the side drains, which are not designed for carrying such huge quantity of water. Therefore, it is essential to intercept and divert the water coming from the hill slopes, accordingly, catch water drains are provided running almost parallel to the track. Depending on site condition, water from the catch water drains may require be diverting by sloping drains and carrying across the track by means of culvert. In some of the situations, depending on topography of top of cutting, there may be requirement of construction of net of small catch water drains which are subsequently connected to main catch water drain so that there is no possibility of water stagnation/ponding upto distance approximately three times depth of cutting from its edge. Catch water drains should be made pucca/lined with impervious flexible material locally available.

**a) Considerations in Design of Catch Water Drains**:

These should be properly designed, lined and maintained. If catch water drains are kuchha/ broken pucca drains, water percolates down to the track through cracks, dissolving the cementing material resulting into instability in the cuttings. Catch water drains should be located slightly away (as per site conditions) from the top edge of cutting and water flow should be led into the nearby culvert or natural low ground. Some additional salient features to be observed are as follows:

i) Catch water drains shall have adequate slope to ensure development of self-cleansing velocity.
ii) Catch water drains shall not have any weep hole.
iii) The expansion joints, if provided, shall be sealed with bituminous concrete.
iv) Regular inspection and maintenance work, specially before onset of monsoon, should be carried out to plug seepage of water.
v) Catch water drains shall have well designed out fall with protection against tail end erosion.

Though capacity and section will depend on terrain characteristics, rainfall etc. but following parameters are important for design of catch water drains:

- Intensity and duration of rain fall.
- Catchment area- shape, size, rate of infiltration etc.
- Velocity of flow which should satisfy the Manning’s formula
- Minimum gradient of drain should be in range of 1 in 400 to 1 in 700.

- Normally catch water drains should trapezoidal cross section.
- The catch water drain should not be given gradient more than about 1 in 50 (but in no case more than 1 in 33) to avoid high water velocity and possibility of washout of lining material
- Rugosity coefficient should be about 0.03.

**b)** Alignment plan, longitudinal section and soil survey records of catch water drain should be updated from time to time as per development in the area of influence.

## 6.6 Erosion Control of Slopes on Banks and Cuttings

Exposed sloping surface of bank/cutting experiences surfacial erosion caused due to the action of exogenous wind and water resulting into loss of soil, leading to development of cuts, rills/gullies adversely affecting the cess width, soil matrix, steepening of slopes etc which depends on type of soil, climatic conditions, topography of area, length of slope etc.

Erosion control measures are commonly classified in following categories:

a) Conventional non-agronomical system,
b) Bio-technical system,
c) Engineering system, and
d) Non- conventional hydro-seeding system.

Most common methods used are the Bio-technical and Engineering System. However, appropriate method needs to be decided depending on site conditions. These methods are explained in following paras

### 6.6.1 Conventional Non-agronomical System:

This system uses asphalting, cement stabilisation, pitching etc. This method is best utilized against seepage, erosion by wave action etc.

### 6.6.2 Bio- Technical Solution:

In this system, vegetation is provided on exposed slopes. It is suited for soil with some clay fraction. Method consists of preparing slope area by grading it for sowing seeds or planting root strips of locally available creeping grass. It's root goes upto 50 to 75mm deep into the slopes serving as a soil anchor and offering added resistance to erosion. Some typical species of grass which develop good network of roots and considered suitable are listed below:

- Doob grass
- Chloris gyne
- Iponea gorneas (Bacharum Booti)
- Casuariva and goat foot creepers etc.
- Vetiver grass (vetiveria zizanioides)

### 6.6.2 Engineering System:

In this system, three methods, as mentioned below, are normally used.

required to be carried out in longitudinal direction of laying. No overlaps are required in transverse direction of laying while jointing.

### 6.6.4 Hydro-seeding System:

This is non-conventional and innovative system of development of vegetation. This system can be tried on mountainous slopes and steep banks/cuttings. In this system, **Verdyol** mulch solution @ 100 to 150 gm/$m^2$ is sprinkled on the surface for germination of vegetation depending upon the local soil and the climatic conditions.

### 6.6.5 Protection of Slopes in Cutting:

**a)** The causes and manifestations of surfacial erosion of slopes of banks and cuttings are almost similar. In case of cuttings, where the slopes are normally steeper than those of banks, special protection measures would be necessary. For cutting slopes steeper than 1:1 with soil conditions favorable for vegetative growth, turf sodding (size 20x20x7.5cm) should be transplanted from adjoining grassed area. To prevent slipping tendency of sodding patches, especially during rains, these should be anchored with wooden pegs.

**b)** In case of cutting slopes, having exposure of medium to large size boulders embedded in erodable soil, special protection measures may be required till the growth of vegetation takes place. Low to medium strength (13 to 22 kN/m) and biaxially oriented geogrids should cover the exposed boulders studded slopes and suitably anchored. Prior to adequate vegetation growth, surfacial erosion developing dislodging tendency of small to medium sized boulders could be checked with the help of polymer nets.

## 6.7. Other Aspects of Construction of Earthwork

### 6.7.1 Execution of Earthwork- General aspects

**a)** The spreading of material in layers of desired thickness over the entire width of embankment should be done by mechanical means and finished by a motor grader. The motor grader blade shall have hydraulic control suitable for initial adjustment and maintain the same so as to achieve the slope and grade.

**b)** Thickness of layer is decided based on field compaction trials. However, as a good practice thickness of layer should be generally kept as 300 mm for fill material and 250 mm for blanket material in loose state before compaction.

**c)** If natural moisture content (NMC) of the soil is less than the OMC, calculated amount of water based on the difference between OMC & NMC and quantity of earthwork being done at a time, should be added with sprinkler attached to water tanker and mixed with soil by motor grader or by other means for obtaining uniform moisture content. When soil is too wet, it is required to be dried by aeration to reduce moisture content near to OMC. Efforts should be made to keep moisture content level of the soil in the range of OMC ± 2% at the time of compaction.

**d)** Fill shall be placed and compacted in layers of specified thickness. The rate of progress should be, as far as possible, uniform so that the work is completed to final level almost at the same time.

**e)** The rolling for compaction of fill material should commence from edges towards center with minimum overlap of 200 mm between each run of the roller. In final pass, roller should simply move over the surface without vibration so that top surface is properly finished.

**f)** Extra bank width of 500 mm on either side shall be rolled to ensure proper compaction at the edges. The extra soil would be cut and dressed to avoid any loose earth at the slopes. This should preferably be done with help of grade cutter.

**g)** At the end of the working day, fill material should not be left uncompacted. Care should be taken during rolling to provide suitable slope on top of the bank to facilitate quick shedding of water and avoid ponding on formation.

**h)** During construction of formation, there may be rainfall to the extent that rain cuts may develop on the surface of formation due to erosion of soil. Care should be taken that these rain cuts are not allowed to develop wide and deep otherwise these locations will remain weak spots. Provisions should be made in contract conditions to attend / repair such rain cuts , as a regular measure.

**i)** Top of the formation should be finished to cross slope of 1 in 30 from one end to other towards cess/drain in multiple lines and from center of formation to both sides in single line.

**j)** Once the top surface of the formation has been finished to proper slope and level, movement of material vehicle for transportation of ballast, sleepers etc. should be avoided, these movements will cause development of unevenness, ruts on the surface which will accumulate water and weaken the formation. The methodology of transportation of P. Way material needs to be planned.

**k)** In conversion/doubling/rehabilitation projects, suitable benching of existing slope shall be done before new earthwork is taken up to provide proper bonding between old and new earthworks. It should be ensured that there is no humus material left on the benched slope. Care needs to be taken to avoid entry of rainwater into the formation from this weak junction., otherwise this would result in development of weak formation, slope failure, maintenance problem due to uneven settlement etc.

**l)** At locations where the water table is high and the fill soil is fine-grained, it may be desirable to provide a granular layer of about 30 cm thickness at the base, above subsoil across the full width of formation.

**m)** At the places where embankment materials are not conducive to plant growth, top soil obtained from site clearance as well as top layer of borrow pit which is rich in organic content and suitable for plant growth, may be stored for covering slopes of embankment & cutting after construction, or other disturbed areas, where re-vegetation is required, as far as practicable.

### 6.7.2 Widening of Embankment:

Before taking up widening of existing of embankment for gauge conversion, it should be ensure that remedial measures for unstable formation have been taken.

i) All vegetation shall be uprooted and taken away from the site of work. The loose materials removed from the slope should be dumped to form the bottom most layer on the ground in the width to be widened. If required, it shall be supplemented with local granular soil.

ii) Starting from the toe, benching on the slope at every 30cm height shall be provided on the slope surface as in Sketch-E, so as to provide proper amalgamation between the old and new earthwork.

iii) Earthwork shall be carried out in layers, each layer sloping out 1:30 and compacting it mechanically using vibratory rollers of around 0.9m width (which are available in the market), 6 to 8 passes of such rollers shall usually suffice to provide the compaction to the specified level.

iv) The width of each layer of earthwork shall be in excess by 300mm of the designed profile to enable compaction near the edges. The excess width, thereafter, cut and dressed, so as to achieve the required bank profile.

v) Earthwork shall be completed upto designed formation level keeping due allowance for the blanket if need be.

### 6.7.3 Raising of Existing Formation:

After widening of the bank to the level of the existing formation, raising shall be done as under:

i) Raising less than 150mm shall be done with ballast, restricting overall thickness to 350mm.

ii) Raising from 150mm to 1000mm, the existing ballast shall be taken out under suitable speed restriction and raising should be done in suitable steps with the material as per specification of blanket material, preferably that of upper blanket layer. After raising to the desired level, clean ballast shall be inserted.

iii) Raising of more than 1000mm, under traffic, would not be cost effective and it may be desirable to lay a detour for passage of traffic temporarily. Final decision shall, however, be based on economic considerations.

### 6.7.4 Earthwork in New Detours:

To facilitate easing out of existing sharp curves, change of gradients and rebuilding of important bridges, new detours shall be necessary. Design and construction of such detours shall be carried out in accordance with this provisions in the Guidelines.

### 6.7.5 Use of Construction Equipments for Execution of Earthwork

Any manual methods of construction cannot achieve the desired quality of earthwork. It would be necessary to deploy modern equipments such as earthmover, motor graders, scraper, dumpers, mobile water sprinklers, vibratory rollers, sheepfoot rollers etc. as per need, on all projects, so that the quality of work is as per laid down standards. It would be desirable to maintain records of work done by various equipments at a particular site to assess the out put and quality control.

