

CHAPTER-10

FORMATION REHABILITATION

10.1 General

Railway formation may develop instability for reasons of poor bearing capacity of formation, inadequate factor of safety against slope stability, excessive settlement and loss of soil from formation on account of erosion, etc. Existence of one or more of these causative factors may lead to development of others and ultimately leads to instability of formation.

Formation failure due to poor bearing capacity alone or in combination comprises most of the unstable stretches. Increase in axle load & GMT also have a significant effect on adequacy of bearing capacity of formation. Therefore, strengthening of formation against bearing capacity failure is an important rehabilitation work.

10.2 Type of Formation Failure

The railway formation generally fails on account of improper design of embankment profile, lack of compaction of earthwork, poor subgrade material and construction of embankment before consolidation of sub-soil. Once the failure sets in, further deterioration is faster. The main forms of failure are given below:

- i) **Failures of the base or sub-soil strata:** Sub-soil strata may fail in shear or settle excessively and cause:
 - a) Slips,
 - b) Heave beyond toe, or
 - c) Excessive deformation.
- ii) **Failures of the fill material:** Fill material may fail in shear which may cause:
 - a) Slips,
 - b) Bulging or creep of slopes, and
 - c) Excessive deformation.
- iii) **Failure of the formation top:** This is due to poor sub-grade material, which results in ballast penetration, mud pumping and cess heave. This generally occurs during monsoons and the causes of the failures are:
 - a) **Due to strength failure:** This occurs due to low shear strength of top soil causing settlement of track with a consequent heave of cess and ballast penetration.
 - b) **Pumping failure:** This occurs due to presence of liquid slurry below the bottom of the sleeper. This may be formed with fine particles derived from the attrition of ballast, dust and water. Sometimes the residual negative pore pressure developed in the formation soil after the passage of the trains tends to cause softening of the soil and assists slurry formation. This slurry migrates upwards to the underside of the sleeper due to contraction and dilation of the ballast voids with passage of trains. This causes serious track irregularities
 - c) **Due to development of cracks on the formation top during summer months:** Shrinkage cracks form in highly shrinkable soil during summer

through which sometimes ballast enters resulting in the settlement of the track. The situation worsens in the rainy season when water enters into the formation through these cracks and causes swelling, resulting in frequent cross level variations.

- d) **Due to the formation of gel on the formation top in Thixotropic soils:** Some soils after coming in contact with water assume a gel-like consistency and loose shear strength all together under the load by assuming a liquid like consistency. When the loads are removed, these soils revert back to their original gel-like consistency within a short period of time known as “**gelation time**”. During the period the topsoil is having liquid-like consistency, there is complete loss of shear strength resulting in penetration of ballast and consequent settlement of track.

10.3 Summary of various probable failures and their remedies

Based on the site investigation and soil testing, the relevant remedial measures should be formulated. Some of the remedial measures suggested for the formation troubles generally encountered are listed below for guidance:

Table 10.1

S. No	Type of problem	Remedial Measures (*)
1.	Inadequate drainage due to high cess, fouled ballast	i) Improving side drainage by lowering the cess and screening of ballast
2.	i) Weak soil at formation top in contact with rain water resulting into mud pumping under trains, ii) Fouling of ballast with subgrade fines, iii) Impaired drainage	i) Improve drainage, ii) Provision of blanket of suitable thickness iii) Laying of Non-woven Geotextile below blanket
3.	i) Strength failure below ballast causing heaving up of cess or in between sleepers, ii) Ballast penetration exceeding 30 cm in formation	i) Provision of blanket of suitable thickness, ii) Laying of Non-woven Geotextile below blanket
4.	Seasonal variation in moisture in formation top in expansive soils causing alternate heaving and shrinkage of formation	i) Blanket of suitable thickness, ii) Thickness of blanket may be reduced with provision of Geogrid layer(s). iii) Laying of Non-woven Geotextile below blanket
5.	Gradual consolidation of earth below embankment. (Bank settlement & heaving of soil	i) Sub-bank may be provided or ii) Prefabricated vertical drain along with sand layer at top/ Geocomposite

	beyond toe)	drain (horizontal) or iii) Stone columns in sub soil.
6.	Creep of formation soil.	Flattening of side slopes with sandwiched construction.
7.	i) Inadequate sides slopes, causing embankment slips after prolonged rains, ii) Longitudinal cracks on cess/slopes	Flattening slopes with provision of berms (slopes analysed with slope stability analysis) & proper drainage system.
8.	Hydrostatics pressure built up under live loads in ballast pockets containing water causing embankment slips	Draining out of ballast pockets by sand or boulder drain.
9.	Erosion of slope/cess	i) Repair of slope/cess, ii) Provision of turfing, mats etc.
10.	Cut slope failure	i) Adequacy of slope/slope protection measure as required, ii) Provision of adequate drainage arrangement (Side drain/Pucca catch water drain etc. and ensure their proper functioning).

*** The above measures suggested are only indicative in nature and final remedial measures shall be decided based on the site investigation, soil testing, past failure history (if any) etc. RDSO's help wherever necessary, may be taken for formulating the remedial measures.**

10.4 Identification, inspection of weak formation:

As also defined in IRPWM- For classification of formation requiring treatment, following steps shall be adopted:

a) Identification of Weak Formation- Identification of Weak Formation shall include the following-

- i) Stretches having speed restrictions due to weak formation.
- ii) Stretches where more than normal track attention is required.
- iii) **Stretches where ballast penetration profile is of 'W' shape and maximum depth of penetration is more than 30 cm.**

In case any of the above conditions are met in the field, then the 4 step action plan given below is to be followed-

b) Action to be taken for weak formation- Following 4-step action plan should be adopted for stretches identified as weak formation: -

- i) Make the formation width, cess level and side drains strictly in accordance with prescribed profile.
- ii) Carry out shallow screening of ballast section (or deep screening where required).
- iii) Ensure no loose or missing fitting.
- iv) Increase the depth of the ballast section to 30cm or even up to 35cm.

If even after adoption of above measures, track maintenance problem persists, then it is a suspect formation and further detailed Geotechnical investigation is to be done for assessing the problem. Based on investigation results, if the formation is classified as Bad Formation then remedial measures for rehabilitation/Strengthening of bad formation should be taken accordingly.

c) Site inspection:

During site inspection of problematic locations, the Pro-forma for reporting details for unstable formation (**Appendix-J**) should be filled up. This should preferably be done before the soil samples and other site details are collected.

The objective of such inspections and investigation is to know the exact cause of the formation problem.

d) Recommended scheme for soil testing:

The identified and suspected locations shall be subjected to detailed examination as per symptoms of failures. Recommended scheme of soil exploration and testing is given in **Table-1.1 of chapter-1(Soil Exploration and Survey)**.

10.5 Methods of Formation Rehabilitation

All formation rehabilitation schemes need to be framed by Railways. Help of an expert may also be taken if required. 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 also be approached to provide consultancy on weak formation, if required.

In general, following points may be kept in view while planning for rehabilitation:

- a) In developing rehabilitation schemes, stretches having similar soil characteristics and Embankment performance should also be included simultaneously.
- b) Cause(s) of instability of formation should be analysed and accordingly rehabilitation measures formulated. There may be requirement of re-profiling of slope along with laying of blanket and other measures.
- c) Geosynthetics may also be used along with laying of blanket for formation rehabilitation as an alternative, in consultation with RDSO as required.
- d) Method of laying of blanket should be appropriate depending upon site conditions/requirements.

Various probable failures and their possible remedies are listed **in Table-10.1** above. Some of the formation rehabilitation measures which can be adopted are as discussed below: -

- a) By providing blanket layer
- b) By laying Geogrid and Non-woven Geotextile at the bottom of ballast along with deep screening by BCM
- c) By cess widening
- d) Rehabilitation of Unstable slopes
- e) Using Formation Rehabilitation Machines.

10.5.1 By Providing Blanket Layer

The weak/unstable formations are mostly those formations where subgrade soil is expansive clay (e.g. Black Cotton Soil). The most significant property of these soils is that when mixed with water they swell considerably, losing their shear strength and on drying they shrink considerably. Because of this swelling and shrinkage, due to ingress of water in the rainy season, the track parameters get disturbed and ballast penetrates in the formation.

The problems caused by expansive clays can be addressed to a large extent by reducing the ingress of water (during rainy season) by provision of blanket layer of adequate thickness in the top layer of formation. The blanket layer acts as a separator as well as reinforcement layer reducing the pressure on the formation below. In case providing blanket layer of large thickness in running traffic conditions is not possible, its thickness can be reduced with provision of layer(s) of geogrid.

In addition to this by providing a non-woven geotextile as separator/filtration layer below blanket (**Fig-10.1**), it prevents the water from top entering into the sub-grade & also prevents upward migration of fine particles from expansive clays (which are very fine grained) into the top coarse layer.

Various methods for laying blanket in running traffic conditions are covered in Para 10.6.