### 6.7.6 Construction of New Formation over Soft Compressible Sub-soil:

Various methods such as i) pre- loading and stage construction, ii) installation of vertical sand drains, and iii) installation of prefabricated vertical drains are available for strengthening of such weak soil by expediting consolidation. Selection of a particular method for safe construction of embankment will basically depend on rate of construction. Therefore, depending on site requirement and techno-economic considerations, a particular method for construction may be decided in consultation with RDSO.

### 6.7.7 Sandwich Construction of Banks with Cohesive Soils:

Sandwich type of construction may be adopted for construction of embankments with cohesive soils having very low permeability (less than $10^{-2}$ cm/sec.) and where height of bank is greater than 3m. In such situations, a layer of coarse sand ( Cu > 2) of about 20 to 30 cm thick should be provided at bank height intervals of 2 to 3m. Sketch –G provides Guidelines for sandwich construction for different heights to improve factor of safety against slope failure, drainage and dissipation of pore water pressure. It is desirable to have a bottom layer of coarse sand in all cases where soils of low permeability is used even for depths upto 3m. However, before adopting such construction, it may be necessary to carry out a detailed technical study alongwith economics of sandwich construction, depending on site conditions and availability of material, if required, in consultation with RDSO.

### 6.7.8 Safety at Work Site:

Necessary precautions towards safety at work site, including doubling and gauge conversion, should be part of the contract document. Similarly, safety for staff working at site should be carefully ensured to avoid any untoward incidence. To the extent possible, the safety instructions are to be suitably incorporated in the

charge, if need be. However, the final acceptance of the blanket material should be at the site where it is laid, as follows:

**(a) Frequency of Tests at Site**: Minimum one test per 500 cum or part thereof.

**(b) Method of Test:** Blanket material should be tested as per IS: 2720 (Part 4) to plot particle size distribution curve, so as to assess its suitability. It would be necessary to carry out wet analysis to assess actual percentage of fines. To expedite testing work, dry sieve analysis may be carried out if variation between results of dry and wet analysis are not significant and adequate margin exists with respect to acceptance criteria. However, in such cases also, wet analysis has to be carried out at frequent interval to verify the extent of variation. In any situation, acceptance of blanket material would be based on wet analysis only. The samples for wet analysis should be prepared as per para 4.3 of IS: 2720 (Part 4).

**(c) Acceptance Criteria** : The material should generally conform to specification as given at para 4.3.4.

**7.2.2 Quality Control Checks on Finished Earthwork:**

**7.2.2.1 Compacted Earth:** Degree of compaction of each layer of compacted soil should be ascertained by measurement of dry density/Relative Density of soil at locations selected in specified pattern. The method of sampling, frequency of tests, method of tests to be conducted and acceptance criteria to be adopted are as under

**a) Method of Sampling** :

i) Various methods of selection of sample points for check of in-situ dry density are in vogue. These are shown in sketch-H. The sampling adopted has to be such that effectiveness of proper compaction having been done for the entire area under consideration can be judged.. For this, the Engineer in-charge should lay down the method adopted in detail depending on site conditions and accordingly records of checks done are properly maintained. However, in absence of such procedure laid down, following method should be adopted:

**Suggested Method of Sampling**: For each layer, a minimum of one sample at a predetermined interval (in compliance with the requirement stated in next para) along the centreline of the alignment, would be taken in a staggered pattern so as to attain a minimum frequency of tests as given in the para 7.2.2.1(b). For subsequent layer, the stagger should be such that the point of sampling does not fall vertically on the earlier sampling points of the layer immediately below. The process of sampling is explained in Sketch-H for guidance. Additional sampling points can be taken, as considered necessary.

ii) In case of bank widening, sampling should be done at an interval of minimum 200metres on widened side(s) of embankment.

In case, there are difficulties in achieving 98% of the MDD values as obtained by Laboratory test, in the field trials, the same may be relaxed upto 95% of MDD with the specific approval of Chief Engineer/construction, recording reasons of such relaxation.

iii) During widening of bank in case of gauge conversion and rehabilitation of unstable formation, compaction of earthwork should be minimum 95% of MDD as obtained by Laboratory test as per Heavy Compaction Test (IS: 2720 (part 8) – 1983) or 70% Relative Density for cohesionless soil (IS: 2720 ( Part 14) – 1983).

**7.2.2.2 Formation Level:** Finished top of sub-grade level may have variation from design level by ±25 mm and finished top of blanket layer may also be permitted to have variation from design level by plus 25 mm. The ballast should be placed only on level formation without ruts or low pockets.

**7.2.2.3 Cross Slope:** Cross slope should be within 1 in 28 to 1 in 30.

**7.2.2.4 Side Slopes:** Side slope should in no case be steeper than designed side slope. Provision of berm width should not be less than the designed width.

**7.2.2.5 Formation Width:** Formation width should not be less than the specified width.

**7.3 Speed Of Section During Opening:** Design and quality of construction should be such, so as to ensure opening of new lines, gauge conversions and doublings at full sectional speed and the same can be maintained through out the service life from geo-technical considerations.

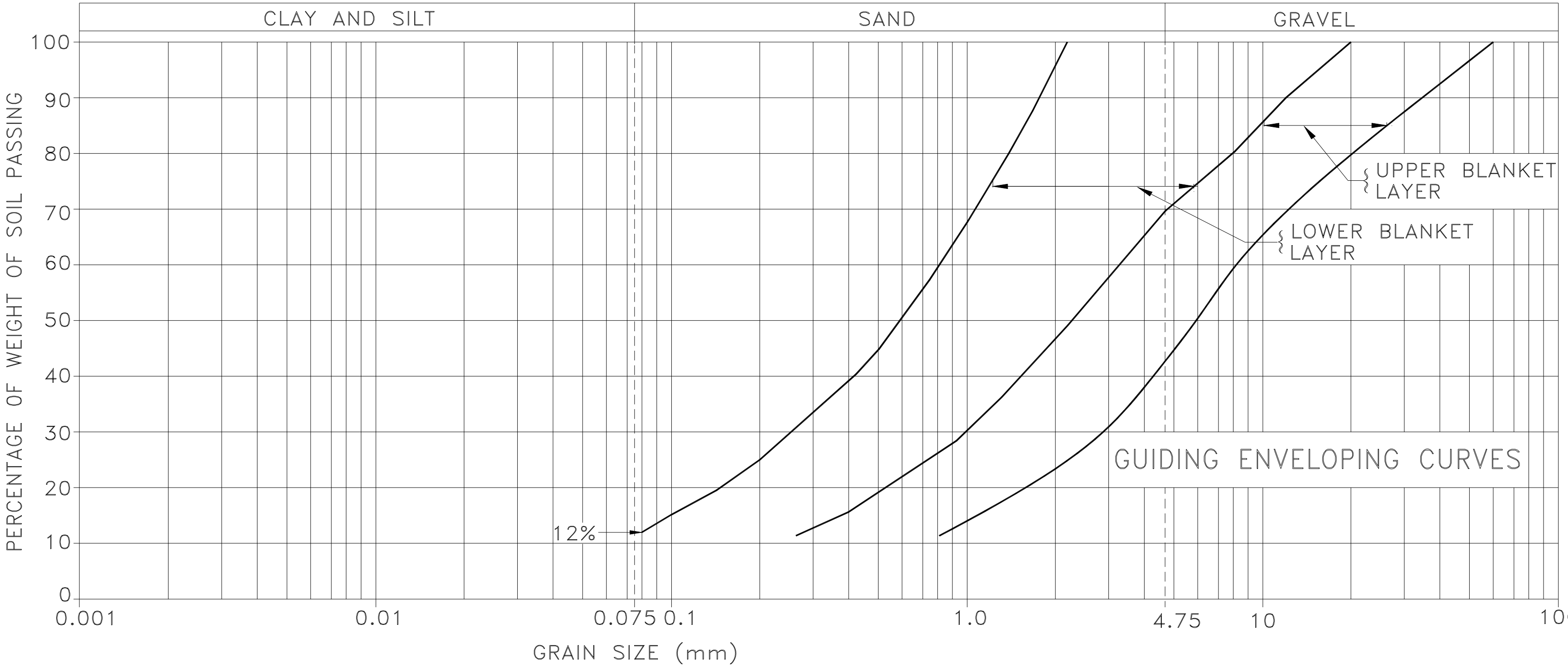
## 8.0 MAINTENANCE OF RECORDS

At work site, details of works along with materials being used are to be properly recorded so that work of satisfactory quality can be achieved which can also be verified at later stage. Records are also required to be maintained to develop completion drawings and other details, which would become permanent records of the section and could be helpful in future to plan developmental activities and remedial measures if need be. Some of important records to be maintained are as follows:

**8.1 Quality Control Records:** At least, following records of quality control as per proformas given in Annexure – VI , needs to be maintained.

i) Characteristics of borrow materials as per proforma No. 1 of Annexure – VI
ii) Quality of blanket materials as per proforma No. 2 of Annexure – X.
iii) Field compaction trial details as per proforma in Table 3 of Annexure – IV
iv) Quality of compaction of earthwork including blanket material as per proforma No. 3 for core cutter method & 4 of Annexure – X for sand replacement method.
v) Quality of material and its compaction for back fill behind bridge approaches etc as per proforma No. 1,2,3 & 4 of Annexure – X.

SKETCH–B
(Para no. 4.3.4.1)




SPECIFICATIONS:

1. THE BLANKET MATERIAL SHOULD BE COARSE,GRANULAR AND WELL GRADED.
2. SKIP GRADED MATERIAL IS NOT PERMITTED.
3. PARTICLES FINER THAN 75 MICRONS CAN BE PERMITTED UPTO 5% IF FINES ARE PLASTIC AND THE LIMITS CAN BE INCREASED TO 12% IF THE FINES ARE NON PLASTIC.
4. UNIFORMITY COEFFICIENT ($D_{60}/D_{10}$), IN NO CASE SHOULD BE LESS THAN 4. PREFERABLY IT SHOULD BE MORE THAN 7.
5. THE COEFFICIENT OF CURVATURE ($D_{30}^2 / D_{60} . D_{10}$), TO BE WITHIN 1 & 3.
6. THE PARTICLE SIZE GRADATION CURVE SHOULD LIE MORE OR LESS WITHIN GUIDING ENVELOPING CURVES.
7. LOWER BLANKET LAYER WILL BE PROVIDED FOR AXLE LOAD UPTO 22.5t AND UPPER BLANKET LAYER IS REQUIRED FOR HIGHER AXLE LOADS.

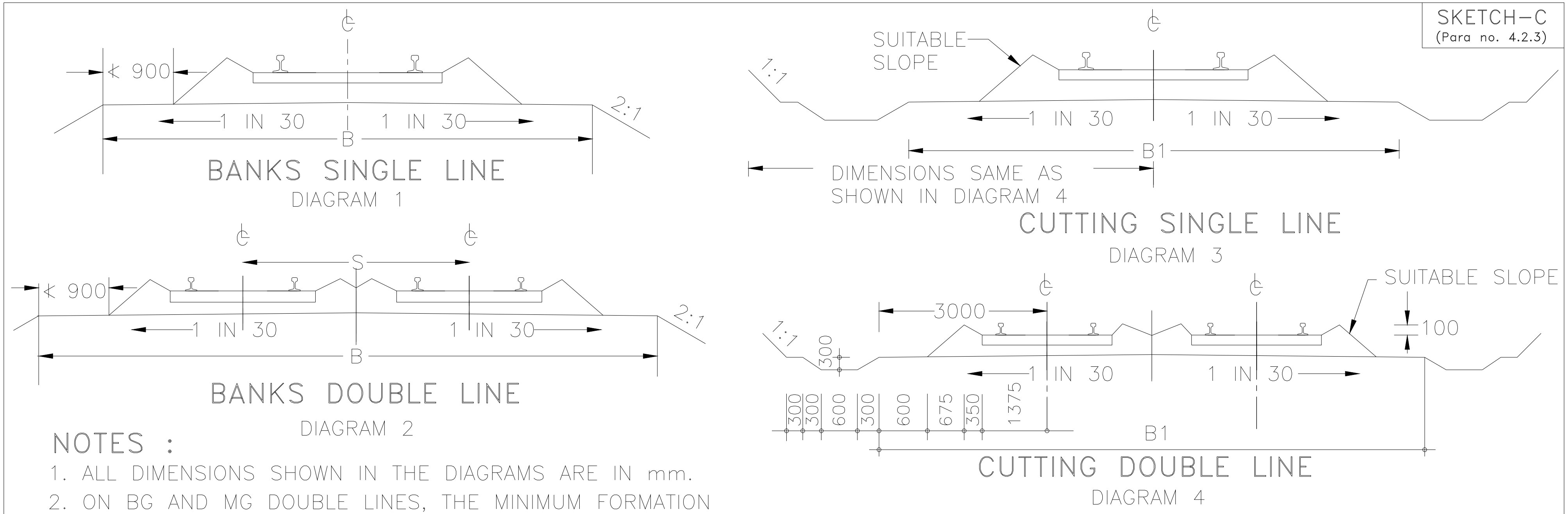
R. D. S. O.

GUIDELINES FOR EARTHWORK IN RLY. PROJECTS

SPECIFICATIONS FOR BLANKET MATERIAL

DRG.NO: GT/SD/0011/Rev.2/2001

SKETCH–C
(Para no. 4.2.3)




NOTES :

1. ALL DIMENSIONS SHOWN IN THE DIAGRAMS ARE IN mm.
2. ON BG AND MG DOUBLE LINES, THE MINIMUM FORMATION WIDTH IS BASED ON DISTANCE (S) BETWEEN TRACK CENTRES OF 5.30m AND 4.96m RESPECTIVELY.
3. IN FLAT TERRAINS THE HEIGHT OF BANK/DEPTH OF CUTTINGS SHOULD PREFERABLY BE NOT LESS THAN 1m FOR ENSURING GOOD DRAINAGE, FORMATION STABILITY AND TO AVOID TRESSPASSING.
4. THESE DIMENSIONS ARE BASED ON A BALLAST CUSHION OF 30cm.
5. THESE DIMENSIONS ARE ALSO APPLICABLE IN CASE OF ALL NEW LINES BECAUSE OF THE POSSIBILITY OF USE OF CONCRETE SLEEPER AT A LATER DATE.
6. ON CURVES THE FOLLOWING INCREASE IN FORMATION WIDTHS SHALL BE MADE:–
   (1) FOR EXTRA BALLAST CUSHION ON OUTERSIDE OF THE CURVE 0.15m ON SINGLE LINE AND 0.30m ON DOUBLE LINE (INCLUDING 0.15m INCREASE IN TRACK CENTRES).
   (2) FOR EXTRA CLEARANCE REQUIRED ON DOUBLE LINE DUE TO EFFECT OF SUPER–ELEVATION ETC. AS STIPULATED IN APPENDIX TO THE SCHEDULE OF DIMENSIONS FOR BG./MG.
7. FORMATION WIDTH HAS BEEN CALCULATED ASSUMING A BALLAST SIDE SLOPE OF 1:1

| GAUGE | MINIMUM FORMATION WIDTHS | | | |
|---|---|---|---|---|
| | IN BANKS (B) | | IN CUTTINGS (B1) | |
| | SINGLE LINE | DOUBLE LINE | SINGLE LINE | DOUBLE LINE |
| BG 1676 | 6.85m | 12.16m | 6.25m | 11.55 |
| MG 1000 | 5.85m | 9.81m | 5.25m | 9.21m |

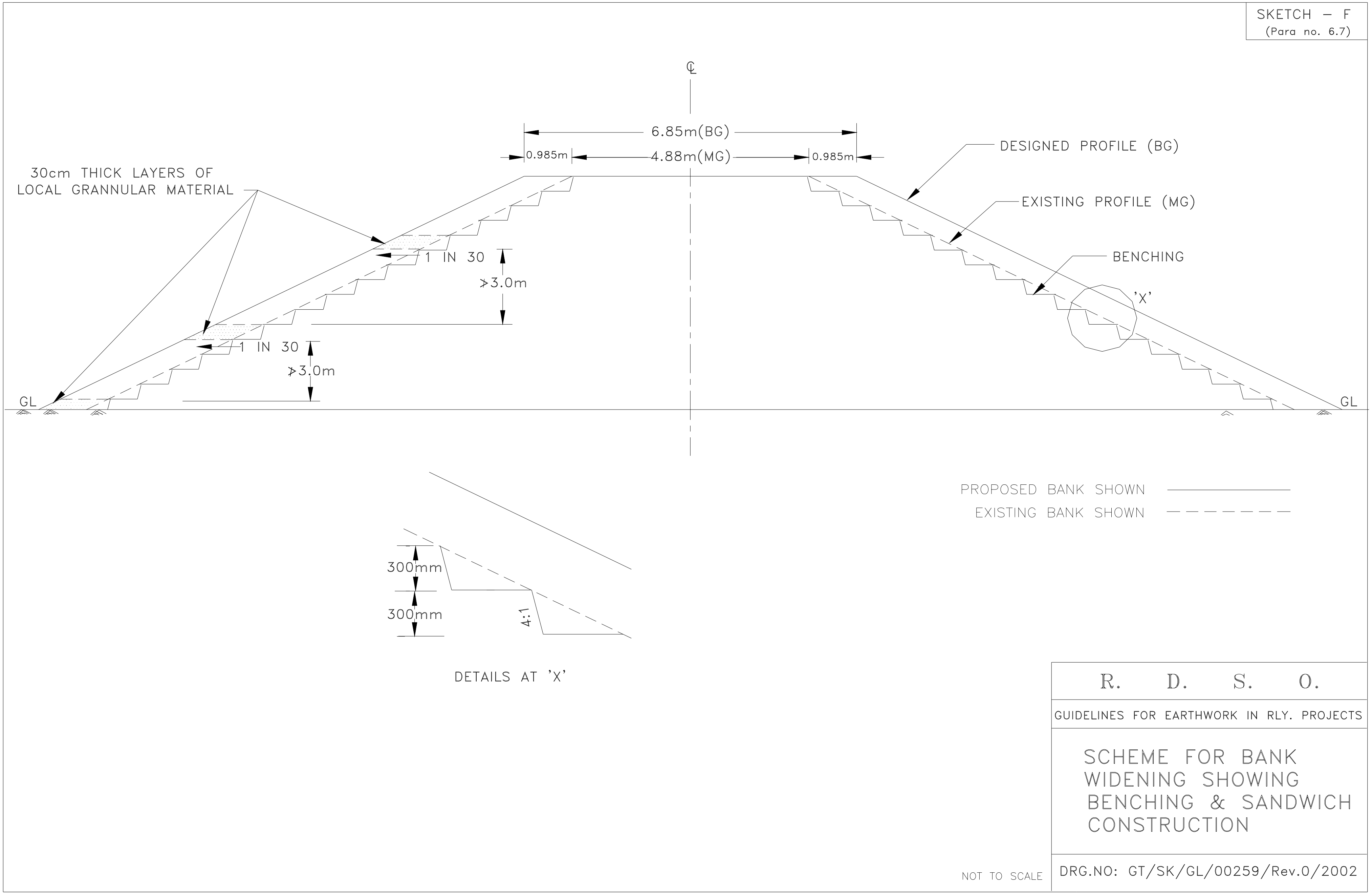
NOT TO SCALE

R. D. S. O.

GUIDELINES FOR EARTHWORK IN RLY. PROJECTS

MINIMUM RECOMMENDED FORMATION WIDTHS FOR BANKS/CUTTINGS FOR CONCRETE SLEEPER TRACK

DRG.NO: GT/SK/GL/0128/Rev.1/2002




R. D. S. O.

GUIDELINES FOR EARTHWORK IN RLY. PROJECTS

SCHEME FOR BANK WIDENING SHOWING BENCHING & SANDWICH CONSTRUCTION

DRG.NO: GT/SK/GL/00259/Rev.0/2002

SKETCH-G
(para no.6.7.7)