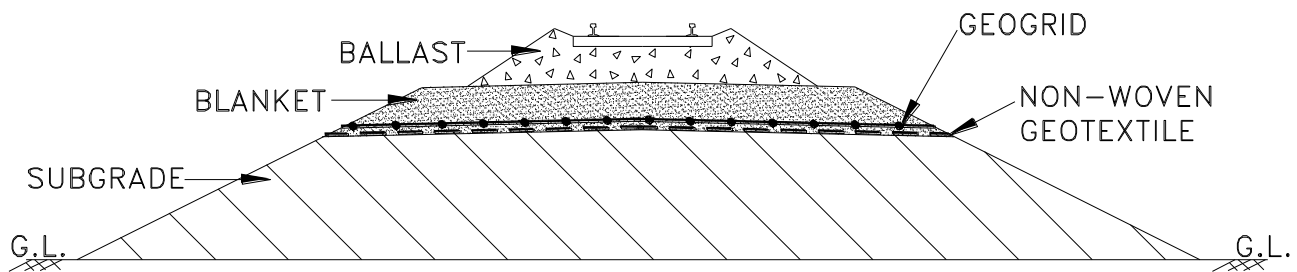


Fig-10.1: Use of Geosynthetic (Geogrid) in formation rehabilitation

10.5.2 By laying Geogrid and Non-woven Geotextile at the bottom of ballast along with deep screening by BCM:

The preferred method for strengthening/rehabilitation of weak/unstable formations will be provision of a Blanket layer of suitable thickness as detailed above. But in cases where it is not possible to adopt this method, and only shallow depth of formation is considered to be affected/weak, another lesser preferred alternative is laying a separator layer of non-woven geotextile and a reinforcement layer of geogrid over it, just below the ballast as shown in Fig-10.2. This type of laying can be done by Ballast Cleaning Machine (BCM) during deep screening of ballast, by adding suitable attachments with BCM for holding and laying non-woven geotextile & geogrid rolls. During the subsequent deep screening cycles, care should be taken not to

disturb about 50-100mm thickness of bottom most layer of ballast, which will not only avoid entanglement of geosynthetics (geogrid and non-woven geotextile) with BCM but this layer will act as a confining layer also for Geosynthetics (geogrid and non-woven geotextile) improving their efficiency.

Non-woven Geotextile, will act as a separator layer preventing ballast getting contaminated with fine grained particles below. The non-woven geotextile also acts a drainage layer, thus assisting in reduction of entry of water into the subgrade, thereby preventing alternative swelling and shrinkage of the expansive subgrade soil due to moisture content variation to some extent. The geogrid layer reduces the imposed stress on the subgrade. In addition to this, the cess/side slopes are attended, if needed, to bring them within the standard profile and erosion protection is done, to prevent entry of water into the subgrade. All these measures combined, will help to address the problem.

However, before adopting the above method, detailed soil investigation must be done ascertaining the root cause of the formation problem. If the nature of the problems suggests that it cannot be solely rectified by adopting this method, then conventional method of providing blanket layer or other appropriate method as determined from investigation done shall be adopted.

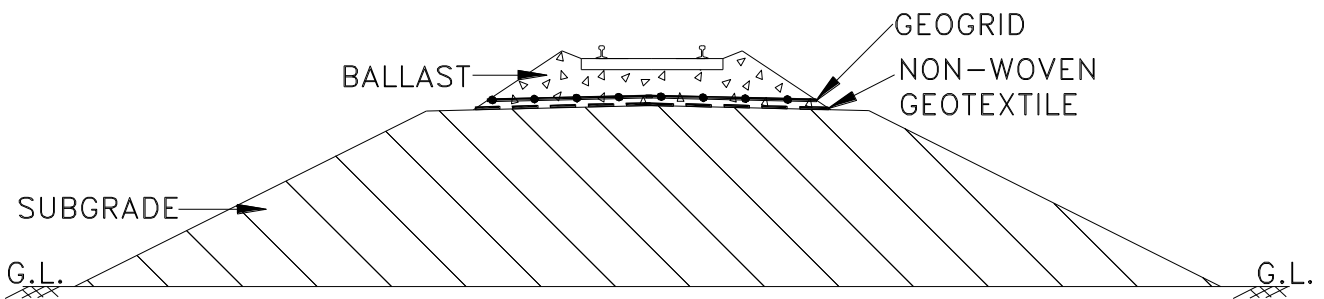


Fig-10.2: Alternative use of Geosynthetic (Geogrid and Non-woven Geotextile) in formation rehabilitation by BCM



Fig-10.3(a): Insertion of Material under BCM



Fig-10.3(b): Linking of Rolls to BCM

10.5.3 By cress widening

Cress widening is one of the methods for improving the strength of Embankment soil by process of confining as the strength of confined material is higher than unconfined material. For detailed procedure, Para 9.2 of Chapter 9 shall be referred to.

This method was used for 9 km length from km 113 to 122 in Vikarabad – Wadi section of South Central Railway, and results were found to be encouraging, as the number of attentions required to maintain track were reduced substantially and TGI values also improved in this stretch.

10.5.4 Rehabilitation of Unstable slopes

- 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 shown in Fig-10.4 below so as to provide proper amalgamation between the old and new earthwork.

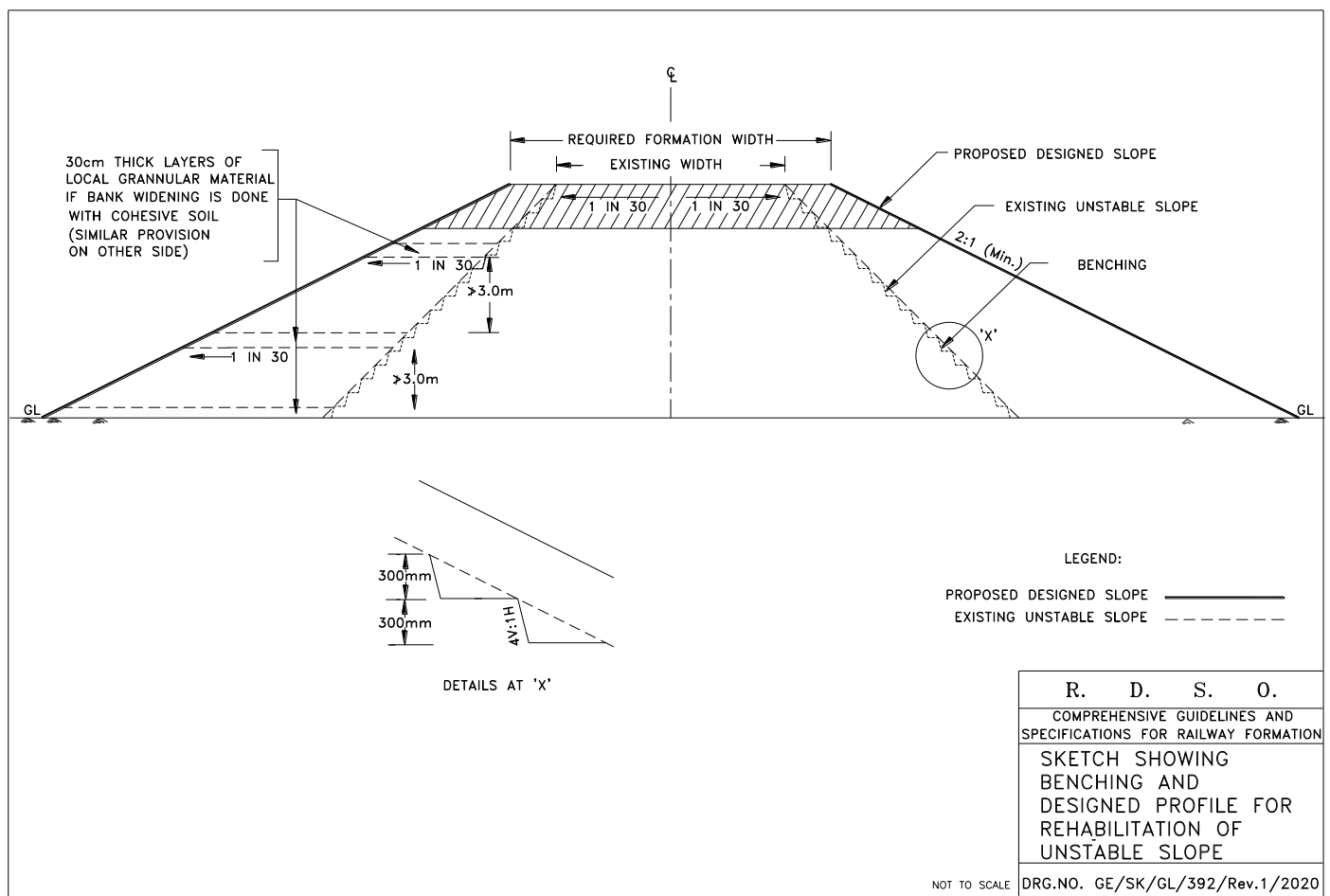


Fig-10.4: Sketch for Rehabilitation of Unstable slopes

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. Compaction on slope shall be ensured by using slope vibratory roller of 10-20T. Preferably, this should be a separately payable item.

- iii) 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, be cut and dressed, so as to achieve the required embankment profile.
- iv) This para covers slope rehabilitation aspects only. Others measures required as per site condition like, drainage arrangement etc. are to be taken as required.

10.5.5 Formation improvement using Formation Rehabilitation Machines

Nowadays Formation Rehabilitation Machines which are fully mechanised are being utilised for rehabilitation of formation in different World Railway systems. Formation Rehabilitation Machines perform all the necessary tasks such as ballast recycling, levelling, lifting, lining and tamping etc. in one operation without disrupting rail traffic on the adjacent track. A formation protective layer (FPL) is installed in order to raise the load-bearing capacity of the subsoil effectively and sustainably. All these machines are designed for simultaneous introduction of geotextiles and geogrids.

Important features of Formation Rehabilitation Machines are:

- i) Total excavation can be achieved in one or two passes
- ii) Old ballast is recycled for use as protective layer material
- iii) Automatic control and moisture regulation of the new protective layer material.
- iv) High uniform consolidation performance thus achieving very good quality of protective layer.
- v) Output of the machine ranging from 40 to 80 m/h depending on the thickness of the protective layer.
- vi) On a double track line no hindrance to traffic on the adjacent track.
- vii) Various thicknesses of protective layers up to 50 cm can be inserted in one pass.

Austrian federal Railways having experience of formation rehabilitation machines known as AHM-800R and RPM 2002.

In addition to the measures detailed in above Paras, proper cross slope should be provided and proper turfing or other erosion control measures shall be undertaken on the side slopes to prevent ingress of moisture in the formation from cess and side slopes.

10.6 Methods of Laying Blanket Layer

(a) Track dismantling method:

The method consists of dismantling a portion of track under traffic block (4hrs duration) and removal of ballast and weak formation layer and replacement with blanket layer and reconnection of track on ballast.

Execution of work:

i) Before traffic block

Decide longitudinal level & select blanketing material (including required moisture content & density), lay single rails if higher length panels exist, provide ramps on to the embankment for movement of tippers to carry blanketing material etc. & remove shoulder ballast.

ii) During traffic block (about 4 hrs. Duration)

- a) Lift single rail panels and remove balance ballast with excavators.
- b) Excavate formation to required depth with excavator.
- c) Roll the formation providing 1 in 30 cross slopes in one direction.
- d) Spread blanket material to optimum thickness for full formation width + 50 cm on cess side(s) to facilitate compaction.
- e) Compact blanket material (being granular cohesion less & well graded) with vibratory roller to achieve min. 70% relative density (IS code no: 2720 (Pt 14) latest version).
- f) Spread ballast & put back track panels (kept on slope of embankment).
- g) Attend track and allow traffic.

iii) After traffic block

Dress side slopes with suitable erosion control measures if required.

a) Progress

Progress of laying of blanket can be in the range of 100-120m per day. Work can be taken up at more number of sites in shadow block.

b) Quality: There is no constraint in achieving good quality of work.

c) Flexibility in execution

Depth of excavation of formation & lifting of track both can be carried out to the requirement of site. Similarly, any thickness of blanket also can be laid. It can be adopted in any type of track structure, electrified or non-electrified. Only requirement is that the site should be approachable to bring machineries and space available to keep track panel, blanket material etc. Method has been successfully implemented in some Railways like SC Rly.

(b) Using Formation Rehabilitation Machine: Details discussed in Para 10.5.5.

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Mechanical Production of Blanket Material

Normally, the blanket material shall be produced mechanically by crushing the stones and/or by mixing, naturally available materials using suitable equipment/plants like crusher or pug mills. Detail of these two methods is given below:

1.0 Crushing Methodology:

In the event of non-availability of natural source of blanket material, depending on the proximity of project site from the parent rock/boulder sources, it may be decided to crush the rock/boulder in order to produce crushed blanket material. Salient features of this methodology are:

- Crushed blanket material may be produced as sole product or in conjunction with ballast or any other nominal size.
- Trials and permutations of feed speed, crushing cycle, and sieve combinations may be required to arrive at the required particle size gradation.
- It is possible to achieve near total produce of desired gradation through production cycle management. Alternately, it may be possible to get by-products of other sizes in the desired proportion and blanket material as main produce or vice-versa.
- Optimisation of production rates and costs can be achieved by controlling the output at each sieve stage.
- It is ideal to mix the required quantity of water for OMC (accounting for loss/gain of moisture due to weather conditions) at the crusher plant and transport the material in wet condition.

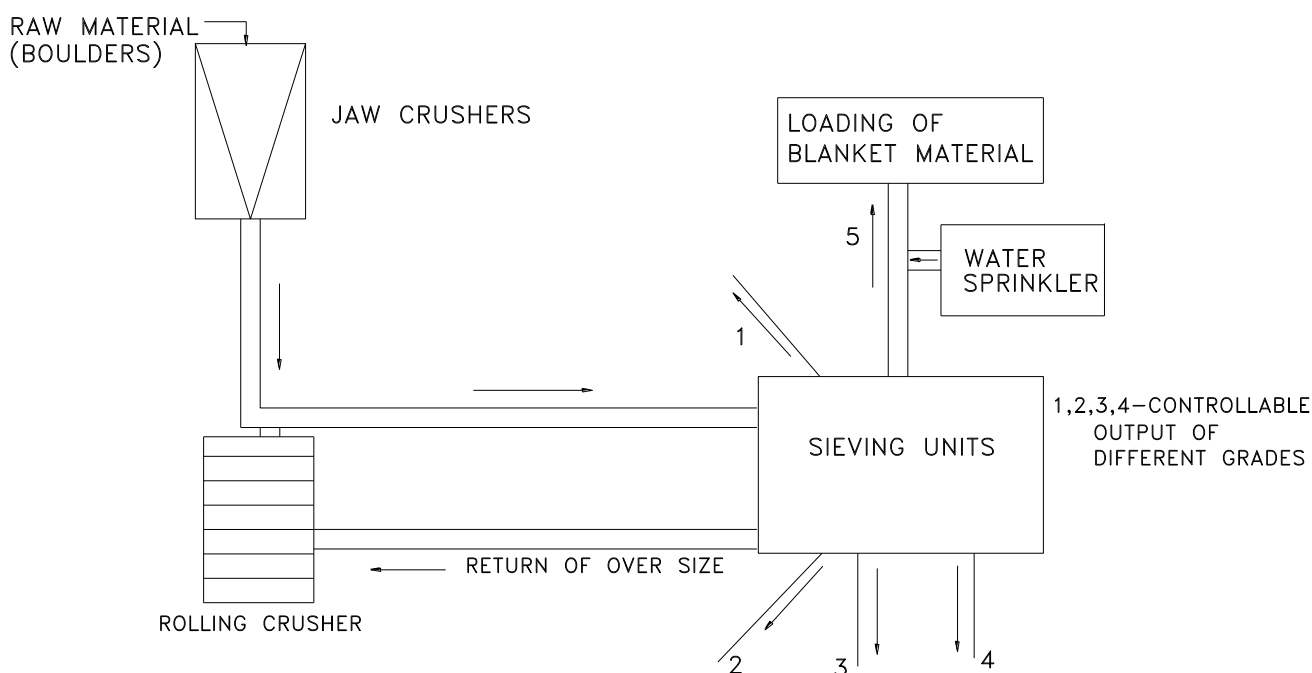


Fig-A1: Schematic Diagram of Manufacture of Blanket Material by Crushers



Fig-A2: General View of Crusher



Fig-A3: View of Storage bin

2.0 Blending Methodology :

- a) Blanket material could be obtained by proper blending of two or more soils or in combination with soils and crushed material like stone chips.
- b) Before approving such sources, trials for blending to judge the final product, needs to be done. Detail methodology of blending to be adopted to produce large quantity of blanket material with consistent quality, needs also to be laid down in advance.
- c) Blending of either natural or crushed materials in a pre-decided ratio could be adopted.
- d) Theoretical and laboratory trials are required in order to establish the desirable ratio of the blending materials. This exercise may be done in advance before finalizing the contracts for such a material.
- e) The methodology of blending trials is explained below :
 - i) Identify the usable materials/soils.
 - ii) Take equal weight of the soils for sieve analysis.
 - iii) Write down the weight retained at each sieving stage for all the soils.
 - iv) Apportion a percentage component to each soil and work out a theoretical mix.
 - v) Draw particle size distribution curve of the mix to find out desirability of gradation.
 - vi) If not successful, make another trial, and so on.
 - vii) Trials and plotting work can also be done using simple computer programs.

2.1 Mechanical blenders using simple technology are now available in the market. Two types of mechanical blenders are quite common:

- a) **Drum type blenders:** Drum type machines may involve weigh batching or manual feeding of material. They involve more moving parts. Hence, these machines are both manpower and maintenance intensive. They may pose a problem of segregation of material and as such do not afford any cost advantage either in the short or long run. These may be suitable for small quantities and not for large-scale production as required in construction projects.
- b) **Pug mill type blenders:** For continuous production of mix in large quantities, the best way is to feed the aggregates/ soils of pre decided gradation by way of 3 or 4 bins with conveyor belt. The required output grading can be achieved by adjustment of gate openings of bins. The use of pug mill type blenders is found

very cost effective, as the manpower involvement is very little and only 4-5 people can run a plant of 100 tph. The pug mill blender consists of:

- i) Four bin aggregate unit
- ii) Pug mill mixer unit
- iii) Water tank and metering system
- iv) Conveyor belts
- v) Storage silos (optional)
- vi) Anti-segregation surge hopper
- vii) Automation and controls

The other important features of this technology are:

- i) Automatic feeding of soils/aggregates under gravity,
- ii) Arrangement for precise control of mixing of water,
- iii) Either direct loading into trucks, or optional storage at plant,
- iv) Availability of domestic manufacturers, and low cost of set up,
- v) Advantage of removal and relocation with ease.