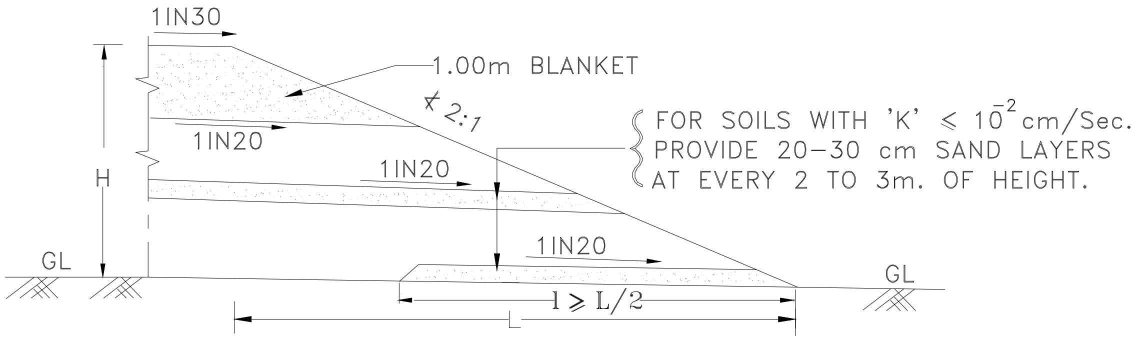



FIG. (a) H ≤ 6m

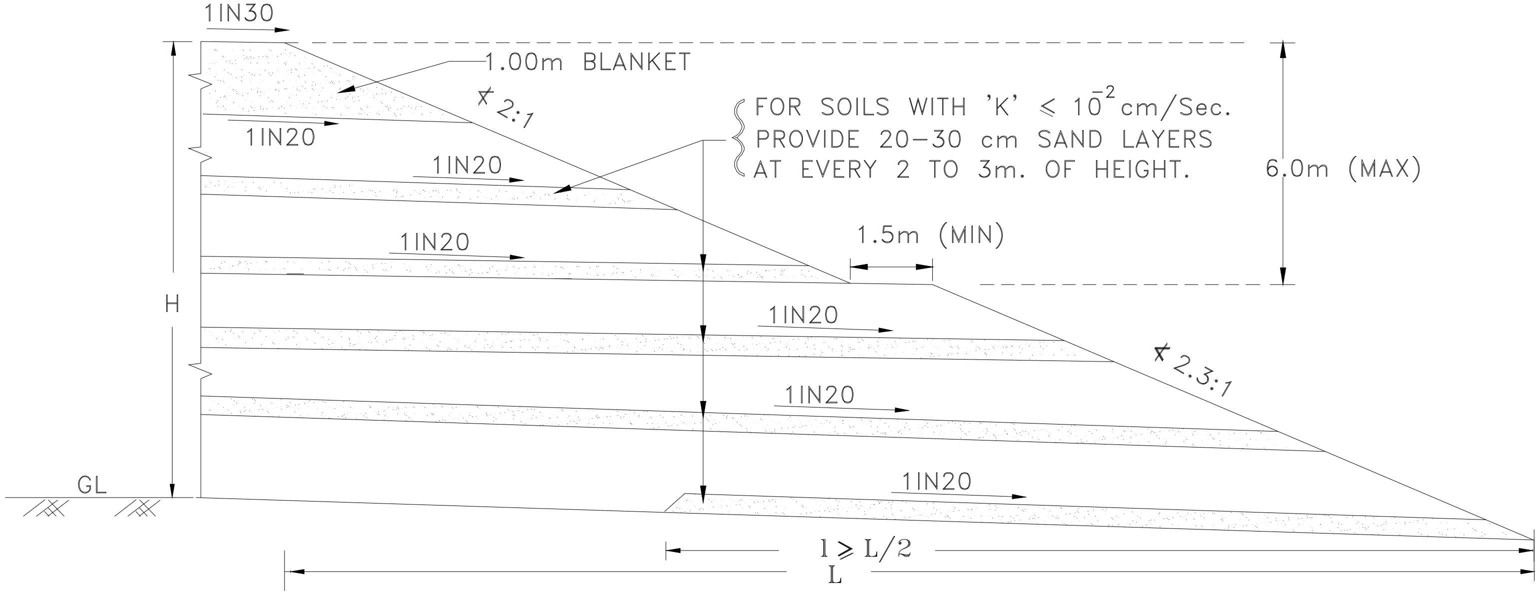



FIG. (b) H – 6m TO 12m

NOTES:

1. FOR BANK OF HEIGHT MORE THAN 12m PROPER COMPUTATION FOR FAILURES AGAINST SLIPS, SETTLEMENT, ETC. SHOULD BE CARRIED OUT.
2. COEFFICIENT OF UNIFORMITY (Cu), OF SAND TO BE USED FOR SANDWICH CONSTRUCTION SHOULD BE GREATER THAN 2.

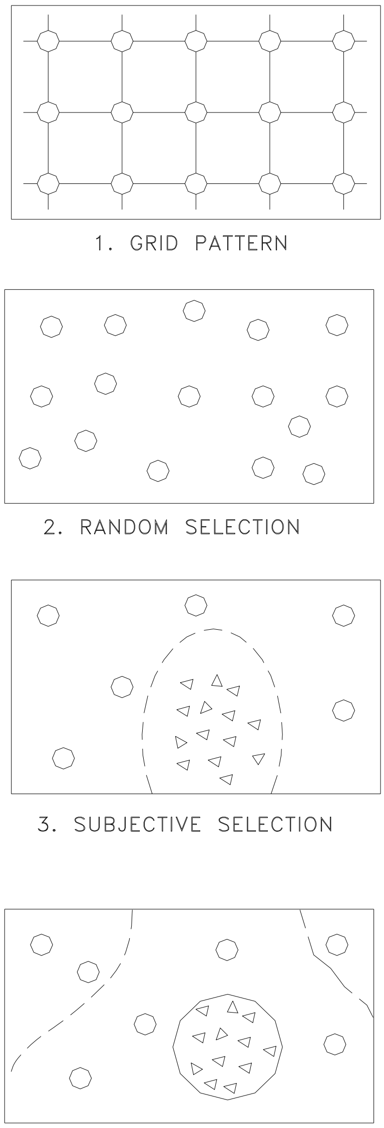
R. D. S. O.

GUIDELINES FOR EARTHWORK IN RLY. PROJECTS

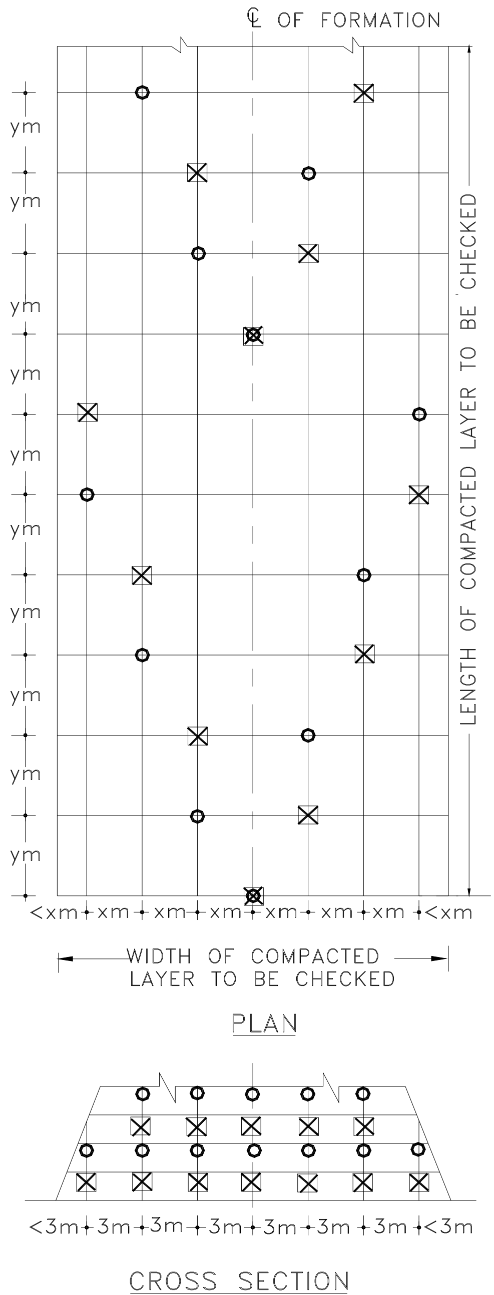
TYPICAL EMBANKMENT PROFILE FOR SANDWICH CONSTRUCTION WITH COHESIVE SOILS

DRG.NO: GE/SD/0019/Rev.0/2003

SKETCH – H
(Para no. 7.2.2.1a)




DIFFERENT SAMPLING PATTERNS
FOR DENSITY CHECK




LEGEND: ☒ SAMPLING POINTS FOR A TYPICAL LAYER
o SAMPLING POINTS FOR NEXT LAYER

SUGGESTED SAMPLING PATTERN FOR
CHECKING OF DENSITY

NOTE: x & y ARE SAMPLING INTERVALS
TO BE DETERMINED AS PER
SAMPLING AREA REQUIREMENT.
(REF. PARA 7.2.2.1b)

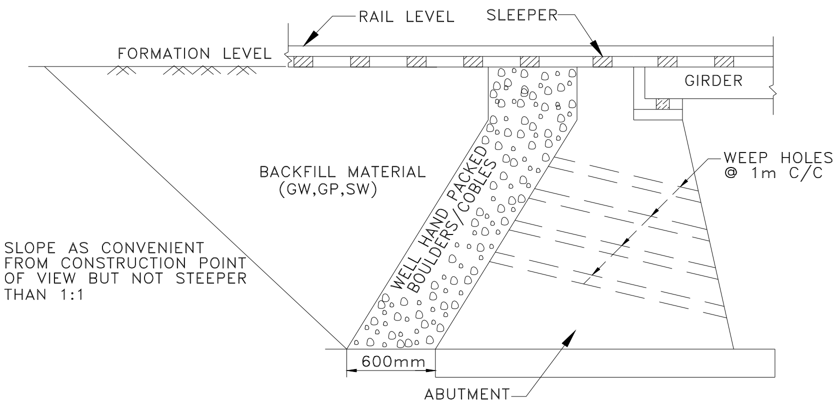
R. D. S. O.