A schematic diagram showing the various arrangements is shown below:

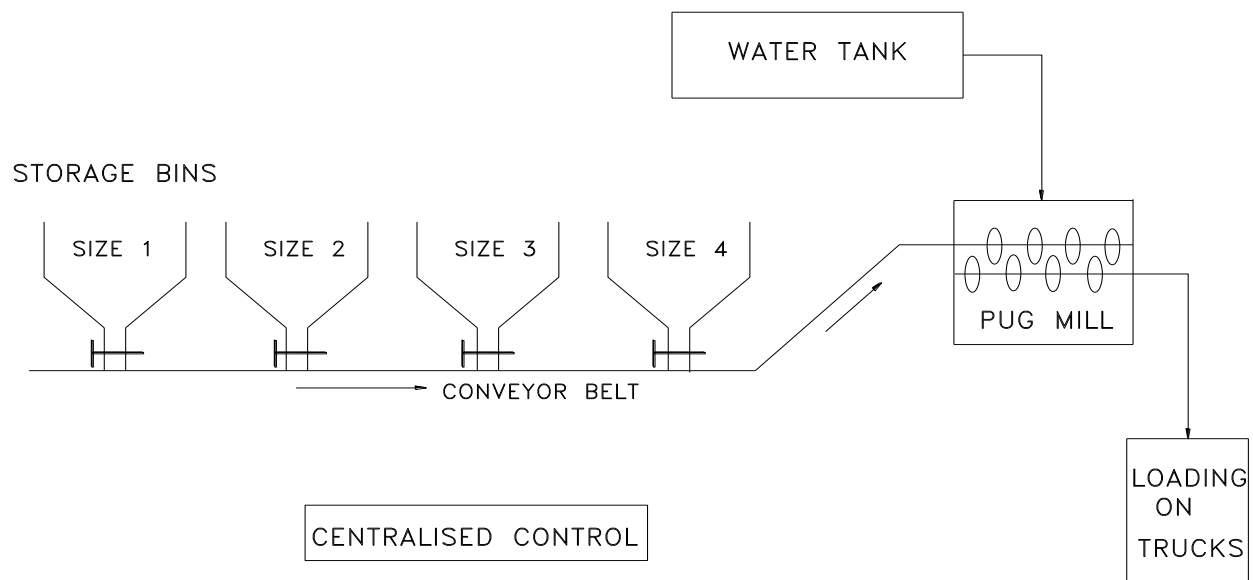


Fig-A4: Schematic Diagram of Manufacture of Blanket Material by Blending

2.2 The equipment for blending should enable blending of two or more materials uniformly so that the blended material satisfies the specification. The equipment chosen should be cost effective and easy to handle with and efficient.

3.0 Specifications of Mechanically Produced Blanket Material: Blanket material produced in a plant should generally conform to specifications as mentioned in Table 3.3 to table 3.6, Chapter 3 of this Comprehensive Guideline and specification.

4.0 Quality Control on Blanket Material at production site:

It is desirable to have a check on quality of material at source/manufacturing point so that major deviation in quality of the material being sent to site does not exist. It would

be in the interest of the supplier to have such tests conducted on his own to avoid any complication at a later stage.

4.1 Method of Test: Blanket material should be tested in pursuance to specifications for blanket material as laid down in Table 3.3 to 3.6 of this Comprehensive Guideline and specification.

4.2 Frequency of Tests at Site: As per Table 7.2 of this Comprehensive Guideline and specification.



Fig-A5: Computer Controlled Bins for Mixing

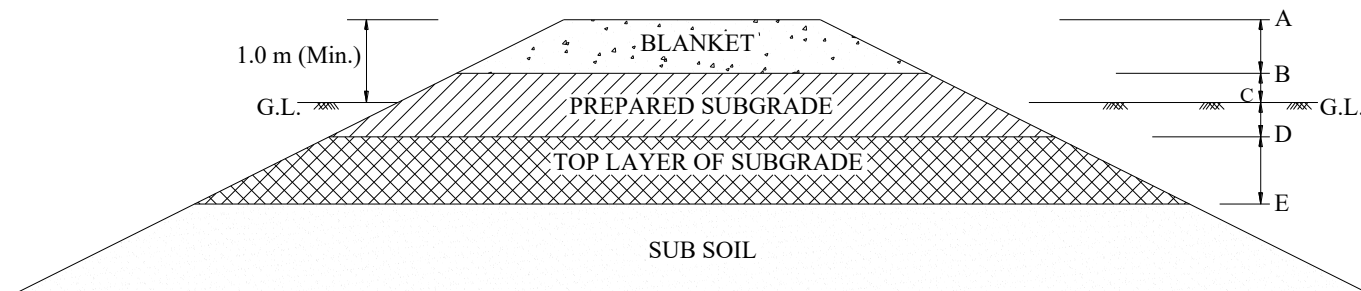


Fig-A6: Blanket Material Being Loaded into Truck

Illustrative Examples for providing minimum thickness of Formation Layers

1.0 Construction of Formation in Embankment & Cutting:

1.1 For Embankment (where height is less than required total uniform thickness)



Fig–B 1: Formation Layers in Embankment

- a) If sub-soil material CD is of better quality than the specifications of prepared subgrade and DE part is of better quality than the specifications of top layer of subgrade, then remaining part of prepared subgrade (BC) and blanket layer (AB) of specified thickness only is required to be provided above ground level for embankment construction. No excavation below ground level is required.
- b) If minimum required depth of sub-soil CE is of better quality than the specifications of top layer of subgrade and inferior to that of prepared subgrade, then upper layer upto CD will be required to be replaced with specified quality of soil equivalent to prepared subgrade. Above ground level remaining part of prepared subgrade (BC) and blanket layer (AB) of specified thickness are required to be provided.
- c) If layer CE upto minimum required depth do not meet the specifications of top layer of subgrade, then upper layers of sub-soil upto "E" level should be removed and compacted with specified quality of soil i.e. in CD, soil with specified quality for prepared subgrade and in DE, soil with specified quality better than that for subgrade/top layer. Above ground level, remaining part of prepared subgrade (BC) and blanket layer (AB) of specified thickness are required to be provided.

Few representative sketches showing thickness of formation layers in embankment depending on site conditions:

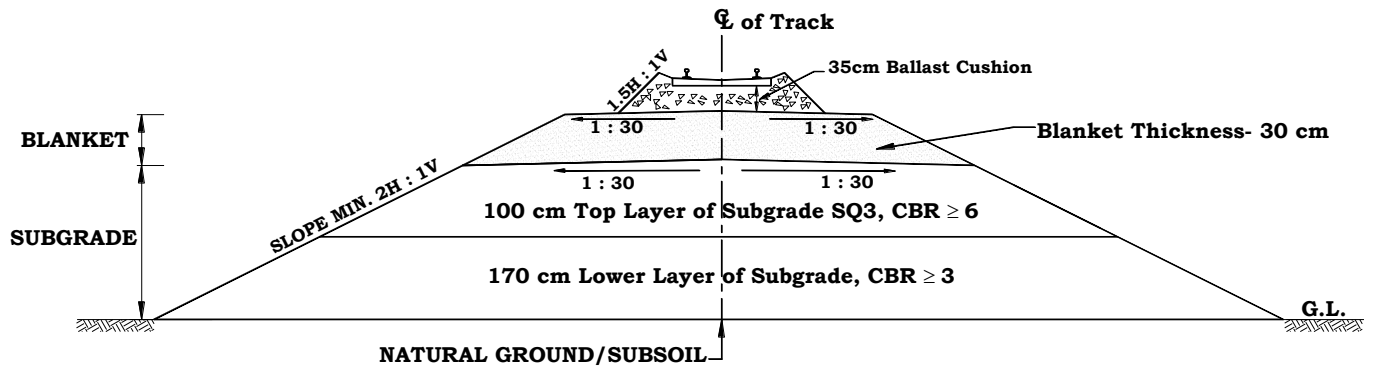


Fig-B2: Height of Bank=3.0m, **Single layer system** (25T Axle load), with SQ3 subgrade (CBR \geq 6)

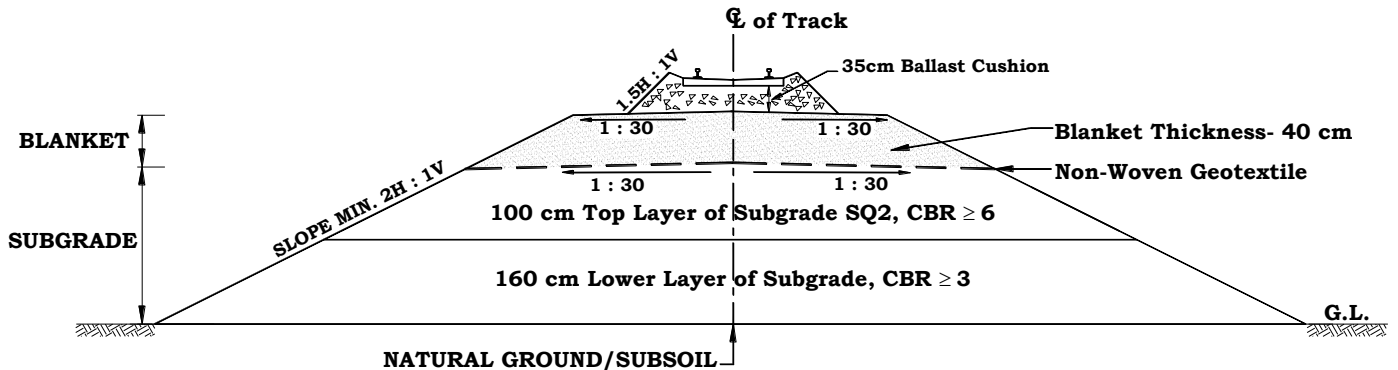


Fig-B3: Height of Bank=3.0m, **Single layer system** (25T Axle load), with SQ2 subgrade (CBR \geq 6)

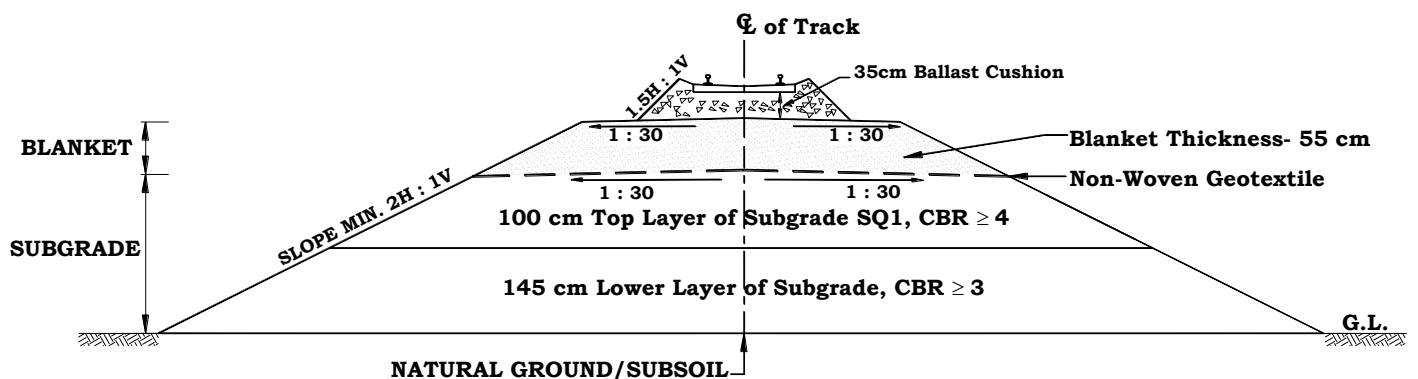


Fig-B4: Height of Bank= 3.0m, **Single layer system** (25t Axle load), with SQ1 Subgrade (CBR \geq 4)

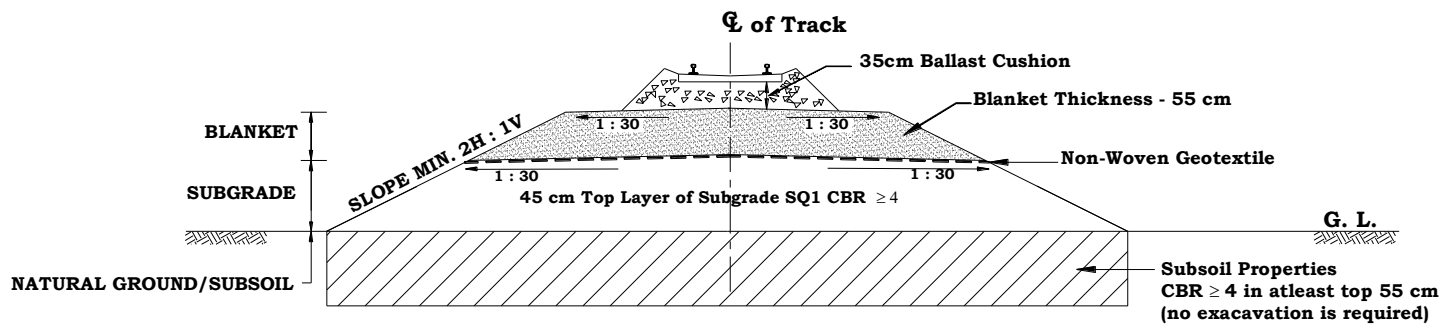


Fig-B5: Height of Bank 1.0m, **Single layer system** (25T Axle load), with SQ1 subgrade & Subsoil with $CBR \geq 4$ (No excavation below GL)

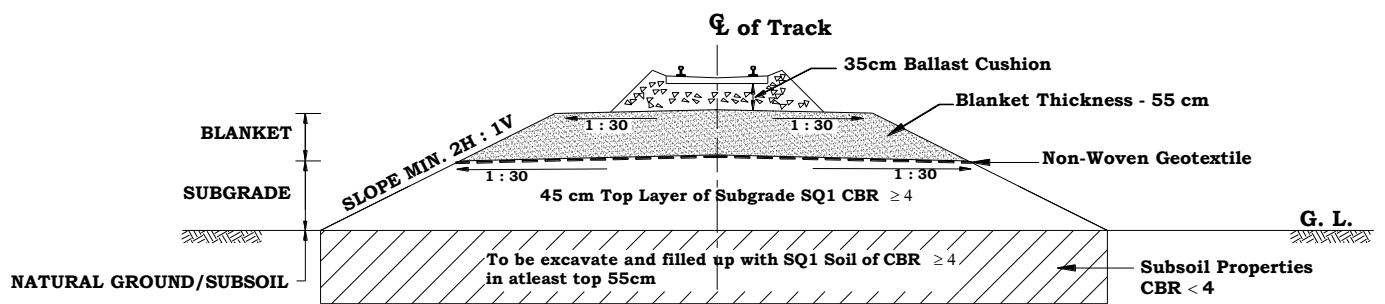


Fig-B6: Height of Bank 1.0m, **Single layer system** (25T Axle load), with SQ1 subgrade & Subsoil with $CBR < 4$ (Excavation & replacement of min 55cm with $CBR \geq 4$ soil below GL)

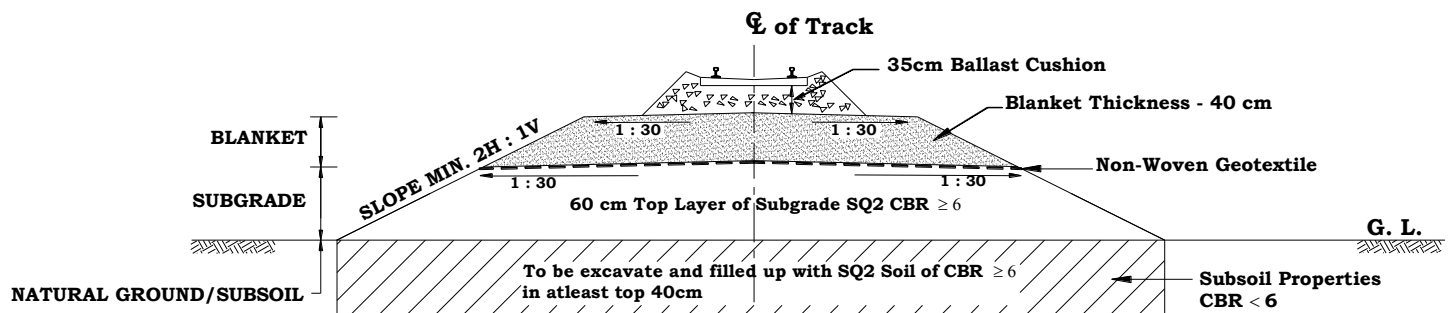


Fig-B7: Height of Bank 1.0m, **Single layer system** (25T Axle load), with SQ2 subgrade & Subsoil with $CBR < 6$ (Excavation & replacement of min 40cm with $CBR \geq 6$ soil below GL)

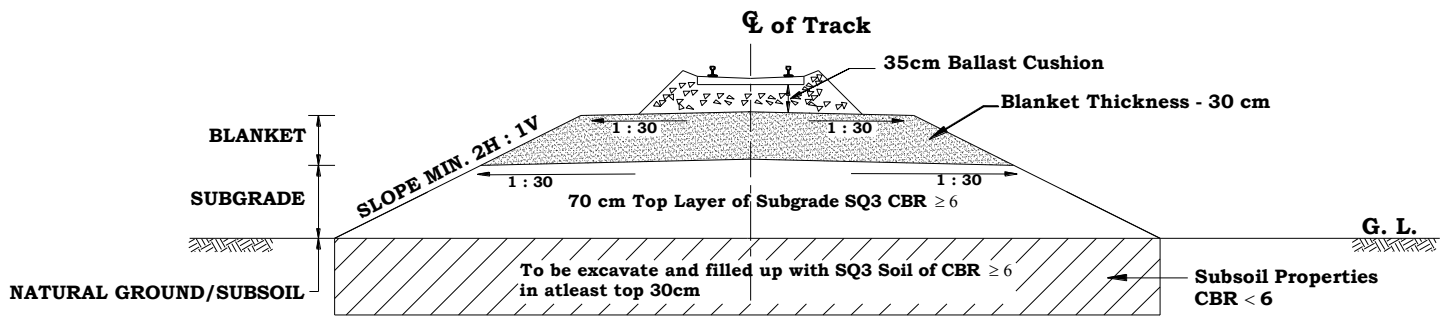


Fig-B8: Height of Bank 1.0m, **Single layer system** (25T Axle load), with SQ3 subgrade & Subsoil with CBR <6 (Excavation & replacement of min 30cm with CBR ≥ 6 soil below GL)

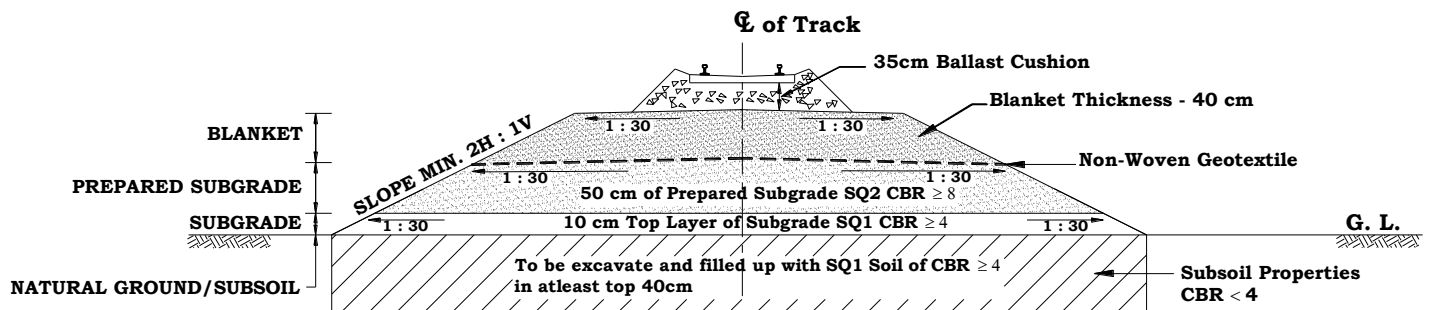


Fig-B9: Height of Bank 1.0m, **Two layer system** (25T Axle load), with SQ2 Prepared Subgrade, SQ1 Subgrade & Subsoil with CBR <4 (Excavation & replacement of min 40cm with CBR ≥ 4 soil below GL)