GUIDELINES FOR EARTHWORK IN RLY. PROJECTS

SAMPLING PATTERNS FOR
CHECK OF COMPACTION

DRG.NO.: GT/SK/GL/00253/Rev.0/2002)

SKETCH– I
(PARA NO. 6.4.2)



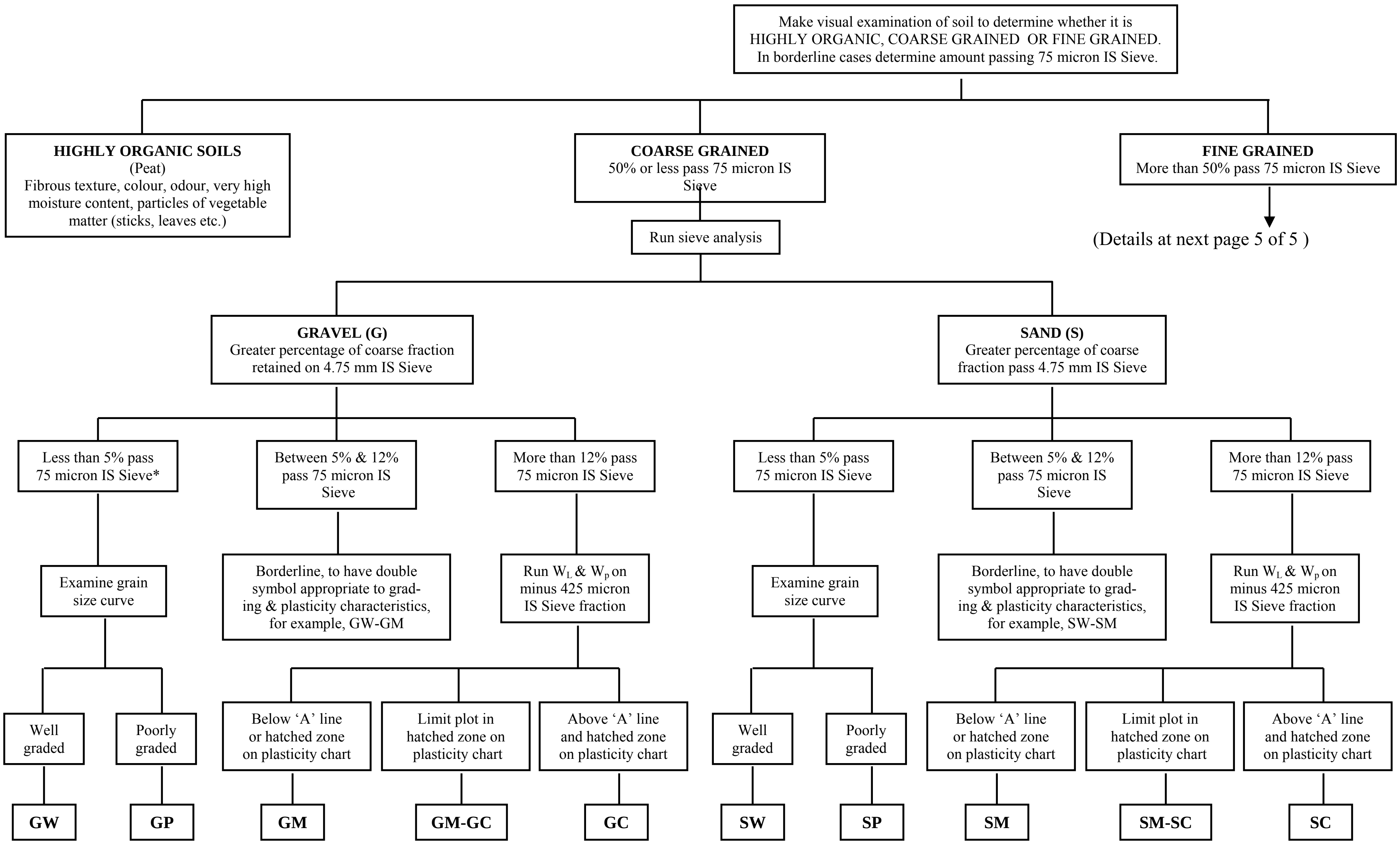

NOTE:– 1. BEHIND ABUTMENTS, WING WALLS AND RETURN WALLS, BOULDER FILLING AND BACKFILL MATERIALS SHALL BE PROVIDED UPTO FULL HEIGHT.

2. THE BOULDER FILLING SHALL CONSIST OF WELL HAND PACKED BOULDERS & COBBLES TO THICKNESS NOT LESS THAN 600mm WITH SMALLER SIZE TOWARDS THE BACK. BEHIND THE BOULDER FILLING, BACKFILL MATERIALS, SHALL CONSIST OF GRANULAR MATERIALS OF GW, GP, SW GROUPS AS PER IS: 1498–1970.

| | |
|---|---|
| | R. D. S. O. |
| | GUIDELINES FOR EARTHWORK IN RLY. PROJECTS |
| | DETAIL OF BACKFILL BEHIND BRIDGE ABUTMENT |
| NOT TO SCALE | DRG.NO. GE/SD/0006/Rev.1/2002 |

**ANNEXURE – I**
(Page 4 of 5 )

## LABORATORY IDENTIFICATION PROCEDURE




$W_L$ = Liquid limit $W_p$ = Plastic limit

*If fines interfere with free drainage properties use double symbol, such as GW-GM.

TABLE –17
STABILITY COEFFICIENTS m and n FOR C'/ϒH = 0.125 & D=1.50

| ϕ′ | SLOPE 2:1 | | SLOPE 3:1 | | SLOPE 4:1 | | SLOPE 5:1 | |
|---|---|---|---|---|---|---|---|---|
| | m | n | m | n | m | n | m | n |
| 20.0 | 2.234 | 1.545 | 2.565 | 1.749 | 2.963 | 2.004 | 3.400 | 2.287 |
| 25.0 | 2.638 | 1.972 | 3.028 | 2.229 | 3.500 | 2.550 | 4.019 | 2.913 |
| 30.0 | 3.072 | 2.425 | 3.529 | 2.749 | 4.083 | 3.149 | 4.692 | 3.598 |
| 35.0 | 3.549 | 2.923 | 4.084 | 3.324 | 4.727 | 3.813 | 5.436 | 4.362 |
| 40.0 | 4.089 | 3.485 | 4.712 | 3.980 | 5.456 | 4.566 | 6.278 | 5.226 |

TABLE –18
STABILITY COEFFICIENTS m and n FOR C'/ϒH = 0.150 & D=1.00

| ϕ′ | SLOPE 2:1 | | SLOPE 3:1 | | SLOPE 4:1 | | SLOPE 5:1 | |
|---|---|---|---|---|---|---|---|---|
| | m | n | m | n | m | n | m | n |
| 20.0 | 2.261 | 1.170 | 2.895 | 1.448 | 3.579 | 1.806 | 4.230 | 2.159 |
| 25.0 | 2.536 | 1.462 | 3.259 | 1.814 | 4.052 | 2.280 | 4.817 | 2.765 |
| 30.0 | 2.836 | 1.791 | 3.657 | 2.245 | 4.567 | 2.811 | 5.451 | 3.416 |
| 35.0 | 3.161 | 2.153 | 4.098 | 2.721 | 5.137 | 3.408 | 6.143 | 4.117 |
| 40.0 | 3.512 | 2.535 | 4.597 | 3.258 | 5.782 | 4.083 | 6.913 | 4.888 |

TABLE –19
STABILITY COEFFICIENTS m and n FOR C'/ϒH = 0.150 & D=1.25

| ϕ′ | SLOPE 2:1 | | SLOPE 3:1 | | SLOPE 4:1 | | SLOPE 5:1 | |
|---|---|---|---|---|---|---|---|---|
| | m | n | m | n | m | n | m | n |
| 20.0 | 2.229 | 1.334 | 2.701 | 1.600 | 3.225 | 1.873 | 3.780 | 2.182 |
| 25.0 | 2.560 | 1.692 | 3.107 | 2.015 | 3.724 | 2.384 | 4.363 | 2.769 |
| 30.0 | 2.909 | 2.065 | 3.542 | 2.464 | 4.262 | 2.941 | 5.995 | 3.406 |
| 35.0 | 3.295 | 2.475 | 4.018 | 2.946 | 4.846 | 3.534 | 5.697 | 4.129 |
| 40.0 | 3.728 | 2.938 | 4.556 | 3.509 | 5.498 | 4.195 | 6.490 | 4.947 |

TABLE –20
STABILITY COEFFICIENTS m and n FOR C'/ϒH = 0.150 & D=1.50

| ϕ′ | SLOPE 2:1 | | SLOPE 3:1 | | SLOPE 4:1 | | SLOPE 5:1 | |
|---|---|---|---|---|---|---|---|---|
| | m | n | m | n | m | n | m | n |
| 20.0 | 2.394 | 1.550 | 2.748 | 1.756 | 3.174 | 2.020 | 3.641 | 2.308 |
| 25.0 | 2.798 | 1.978 | 3.212 | 2.237 | 3.711 | 2.561 | 4.259 | 2.924 |
| 30.0 | 3.236 | 2.441 | 3.718 | 2.758 | 4.293 | 3.156 | 4.931 | 3.604 |
| 35.0 | 3.715 | 2.940 | 4.269 | 3.333 | 4.938 | 3.819 | 5.675 | 4.364 |
| 40.0 | 4.255 | 3.503 | 4.896 | 3.983 | 5.667 | 4.569 | 6.517 | 5.228 |

**TABLE -1 FIELD COMPACTION TRIAL OBSERVATION** **ANNEXURE- IV**



**Project** ______________________________ **Date** ______________________

**Location** ____________________________________

| Strip No. | Location on the ramp | Moisture content before watering | | | | Moisture content after adding the water | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Container No. | Weight of wet soil.(gms) | Weight of dry soil.(gms) | Moisture content(%) | Container No. | Weight of wet soil.(gms) | Weight of dry soil.(gms) | Moisture content(%) |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| J | 1 | | | | | | | | |
| | 2 | | | | | | | | |
| | 3 | | | | | | | | |
| | 4 | | | | | | | | |
| K | 1 | | | | | | | | |
| | 2 | | | | | | | | |
| | 3 | | | | | | | | |
| | 4 | | | | | | | | |
| L | 1 | | | | | | | | |
| | 2 | | | | | | | | |
| | 3 | | | | | | | | |
| | 4 | | | | | | | | |
| M | 1 | | | | | | | | |
| | 2 | | | | | | | | |
| | 3 | | | | | | | | |
| | 4 | | | | | | | | |