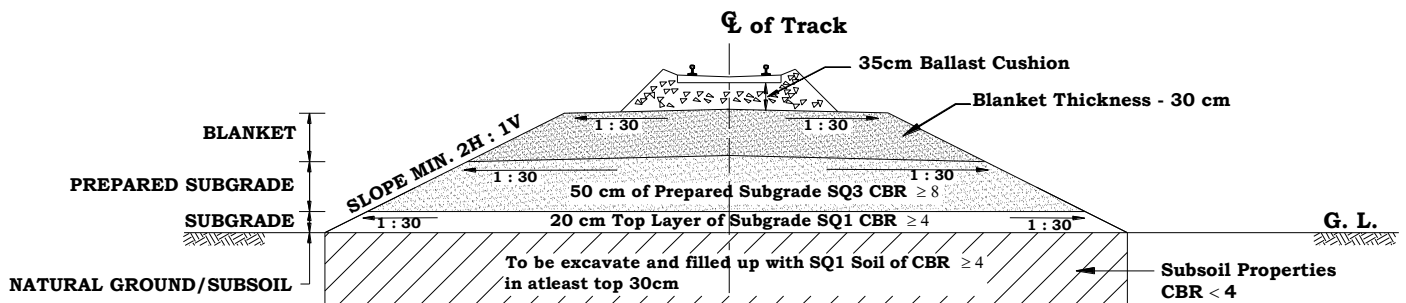


Fig-B10: Height of Bank 1.0m, **Two layer system** (25T Axle load), with SQ3 Prepared Subgrade, SQ1 Subgrade & Subsoil with CBR <4 (Excavation & replacement of min 30cm with CBR ≥ 4 soil below GL)

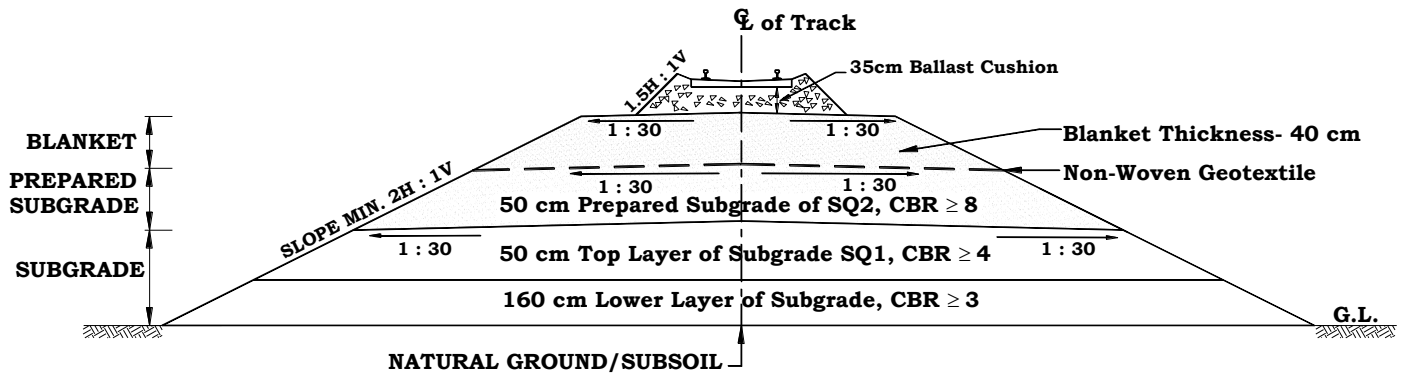


Fig-B11: Height of Bank 3.0m (Two layer system), 25T axle load, with SQ2 Prepared subgrade and SQ1 Subgrade

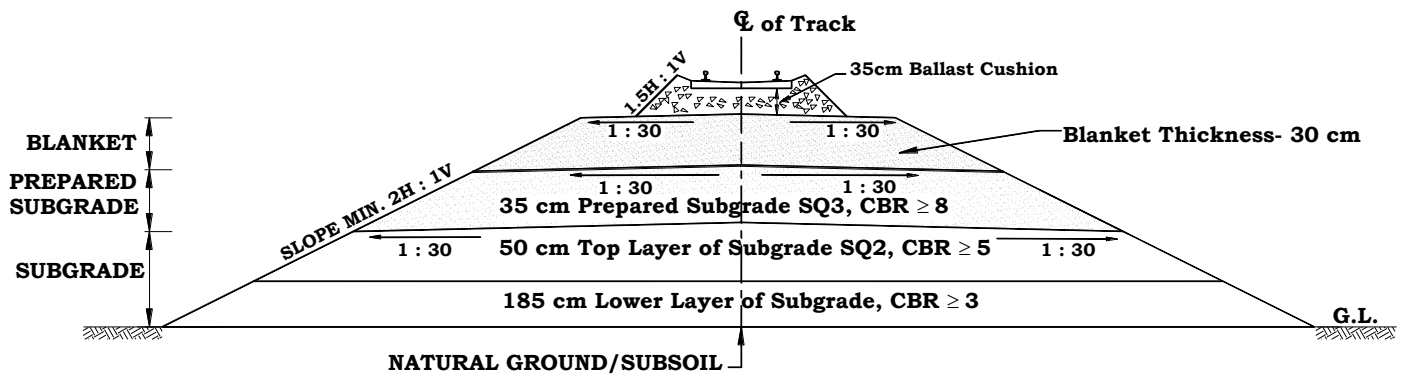
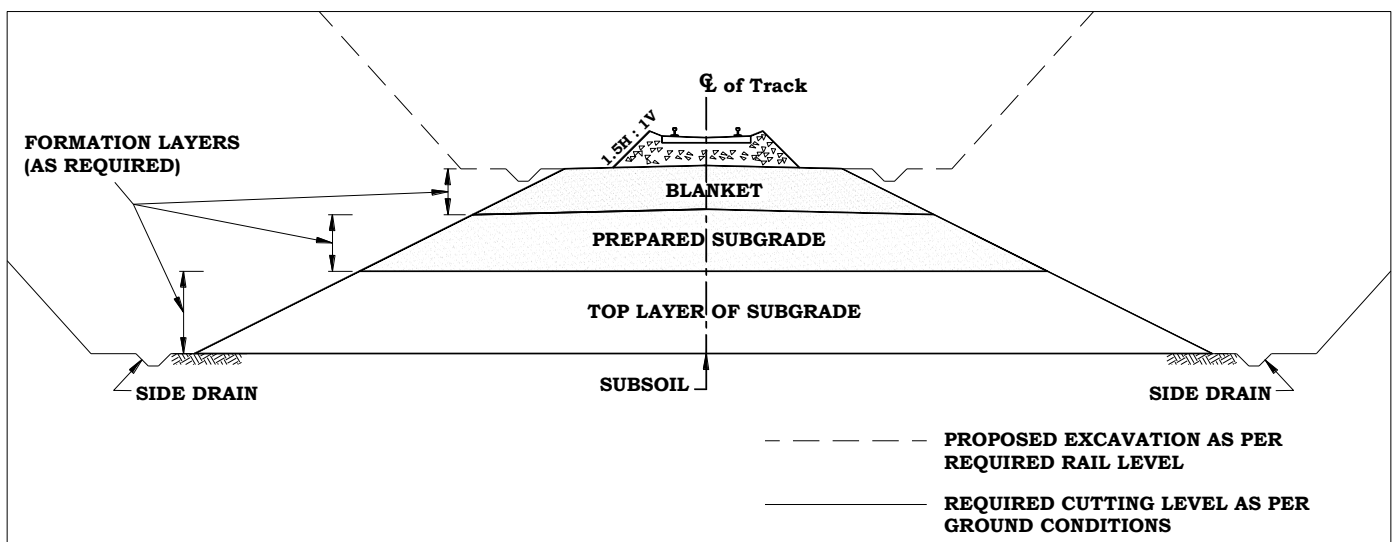


Fig-B12: Height of Bank 3.0m (Two layer system), 25T axle load, with SQ3 Prepared Subgrade & SQ2 Subgrade

1.2 For Cutting



- a) As per bore log details from soil exploration & survey, at least 1.5m depth below the required cutting level, should be checked for conformity with specifications of construction material (quality of formation layers-blanket/prepared sub-grade/sub-grade top layer) as mentioned in **Para 3.10**.

If soil encountered in this depth is of poorer quality than as specified in **Para 3.10** then the excavation for cutting will have to be planned accordingly taking into consideration the additional provisions for conformity with quality of soil as specified for formation layers (blanket/prepared sub-grade/sub-grade top layer) in the required depth, which will then cater to the requirement of heavy axle load. Same has been illustrated in **Fig-B 2** given above.

- b) For example, if in the depth of 1.5m below the proposed cutting level (as per required grade/level), soil encountered meets the specification of subgrade-top layer, then additional depth of excavation for cutting should take into account the depth of prepared subgrade & blanket only.
- c) Suitable drainage system shall be ensured in cuttings as described in Chapter 6 for Execution of Earthwork.