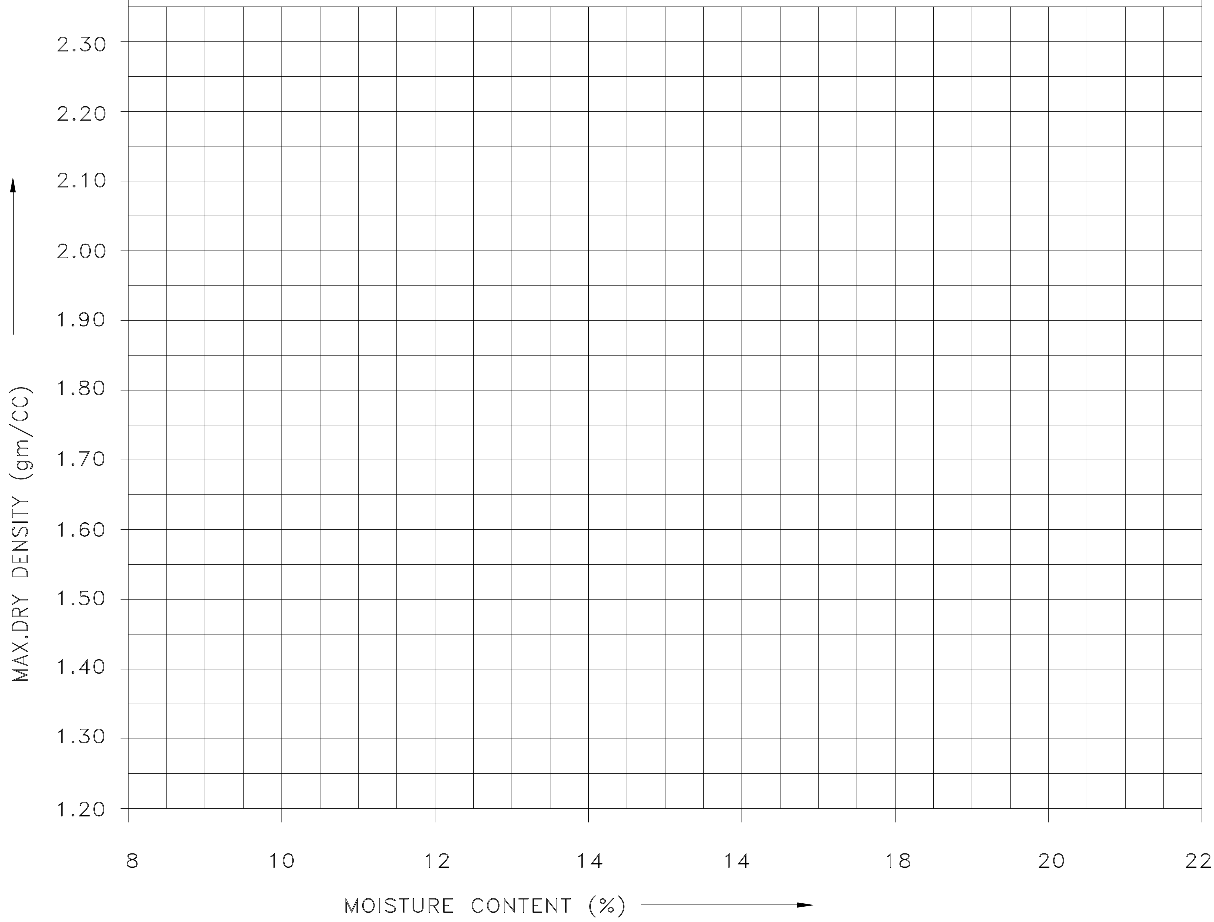
**Signature of Monitoring official**__________________
**Name**_______________________________________
**Designation**__________________________________
**Date** ______________________

**Signature of Project Official**______________________
**Name**______________________
**Designation**_________________________________
**Date** ______________________

FIG. 3 OF 3

| NAME OF PROJECT | LIFT | NOTATION |
|---|---|---|
| LOCATION | 225mm | ○———○ |
| | 300mm | ●———● |
| | 375mm | △———△ |
| | 450mm | ▲———▲ |

MOISTURE CONTENT Vs MAX.DRY DENSITY FOR VARIOUS LIFT THICKNESS




| OFFICIALS – IN – CHARGE | | QUALITY CONTROL OFFICIALS | |
|---|---|---|---|
| SIGNATURE | ______________ | SIGNATURE | ______________ |
| NAME OF OFFICER | ______________ | NAME OF OFFICER | ______________ |
| DESIGNATION | ______________ | DESIGNATION | ______________ |
| DATE | ______________ | DATE | ______________ |
| SIGNATURE | ______________ | SIGNATURE | ______________ |
| NAME OF OFFICER | ______________ | NAME OF OFFICER | ______________ |
| DESIGNATION | ______________ | DESIGNATION | ______________ |
| DATE | ______________ | DATE | ______________ |

**ANNEXURE – V**
**(page 1 0f 3)**

**Typical Compaction Characteristics for natural soils, rocks and artificial materials (Ref: BS: 6031 – 1981, Table 4)**

| **Material** (1) | **Major divisions** (2) | **Subgroups** (3) | **Suitable type of compaction plant** (4) | **Maximum number of passes for satisfactory compaction** (5) | **Maximum thickness of compacted layer (mm)** (6) | **Remarks** (7) |
|---|---|---|---|---|---|---|
| Rock-like materials | Natural rocks | All rock fill (except chalk) | Heavy vibratory roller not less than 180 kg per 100 mm of roll<br>Grid roller not less 180 kg per 100 mm of roll<br>Self- propelled tamping rollers | 4 to 12 | 500 to 1500 depending on plant used | If well graded or easily broken down then this can be classified as a coarse-grained soil for the purpose of compaction. The maximum diameter of the rock fragment should not exceed two third of the layer thickness. |
| | | Chalk | See remarks | 3 | 500 | This material can be very sensitive to weight and operation of compacting effort and spreading plant. Less compactive effort is needed than with other rocks. |
| Artificial | Waste material | Burnt and unburnt colliery shale | Vibratory roller<br>Smooth wheeled roller<br>Self-propelled tamping roller | 4 to 12 depending on weight of plant | 300 | |
| | | Pulverized fuel ash | Vibratory roller<br>Self-propelled tamping roller<br>Smooth wheeled roller<br>Pneumatic tired roller | | | Includes lagoon and furnace bottom ash |
| | | Broken concrete, bricks, steelworks,<br>slag , etc. | Heavy vibratory roller<br>Self-propelled tamping roller<br>Smooth wheeled roller | | | Non-processed sulphide brick slag should be use with caution |

(continued)

| (1) | (2) | (3) | (4) | (5) | (6) | (7) |
|---|---|---|---|---|---|---|
| Coarse-grained soils | Gravel sand, gravelly soils | Well graded gravel and gravel/sand mixture: little or no fines<br>Well graded gravel/ sand mixtures with excellent clay binder<br>Uniform gravel: little or no fines<br>Poorly graded gravel and gravel/sand mixtures: little or no fines<br>Gravel with excess fines, silty gravel, clayey gravel, ,poorly graded gravel/ sand/clay mixtures | Grid roller over 540 kg per 100mm of roll<br>Pneumatic tired over 2000 kg per wheel<br>Vibratory plate compactor over 1100 kg/sq.m. of base plate<br>Smooth wheel roller<br>Vibratory roller<br>Vibro-rammer<br>Self-propelled temping roller | 3 to 12 depending on type of plant | 75 to 275 depending on type of plant | |
| | Sand and sandy soils | Well graded sands and gravelly sands; little or no fines<br>Well graded sands with excellent clay binder | | | | |
| | Uniform sands and gravels | Uniform gravels; little or no fines<br>Uniform sands; little or no fines<br>Poorly graded sands; little or no fines<br>Sands with fines, silty sands, clayey sands, poorly graded sand/clay mixtures | Smooth wheeled roller below 500kg per 100mm of roll<br>Grid roller below 540kg per 100mm of rolling<br>Pneumatic tired roller below 1500kg per wheel<br>Vibratory roller<br>Vibrating plate compactor<br>Vibro-tamper | 3 to 16 depending on type of plant | 75 to 300 depending on type of plant | |

| **(1)** | **(2)** | **(3)** | **(4)** | **(5)** | **(6)** | **(7)** |
|---|---|---|---|---|---|---|
| Fines soils | Soils having low plasticity | Silts (inorganic) and very fine sands, rock flour, silty or clayey fine sands with slight plasticity<br>Clayey silts (inorganic)<br>Organic silts of low plasticity | Sheepsfoot roller<br>Smooth wheeled roller<br>Pneumatic tired roller<br>Vibratory roller over 70 kg per 100 mm of roll<br>Vibratory plate compactor over 1400 kg/sq.m of base plate<br>Vibro-tamper<br>Power rammer | 4 to 8 depending on type of plant | 100 to 450 depending on type of plant | If water content is low, it may be preferable to use vibratory roller. Sheepsfoot rollers are best suited to soils at water contents below their plastic limit. |
| | Soils having medium plasticity | Silty and sandy clays (inorganic) of medium plasticity<br>Clays (inorganic) of medium plasticity | | | | |
| | | Organic clays of medium plasticity | | | | Generally unsuitable for Earthworks |
| | Soils having high plasticity | Micaceous or diatomaceous fine sandy and silty soils, plastic silts<br>Clay ( inorganic) of high plasticity, fat clays | | | | Should only be used when circumstances are favourable. |
| | | Organic clays of high plasticity | | | | Should not be used for earthworks |

Note: The information in this table should be taken only as a general guide. Field trials for compaction should be conducted for working out optimum layer thickness and number of roller passes for the type of compaction equipment being used. Compaction of mixed soils should be based on that subgrade requiring most compactive effort.

**ANNEXURE VI**
(page 1 0f 4)

**PROFORMA NO 1**

## Details of Borrow soil/ Formation subgrade

| S. no | Date of taking sample | Location of subgrade sample Chainage/km | Soil type | | | | Soil classification | LL | PL | Whether of dispersive nature | Suitable/ Non suitable, | Signature and name of Rly official | Signature and name of contractor | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Gravel % | Sand % | Silt % | Clay % | | | | | | | | |
| 1 | 2 | 3 | 4 | 5 | 6 | | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 |

**ANNEXURE VI**
**(page 2 of 4)**

**PROFORMA NO 2**

## QUALITY OF BLANKET MATERIAL

1. Height of bank
2. Type of material: Crusher / Blending

| S.no | Date of taking sample | Location of blanket layer Ch/km | Soil type | | | Fines Plastic/non plastic % | $C_u$ | $C_c$ | Quality Non suitability, skip grading etc | Abrasion Value (only for axle load > 22.5 t) | Signature and name of Rly official | Signature and name of contractor | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Gravel % | Sand % | Silt + Clay % (passing 75 mic) | | | | | | | | |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 |

**ANNEXURE-VI**
(page 3 of 4)

PROFORMA FOR FIELD COMPACTION RECORD **PROFORMA No 3**

Chainage / km from …… to……….
Height of bank:
Type of roller being used:

Soil Classification:
OMC:
Lab. MDD/ Field Trial MDD:

## CORE CUTTER METHOD

| Date of Laying | Layer no. | location coordinate for check | Placment moisture content (%) | No. of passes | Wt.of core cutter+wet soil (g) | Wt.of core cutter (g) | Wt of wet soil (g) | Vol.of core cutter (cc) | Bulk density, $\gamma b$ (g/cc) |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |

| Moisture content of compacted layer (%) | Dry Density, $\gamma d$ (g/cc) | Degree of compaction (%) | Sig. And name of Rly officer | Sig.and name of contractor | Remarks |
|---|---|---|---|---|---|
| 11 | 12 | 13 | 14 | 15 | 16 |

Note: In case of compaction of blanket material, percentage of fines should also be mentioned in a column. The above format is taken from Appendix A (page 8) of IS: 2720 Pt 29 - 1975

**ANNEXURE-VI**
(page 4 0f 4)

**PROFORMA FOR FIELD COMPACTION RECORD** **Proforma No. 4**

Chainage /km from …… to……….
Height of bank:

Soil Classification:
$\gamma$ max (from lab) ………………..
$\gamma$ min (from lab) ……………….