Representative sketches showing thickness of formation layers in Cutting depending on site conditions is given below:

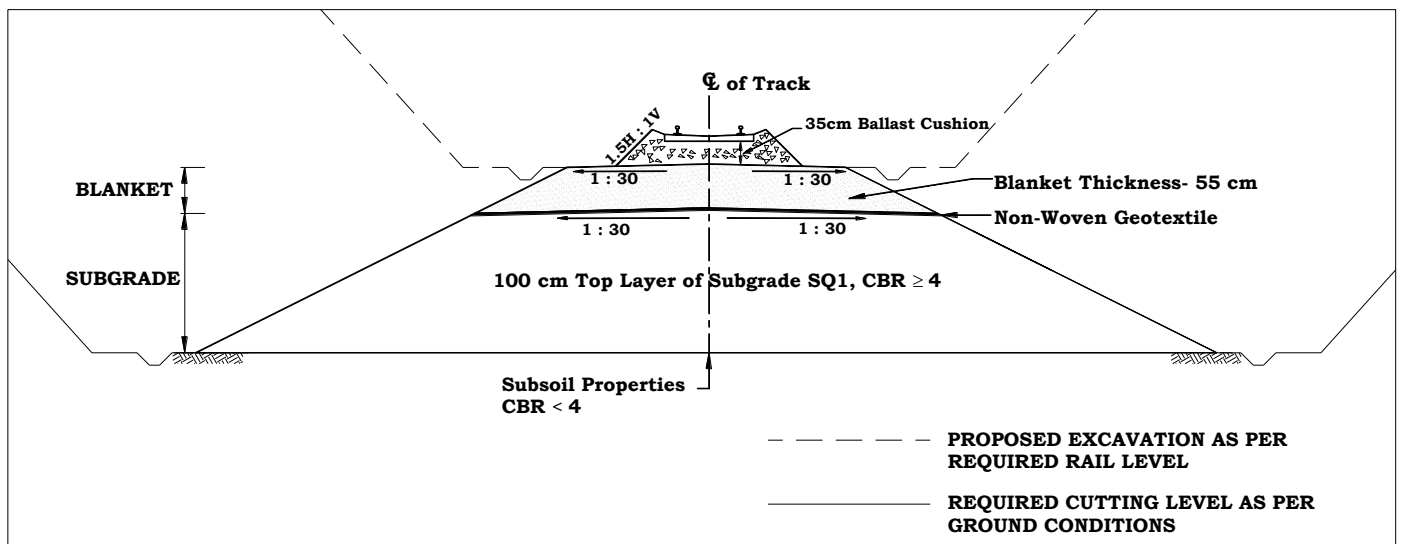


Fig-B14: Cuttings, 25T Axle Load (Single Layer System)

Specifications of Geosynthetic Products

1.0 Specification of Non-woven Geotextile to be used as separator/filtration in Railway Formation Specification No. RDSO/2018/GE: IRS-0004-Part-I (March 2019)

A) Properties of Nonwoven Geotextile :

The Non-woven geotextile to be used as separator/filtration layer (Primary role as separator and secondary role as filtration), shall have following properties, when tested as per the latest edition of the test method indicated therein, for Railway application:

Sl. No.	Property	Test Method	Value
I	Polymer and Type		
1	Material/Polymer	-	Polypropylene/ Polyethylene/ Polyamide, Polyester or any combination thereof
2	Type/Structure	-	Non-woven Needle Punched and Mechanically or Thermally bonded type or equivalent
II	Mechanical Properties		
1	Elongation at Failure (*)	ASTM D4632 - 2015	>50% in both direction
2	Grab Strength (*): On top of subgrade or prepared subgrade before laying blanket or anywhere within the embankment Below the ballast and above the Blanket Layer		700 N 1750 N
III	Hydraulic Properties		
1	Apparent Opening size	ASTM D4751- 2016	≤ 85 micron
2	Water Flow Rate normal to the Plane	ASTM D4491- 2017	20 lit/m²/Sec
IV	Survivability Properties		

1	Trapezoidal Tear Strength (*) On top of subgrade or prepared subgrade before laying blanket or anywhere within the embankment Below the ballast and above the Blanket Layer	ASTM D4533-2018	250 N 800 N
2	Puncture Strength-CBR (*) On top of subgrade or prepared subgrade before laying blanket or anywhere within the embankment. Below the ballast and above the Blanket Layer	ASTM D6241-2014	1800 N 5800 N
V	Durability Properties		
1	Abrasion Strength (% strength retained in breaking load) (*)	ASTM D4886 -2018	80%
2	Resistance to U.V. Light Weathering (% strength retained in breaking strength) after 500 hrs. of exposure	ASTM D4355-2018	Not less than 70% (After unwrapping, the geotextile should be installed and covered within a maximum of 14 days)
3	Minimum retained Ultimate Tensile Strength(*)	EN: 12447-2001 and EN ISO: 13438-2004	50% (tested as per Clause B.4 of EN: 13250-2016, for 100 year service life)

* is Minimum Average Roll Value (MARV), which is derived statistically as average value minus two standard deviations.

Note:

1. The adherence to above listed specification should be checked by testing the samples at IIT, NIT, Government labs or any other NABL accredited lab.
2. Manufacturing of non-woven geotextile shall be in accordance with the manufacturer's QAP for quality control.
3. The product being supplied by the manufacturer should have been successfully used for similar application (separator /filtration-Primary role as separator and secondary role as filtration) at minimum 3 locations, with minimum 3 years' experience at one of the locations, with supporting documents as an evidence for satisfactory performance.
4. To ensure proper quality assurance and reproducibility of the product, following stipulations are as under:
 - i) The manufacturer of non-woven geotextile should have ISO: 9001/CE Certification for the product being supplied. The manufacturer of Geo-synthetics should have a well-

documented Quality Assurance Procedure (QAP)/Factory Production Control (FPC) Manual, covering every specific product produced on specific production site, which shall be referred/stipulated in the ISO: 9001/CE Certification. The QAP/FPC Manual shall consist of a permanent internal production control system to ensure that product being manufactured conforms to the requisite properties and it addresses following items:

- a) Produce design requirement and criteria.
- b) Acceptance criteria of raw/incoming material and procedures to ensure that these are met.
- c) Relevant features of the plant and production process; giving frequency of inspections, checks & tests, together with values/criteria required on equipment and action(s) to be taken when control values or criteria are not obtained.
- d) Tests on finished products – Size of the samples and frequency of sampling with results obtained.
- e) Details of alternative tests and procedures, if any, and their correlation with reference tests.
- f) Calibration of equipment having influence on test results.
- g) Records to be maintained for various inspections, checks and tests carried out during factory production.
- h) Assessment of results of various inspections, checks and tests carried out during factory production; where possible and applicable.
- i) System of traceability and control of designs, incoming materials and use of materials.
- j) Corrective action for non-conforming materials and finished products.
- k) Training, job description and responsibility of the personnel involved in the manufacturing process.
- ii) Any subsequent changes in raw materials, manufacturing procedures or the control scheme that affects the properties of a product shall be recorded/revised in the QAP/FPC Manual and certified by the ISO: 9001/CE Certification.
- iii) Surveillance of QAP/FPC Manual shall be undertaken at least once per year. The surveillance shall include a review of the test plan(s) and production processes for each product to determine if any changes have been made since the last assessment or surveillance. The significance of changes shall be assessed.
- iv) Records of all in-house test results, as per QAP/FPC Manual, shall be shown to the purchaser; whenever requested by the purchaser

(B) Packing, Handling, Storage and Laying of Geotextiles

- i) A tag or other method of identification shall be attached to each roll of non –woven geotextile indicating following:
 - a) Manufacturer or Supplier Name
 - b) Product or Style Name
 - c) Roll Number
 - d) Lot or Batch Number

- ii) Rolls of non –woven geotextiles should not be dragged on the ground and they must be lifted off the ground before moving them.
- iii) Non –woven Geotextiles slowly degrade in the presence of Ultra Violet (UV) rays which are present in sunlight. Hence, they should be wrapped with a material that will protect them from damage due to shipment, sunlight (UV exposure) and contaminates. The protective wrapping, in which the non –woven geotextiles come wrapped from factory, should be kept on till their storage and installation. After unwrapping, the geotextile should be installed and covered within a maximum of 14 days.
- iv) If stored outside, they should be elevated from the ground surface and adequately covered to protect them from site construction damage, precipitation, UV radiation including sun light, chemicals that are strong acids/bases, flames including welding sparks, temperatures in excess of 710C etc.
- v) If the protective wrapping of the non –woven geotextile roll is damaged, the rolls must be elevated off the ground surface and covered with a tarpaulin or opaque plastic sheet. If the outer layer of the geotextile itself is damaged, the outermost wraps of the geotextile must be removed and discarded. This is also required when the roll is exposed to sunlight for a period beyond that permitted by the project specifications.
- vi) If the non –woven geotextiles is exposed to moisture or water, prior to installation, it absorbs water up to three times their weight. This can lead to serious handling problems due to extra weight and installation problem because it is nearly impossible to unroll wet rolls. In addition, the strength of wet non –woven geotextile may also diminish to the point that it may not support the required load during installation/construction.
- vii) If the non –woven geotextile becomes wet, it is permissible to remove the waterproof cover to allow for a few days of exposure to wind in order to dry the fabric.
- viii) In trenches, after placing the backfill material, the non –woven geotextile shall be folded over the top of the filter material to produce a minimum overlap of 300mm for trenches greater than 300mm wide. In trenches, less than 300mm wide, the overlap shall be equal to the width of the trench. The non –woven geotextile shall then be covered with the subsequent course.
- ix) Damages to non –woven geotextile, if any during installation, shall be repaired by placing a non –woven geotextile patch over the damaged area and extending it 1m beyond the perimeter of the tear or damage.
- x) For laying of Non-woven geotextile:
 - a) Major protrusions on the surface on which non –woven geotextile is to be laid, such as rocks & bush stamps, shall be removed and local depressions etc. shall be filled with approved soil before laying the geotextile. The geotextile shall be

rolled out smoothly. The non –woven geotextile should not be dragged across the subgrade. The entire roll should be placed and rolled out as smoothly as possible. Wrinkles and folds in the fabric shall be removed by stretching as required.

- b) Adjacent rolls of non –woven geotextiles shall be overlapped, sewn or joined as required. Overlaps can be used to provide continuity between adjacent non –woven geotextile rolls through frictional resistance between the overlaps. The amount of overlap depends primarily on the soil conditions as given in the Table below:

Soil CBR	Minimum Overlap
Greater than 3	300- 450 mm
1 – 3	600 – 1000 mm
Less than 1	Sewn

- c) For curves, the non –woven geotextile shall be folded or cut and overlapped in the direction of construction. Folds in the non –woven geotextile shall be stapled or pinned approximately 0.6m centre-to-centre. Before covering, the condition of the non –woven geotextile shall be checked for damage (i.e. holes, nips, tears etc.).
- xi) Before laying the first lift of granular subgrade on the non –woven geotextile, a trial stretch of 100m shall be laid to establish a proper construction methodology of placing and compacting the sub-grade in a manner that no damages are caused to the separation layer of non-woven geotextile.