**SAND REPLACEMENT METHOD**

| Location | Bulk density of sand, ($\gamma s$) g/cum | Wt of wet soil from hole, $W_w$ (g) | Wt of Cylinder + Sand, before pouring W1 (g) | Wt of sand + Cylinder after pouring W2 (g) | Mean weight of sand in cone W3 (g) | Wt of sand in hole Wb = W1 - W2-W3 | Bulk Density of soil $\gamma b = (W_w / Wb) * \gamma s$ | Moisture content (w), % | Dry Density of soil $\gamma d = \gamma b/1+w$ | Relative Density $I_D$ | Sign. and name of Rly Official | Sign and name .of contractor | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|

Note: Relative density, $I_D$, is worked out as , $I_D = \gamma \max (\gamma d - \gamma \min) / \gamma d (\gamma \max - \gamma \min)$

The above format is taken from appendix A (Page 18 and 19) of IS: 2720 (Pt 28 )1974

**Summary of Quality control tests of Earth Work**

**ANNEXURE – VII**
(page 1 0f 1)

| Item/ Material | tests to be conducted | Testing equipment to be used | IS Code Ref. | Frequency of test | Sampling | Acceptance Criteria | Purpose of test |
|---|---|---|---|---|---|---|---|
| i) Borrow material | Soil classification, OMC, MDD, NMC, NDD | Sieve, hydrometer, Atterberg limit apparatus, modified Proctor mould, oven, balance, weight, distilled water, dispersing agent. | IS: 2720 Relevant part | Minimum one test for every 5000 cum or change of strata wherever is earlier | Disturbed sample | Should not be "unsuitable type " as given in para 5.1 | - Suitability of material<br>-To decide OMC & MDD |
| ii) Blanket material | Soil classification, Particle size distribution curve,% fine, Cu, Cc, γmax, γmin, or OMC & MDD | as above plus RD apparatus | -do- | Minimum one test for 500 cum | Sampling from material placed at formation | Should conform to specification given as per para 4.3.4.1 | Suitability of material |
| iii) Compacted earth (Sub-grade)<br><br>iv) Blanket Layer | Field dry density<br><br>Field dry density | Core Cutter & Sand replacement Apparatus, Nuclear Moisture- Density Gauge, Continuous compaction recorder mounted in roller.<br>-do- | IS - 2720 Relevant part | a) Min. one test in each compacted layer for every 200 sqm in top 1 m of subgrade<br>b) Min. one test in each compacted layer for every 500 sqm below top 1 m of subgrade<br>c) Min. one test in each compacted layer of blanket for every 200sqm | Sampling as per para 7.2.2.1(a)<br><br>Sampling as per para 7.2.2.1(a) | 98% of Lab. MDD as per Heavy Compaction test or as decided from field compaction trial or 70% of Density index for soils having fines < 5% | To ascertain degree of compaction<br><br>To ascertain degree of compaction |

**<u>SALIENT FEATURES OF VIBRATORY ROLLERS MANUFACTURED IN INDIA</u>**

**ANNEXURE - VIII**
(page 1 0f 1)

| MAKE | MODEL No. | OPERATING WEIGHT (Kg) | DRUM DETAIL | | | NORMAL AMPLITUDE (mm) | VIBRATING FREQENCY (Hz) | REMARKS |
|---|---|---|---|---|---|---|---|---|
| | | | DRUM WIDTH (mm) | AXLE LOAD (T) | | | | |
| | | | | FRONT | REAR | | | |
| ESCORTS | EC 5250 STD | 9350 | 2130 | 5.050 | 4.300 | 1.72 | 30 | |
| | EC 5250 D | 9550 | 2130 | 5.250 | 4.300 | 1.72 | 30 | It is used for better gradeability. |
| | EC 5250 PD | 10500 | 2130 | 6.650 | 4.300 | 1.53 | 30 | It is used for better gradeability & breaking clods. |
| | HD 85 | 9300 | 1680 | 4.650 | 4.650 | 1.27/0.75 | 0-30/42 | |
| GREAVES BOMAG | BW 212-D-2(2A) | 10424 | 2100 | 6.463 | 3.961 | 1.67 | 40/31 | It is used for better gradeability. |
| | BW 212-PD-2 | 10879 | 2100 | 6.201 | 4.678 | 1.5 | 30 | It is used for better gradeability & breaking clods. |
| L&T | 1104 STD | 11150 | 2330 | 5.770 | 5.380 | 1.6/0.6 | 28/36 | |
| | 1104 D | 11150 | 2330 | 5.900 | 5.535 | 1.6/0.6 | 28/36 | It is used for better gradeability. |
| | 1104 PD | 11835 | 2330 | 6.300 | 5.535 | 1.6 | 28 | It is used for better gradeability & breaking clods. |
| INGERSOLL-RAND | ISD-100 STD | 10740 | 2135 | 6.210 | 4.535 | 1.7 | 0-30 | |
| | ISD-100 D | 10830 | 2135 | 6.295 | 4.535 | 1.7 | 0-30 | It is used for better gradeability. |
| | ISD-100 F | 11740 | 2135 | 7.205 | 4.535 | 1.41 | 0-30 | |

<u>NOTE</u> : The rollers indicated above can also be used in Static mode. The list includes rollers manufactured by reported firms only.
<u>LEGEND</u> : STD = Standard Type, D = Drum Type & PD = Pads+ Drum Type

**ANNEXURE - IX**


## LIST OF RELEVENT I.S. CODES

| S. NO. | I.S. CODE NO. | DISCRIPTION |
|---|---|---|
| 1. | IS: 2720 -1983 Part-1 (Revision 2) | Methods of test for soils. Preparation of dry soil samples for various tests. |
| 2. | IS: 2720-1973 Part-2 (Revision 2) | Methods of test for soils. Determination of water content |
| 3. | IS: 2720-1964 Part-3 Section 1 | Methods of test for soils. Determination of specific gravity. Fined grained soils (Reaffirmed 1987) |
| 4. | IS: 2720-1980 Part-3 Section 2 (Revision 1) | Methods of test for soils. Determination of specific gravity. Section 2 Fine, Medium and coarse-grained soils. (Reaffirmed 1987) |
| 5. | IS: 2720-1985 Part-4 (Revision 2) | Methods of test for soils. Grain size analysis. |
| 6. | IS: 2720-1985 Part-5 (Revision 2) | Methods of test for soils. Determination of liquid and plastic limits. |
| 7. | IS: 2720-1972 Part –6 (Revision 1) | Methods of test for soils. Determination of shrinkage factors. |
| 8. | IS: 2720-1980 Part-7 (Revision 2) | Methods of test for soils. Determination of water content-dry density relation using light compaction. |
| 9. | IS: 2720-1974 Part-8 (Revision 1) | Methods of test for soils. Determination of water content-dry density relation using heavy compaction. |
| 10. | IS: 2720-1971 Part-9 | Methods of test for soils Determination of dry density –moisture content relation by constant weight of soil method. (Reaffirmed 1990) |
| 11. | IS: 2720-1991 Part-10 (Revision 2) | Methods of test for soils. Determination of unconfined compressive strength. |
| 12. | IS: 2720-1971 Part-11 | Methods of test for soils. Determination of the shear strength parameters of a specimen tested in unconsolidated undrained triaxial compression without the measurement of pore water pressure. (Reaffirmed 1990) |
| 13. | IS: 2720-1981 Part-12 | Methods of test for soils. Determination of shear strength parameters of soil from consolidated undrained triaxial compression test with measurement of pore water pressure. |

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| 14. | IS: 2720-1986 Part-13 (Revision 2) | Methods of test for soils. Direct shear test |
| 15. | IS: 2720-1983 Part-14 (Revision 1) | Methods of test for soils. Determination of density index (Relative density) of cohesionless soils. |
| 16. | IS: 2720-1965 Part-15 | Methods of test for soils. Determination of consolidation properties. |
| 17. | IS: 2720-1987 Part-16 (Revision 2) | Methods of test for soils. Methods of test for soil. Laboratory determination of CBR. |
| 18. | IS: 2720-1966 Part-17 | Methods of test for soils. Laboratory determination of permeability. (with amendment No. 1) |
| 19. | IS: 2720-1964 Part-18 | Methods of test for soils. Determination of field moisture equivalent. |
| 20. | IS: 2720-1964 Part-19 | Methods of test for soils. Determination of centrifuge moisture equivalent. |
| 21. | IS: 2720-1966 Part-20 | Methods of test for soils. Determination of linear shrinkage. (with amendment No. 1) |
| 22. | IS: 2720-1977 Part-21 (Revision 1) | Methods of test for soils. Determination total soluble solids. |
| 23. | IS: 2720-1972 Part-22 (Revision 1) | Methods of test for soils. Determination of organic matter. |
| 24. | IS: 2720-1976 Part-23 (Revision 1) | Methods of test for soils. Determination of calcium carbonate. |
| 25. | IS: 2720-1976 Part-24 (Revision 1) | Methods of test for soils. Determination of cation exchange capacity. |
| 26. | IS: 2720-1982 Part-25 (Revision 1) | Methods of test for soils. Determination of silica sesquioxide ratio. |
| 27. | IS: 2720-1973 Part-26(Revision 1) | Methods of test for soils. Determination of pH value. |
| 28. | IS: 2720-1977 Part-27 (Revision 1) | Methods of test for soils. Determination of total soluble sulphate. |
| 29. | IS: 2720-1974 Part-28 (Revision 1) | Methods of test for soils. Determination of dry density of soils in -place by the sand replacement method. |
| 30. | IS: 2720-1975 Part29 (Revision 1) | Methods of test for soils. Determination of dry density of soils in- place by the core cutter method. |

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| 31. | IS: 2720-1980<br>Part-30<br>(Revision 1) | Methods of test for soils.<br>Laboratory vane shear test. |
| 32. | IS: 2720-1969<br>Part-31 | Methods of test for soils.<br>Field determination of california bearing ratio. |
| 33. | IS: 2720-1970<br>Part-32 | Methods of test for soils.<br>North Dakota cone test. (Withdrawn) |
| 34. | IS: 2720-1971<br>Part-33 | Methods of test for soils.<br>Determination of the density in- place by the ring and water replacement method. |
| 35. | IS: 2720-1972<br>Part-34 | Methods of test for soils.<br>Determination of dry density of soil in- place by rubber balloon method. |
| 36. | IS: 2720-1974<br>Part-35 | Methods of test for soils.<br>Part-35 Measurement of negative pore water pressure. |
| 37. | IS: 2720-1987<br>Part-36<br>(Revision 1) | Methods of test for soils.<br>Part-36 Laboratory determination of permeability of granular soils (constant head). |
| 38. | IS: 2720-1976<br>Part-37 | Methods of test for soils.<br>Part-37 Determination of sand equivalent value of soils and fine aggregates. |
| 39. | IS: 2720-1976<br>Part-38 | Methods of test for soils.<br>Part-38 Compaction control test (Hilf method). |
| 40. | IS: 2720-1977<br>Part-39 Section 1 | Methods of test for soils.<br>Direct shear test for soils containing gravel.<br>Section 1 Laboratory test. |
| 41. | IS: 2720-1979<br>Part-39<br>Section 2 | Methods of test for soils.<br>Direct shear test for soils containing gravel.<br>Section 2 in-situ shear test. |
| 42. | IS: 2720-1977<br>Part-15 | Methods of test for soils.<br>Determination of free swell index of soils. |
| 43. | IS: 2720-1977<br>Part-16 | Methods of test for soils.<br>Measurement of swelling pressure of soils. |
| 44. | IS: 2810-1979<br>Revision 1 | Glossary of terms relating to soil dynamics. |
| 45. | IS: 4434-1978<br>Revision 1 | Code of practice for in-situ vane shear test for soils. |
| 46. | IS: 4968-1976<br>Part 1<br>Revision 1 | Method of subsurface sounding for soils.<br>Part I Dynamic method using 50mm cone without bentonite slurry. |
| 47. | IS: 4968-1976<br>Part 2<br>Revision 1 | Method of subsurface sounding for soils.<br>Part II Dynamic method using cone and bentonite slurry. |
| 48. | IS: 4968-1976<br>Part 3<br>Revision 1 | Method of subsurface sounding for soils.<br>Part III Static cone penetration test. |
| 49. | IS: 5249-1969 | Method of test for determination of in-situ dynamic properties of soils. |
| 50. | IS: 460-1985 | Specification of test sieves. |

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| | Part 1<br>Revision 3 | Wire cloth test sieves. |
| 51. | IS: 460-1985<br>Part 2<br>Revision 3 | Specification of test sieves.<br>Perforated plate test sieve. |
| 52. | IS: 460-1985<br>Part 3<br>Revision 3 | Specification of test sieves.<br>Part III Methods of examination of apertures of test sieves. |
| 53. | IS: 1498-1970<br>Revision 1 | Classification and identification of soils for general engineering purposes. |
| 54. | IS: 1607-1977 | Methods for test sieving. |
| 55. | IS: 4616-1968 | Specification for SheepsFoot roller. |
| 56. | IS: 5421-1981<br>Revision 1 | Glossary of terms relating to test sieves and tests sieving. |
| 57. | IS: 5500-1969 | Specification for vibratory roller. |
| 58. | IS: 5501-1969 | Specification for pneumatic tyred roller. |
| 59. | IS: 5502-1969 | Specification for smooth-wheeled diesel road roller. |
| 60. | IS: 1888-1982<br>Revision 2 | Method of load test on soils. |
| 61. | IS: 1892-1979 | Code of practice for site investigations for foundations. (With amendment no. 1) |
| 62. | IS: 2131-1981<br>Revision 1 | Method for standard penetration test for soils. (Reaffirmed 1987) |
| 63. | IS: 2132-1972<br>Revision 1 | Code of practice for thin walled tube sampling of soils. |
| 64. | IS: 2132-1972<br>Revision 1 | Code of practice for thin walled tube sampling of soils. |
| 65. | IS: 10074-1982 | Specification for compaction mould assembly for light and heavy compaction test of soils. |
| 66. | IS: 10077-1982 | Specification for equipment for determination of shrinkage factors. |
| 67. | IS: 10379-1982 | Code of practice for field control of moisture and compaction of soils for embankment and sub-grade. |
| 68. | IS: 10837-1984 | Specification for moulds and accessories for determination of density index (relative density) of cohesionless soils. |
| 69. | IS: 11196-1985 | Specification for equipment for determination of liquid limit of soils-cone penetration method. |
| 70. | IS: 11229-1985 | Specification for mould assembly for determination of permeability of soils. |
| 71. | IS: 11209-1985 | Specification for shear box for testing of soils. |
| 72. | IS: 4081 | Safety Code for Blasting and Related Drilling Operations |
| 73. | IS: 3764 | Safety Code for Excavation Work |

**Note:** Latest version of BIS codes shall be referred.

**ANNEXURE - X**
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## LIST OF EQUIPMENTS FOR FIELD LAB

| S N. | DESCRIPTION OF EQUIPMENT | REFERENCE OF I.S. CODE | UNIT |
|---|---|---|---|
| 1 | IS set of sieves with base & top lid<br>20mm, 19mm,10mm, 4.75mm, 2 mm<br>600mic, 425mic, 212mic, 75mic,. | ISS-460 | 2 sets |
| 2 | Hand operated sieve shaker for above sieves. | | 1 no. |
| 3 | BALANCE | | |
| | i) Pan balance - 10 kg capacity (with 1.0 gm Least Count) | | 1 no. |
| | ii) Electronic balance - 500 gm capacity (with 0.1 gm Least Count ) | | 1 no. |
| 4 | Field density apparatus complete. | | |
| | a) sand replacement | 2720-1974 part-XXVIII | 2 sets |
| | b) core cutter with dolly | 2720-1975 part-XXIX | 5 sets |
| 5 | Modified heavy Proctor density apparatus full unit. | 2720 part-8-1983 | 2 sets |
| 6 | Liquid Limit apparatus hand operated with counter & grooving tools. | 2720 part-V-1985 | 2 sets |
| 7 | Shrinkage limit apparatus | | 1 no. |
| 8 | Stainless steel spatula - 25cm long | | 2 no. |
| 9 | Porcelain bowl for LL - 15cm dia. | | 3 no. |
| 10 | Aluminium dish with lid – 5cm dia. | | 4 no. |
| 11 | Wash bottle - 1 lit. capacity<br>500ml capacity | | 6 no. |
| 12 | Glass plate 10mm thick 50x50 cm | | 2 no. |
| 13 | Ground glass 5mm thick 50x50 cm | | 2 no. |
| 14 | Enameled trays 45x30cm | | 3 no. |
| | 20x20cm | | 3 no. |
| 15 | enameled plates 6inch dia | | 10 no. |
| | 8 inch dia. | | 10 no. |
| | 10 inch dia. | | 10 no. |
| 16 | Frying pans | | 3 no. |
| 17 | Stove janta | | 2 no. |
| 18 | Straight edge 300mm long | | 3 no. |

**ANNEXURE - X**
(Page 2 of 2)

## LIST OF EQUIPMENT FOR FIELD LAB

| S. NO. | DESCRIPTION OF EQUIPMENT | REFERENCE OF I.S. CODE | UNIT |
|---|---|---|---|
| | Grain size analyser of fines | | |
| 19 | a)Hydrometer | IS-2720 part-4-1985 | 2 no. |
| | b)Thermometer 0 to 50 c | | 2 no. |
| | c) Glass cylinder 1000cc capacity with 60mm dia. | | 5 no. |
| 20 | Desiccators as IS –6128 | | 2 no. |
| 21 | Can of 10 litre capacity for distilled water | | 3 no. |
| | Wooden mortar and pestle. | | |
| 22 | Specific gravity test apparatus. | | 1 no. |
| 23 | Density bottle-50ml capacity | | 2 no. |
| | Glass cylinder 100 cc capacity (for l | | 2 no. |
| 24 | Free Swell index test) | | |
| | Oven- thermostatically controlled to | | 1 no. |
| 25 | maintain a temperature 105-110c | | |
| | **Consumable Item** | | |
| | Sieve brush | | |
| 26 | Wire brush | | |
| 27 | Sodium carbonate | | |
| 28 | Sodium hexa meta phosphate. | | |
| 29 | Kerosene | | |
| 30 | Mercury | | |
| | **Additional Equipment** | | |
| 31 | Hand auger 150mm dia with extension rod | | |
| 32 | Sampling tube 100mm dia. And 450mm length | | |

# Correction Slip No. 1

## (Guidelines for Earthwork in Railway Projects, July, 2003)

Para 9.0 of the 'Guidelines for Earthwork in Railway Projects, July 2003' stands modified as under:

**Para 9.1 -** " New Lines/Doubling/Gauge Conversion works are to be executed by Railways, as per Guidelines issued by RDSO. Railways should ensure proper quality control over earthwork. RDSO may be consulted for help in establishing proper testing facilities, training of supervisors and for any problem of formation encountered in the work."

**Para 9.2 -** Same as before

**Para 9.3 -** Same as before

**Para 9.4 -** " All formation rehabilitation schemes need to be framed by railways themselves in consultation with respective GE cell on railways. It is the responsibility of executive authority to ensure that formation rehabilitation work is carried out in accordance with rehabilitation scheme and adequate control is exercised in execution. However, RDSO may be approached to provide consultancy on weak formation, if required."

**Para 9.5 -** " Certification for quality of earthwork in formation in respect of New lines, Gauge Conversion and Doubling projects etc. will be done by Executive authority at SAG level (i.e. CE/Con of respective projects). CE/Con will submit details for certification of quality of earthwork to CRS as per RDSO check list titled as 'Check List for Certification of Earthwork, June 2004."

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