(C) Measurement for Payment of Geotextiles

The geotextiles for separation / filter layer shall be measured in square metres, with no allowance for overlapping at transverse & longitudinal joints. The contract unit rate for the accepted quantities of geotextile shall be in full compensation for furnishing, preparing, hauling and placing geotextiles including all labour, freight, tools, equipment and incidentals to complete the work as per specifications.

2.0 Specifications for Geogrid to be used as reinforcement/stabilisation for Railway Formation (Specification No. RDSO/2018/GE: IRS-0004- Part-III) February 2020.

A) Properties of Geogrid

The geogrid used as reinforcement/stabilisation layer shall have following properties, when tested as per the latest edition of the test method indicated therein, for Railway application:

Sl. No.	Property	Test Method	Value
I	Material/Polymer		
1	Material/Polymer	-	Polypropylene
II	Mechanical Properties		

1.	Tensile Strength at 2% Strain (**) (i) For use below ballast in existing line (ii) For use below blanket in new line	ISO 10319-2015	10 KN/m x 10 KN/m* 9 KN/m x 9 KN/m*
2.	Strain at Ultimate Tensile Strength (**)	ISO 10319-2015	6-15 %
3.	Aperture Stability/Torsional Rigidity Modulus (**) (i) For use below ballast in existing line (ii) For use below blanket in new line	ASTM-D7864-2015	Average Torsional Stiffness ≥0.33 N-m/deg ≥0.40 N-m/deg
4.	Junction Efficiency (**)	ASTM-D7737-2015	90%
III	Durability Characteristics		
1.	Resistance to Installation damage (% tensile strength at 2% strain) (**)	ASTM-D5818-2018	90%
2.	Resistance to Chemical Degradation (% Average Ultimate rib Tensile Strength) (**)	ASTM D6213-2017	100%
3.	Resistance to U.V. Light Weathering (% strength retained in breaking strength) after 500 hrs of exposure (**)	ASTM-D4355-2018	95%
4.	Minimum retained Ultimate Tensile Strength (**)	EN ISO-13438-2004	50% (tested as per Clause B.4.2 of EN: 13250-2016, for 100 Year Service Life)

* MD: Machine Direction (Longitudinal to the roll) X CD (90° of Machine Direction): Transverse Direction (Across the roll width)

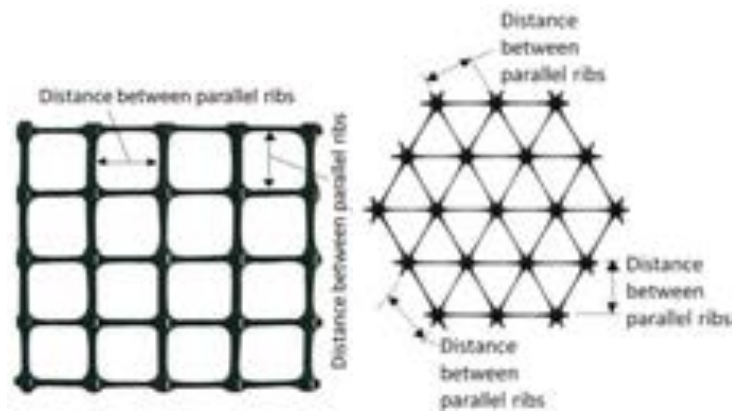
** Values marked are Minimum Average Roll Value (MARV), which is derived statistically as average value minus two standard deviations.

Note:

- The adherence to above listed specification should be checked by testing the samples at IIT, NIT, Government labs or any other NABL accredited lab.
- Aperture Opening of Geogrid:
 - For use below ballast in existing line, the distance between parallel ribs of the geogrid should be 60mm ± 5mm.

- b) For use below blanket in new line, the distance between parallel ribs of the geogrid should be $30\text{mm} \pm 5\text{mm}$.

Aperture size/opening specified above is the clear distance between inner faces of ribs. Reference diagrams are as given below for illustrations.



(Ref. ISO 10319-2015)

3. The particle grading for the installation damage test result determined in accordance with ASTM D5818 shall use Ballast grading as defined in IRS-GE-1 June 2016, for use below bottom of ballast in existing line and Blanket grading as defined in table 3.7 of chapter 3, for use below in blanket layer in new line.
4. The product being supplied by the manufacturer should have been successfully used as per functional requirement for similar Railway application (reinforcement / stabilization) at minimum 3 locations, with minimum 3 years India/International experience at one of the locations, and certificate duly certified by client/executive which is a government agency/PSU, should be submitted as an evidence for satisfactory performance.
5. Manufacturing of geogrid shall be performed in accordance with **the manufacturer's QAP** for quality control.
6. To ensure proper quality assurance and reproducibility of the product, following stipulations are as under:
 - a) The manufacturer of the Geogrid should have ISO: 9001 and CE Certification of the product being supplied. The manufacturer of Geo-synthetics should have a well-documented Quality Assurance Procedure (QAP)/Factory Production Control (FPC) Manual, covering every specific product produced on specific production site, which shall be referred/stipulated in the ISO: 9001 and CE Certification. The QAP/FPC Manual shall consist of a permanent internal production control system to ensure that product being manufactured conforms to the requisite properties and it addresses following items:
 - i) Produce design requirement and criteria.
 - ii) Acceptance criteria of raw/incoming material and procedures to ensure that these are met.

- iii) Relevant features of the plant and production process; giving frequency of inspections, checks & tests, together with values/criteria required on equipment and action(s) to be taken when control values or criteria are not obtained.
 - iv) Tests on finished products – Size of the samples and frequency of sampling with results obtained.
 - v) Details of alternative tests and procedures, if any, and their correlation with reference tests.
 - vi) Calibration of equipment having influence on test results.
 - vii) Records to be maintained for various inspections, checks and tests carried out during factory production.
 - viii) Assessment of results of various inspections, checks and tests carried out during factory production; where possible and applicable.
 - ix) System of traceability and control of designs, incoming materials and use of materials.
 - x) Corrective action for non-conforming materials and finished products.
 - xi) Training, job description and responsibility of the personnel involved in the manufacturing process.
- b) Any subsequent changes in raw materials, manufacturing procedures or the control scheme that effects the properties of a product shall be recorded/revised in the QAP/FPC Manual and certified by the ISO: 9001 and CE Certification.
 - c) Surveillance of QAP/FPC Manual shall be undertaken at least once per year. The surveillance shall include a review of the test plan(s) and production processes for each product to determine if any changes have been made since the last assessment or surveillance. The significance of changes shall be assessed.
 - d) Records of all in-house test results, as per QAP/FPC Manual, shall be shown to the purchaser; whenever requested by the purchaser.

B) Packing, Handling, Storage and Laying of Geogrid

- i) A tag or other method of identification shall be attached to each roll indicating the following:
 - a) Manufacturer or Supplier Name
 - b) Product name and Style
 - c) Roll Number
 - d) Lot or Batch Number
- ii) Geogrids shall be stored in a manner that prevents excessive mud, wet concrete, epoxy or other deleterious materials from coming in contact with and affixing to the geogrid.
- iii) If the geogrid comes in the protective wrapping, it should be kept in wrapped condition till their storage and installation. After unwrapping, the geogrid should be installed and covered within a maximum period of 1 month.

If the Geogrid is supplied in unwrapped condition, it should be installed and covered within a maximum period of 1 month from the date of manufacturing. In case Geogrid is supplied after more than a month's period to the site it should be ensured that it conforms to Resistance to UV light weathering criteria before laying.

- iv) Prior to laying of geogrid as reinforcement layer, the surface shall be properly prepared, ruts should be made good and dressed to the specified lines and levels.
- v) Geogrid reinforcement shall be placed flat, pulled tight and held in position by pins or suitable means until the subsequent layer is placed. Geogrid should be rolled out on the compacted surface parallel to the centre line of track.
- vi) The minimum overlap shall be of

CBR (%)	Overlap
Greater than 3	300 mm
1-3	600 mm

Overlaps must be maintained during the filling operation. This is generally achieved by placing small heaps of fill locally over the overlaps ahead of main filling operation.

- vii) No vehicle shall be allowed on geogrid unless it is covered by at least 150mm thick overlying material.

C) Measurement for Payment of Geogrid

The geogrid shall be measured in square metres, with no allowance for overlapping at transverse & longitudinal joints. The contract unit rate for the accepted quantities of geogrid shall be in full compensation for furnishing, preparing, hauling and placing geogrid including all labour, freight, tools, equipment and incidentals to complete the work as per specifications.

D) Acceptance Criteria

Conformance testing on the geogrid delivered to the site shall be undertaken by the Contractor in accordance with the requirements of Clause.

i) General

The Chief Engineer (open line/Construction) or equivalent in PSU's shall be the accepting authority and shall accept test certificates, verifying compliance with Clause (A), for tests carried out, in accordance with this Technical Specification, on the materials **to be used for the specific project. In addition, Contractor's** quality system shall demonstrate that the specified minimum frequency of testing has been maintained and ensuring traceability of the material.

Presently Tests Aperture Stability/Torsional Rigidity Modulus are not carried out in India, therefore upto one year, Manufacturer certificate is required for the procurement of Geogrid. All manufacturers should develop Testing facilities in one year time and this should be carried out as routine testing of Geogrid. The test certificates shall not be older than 12 months on the date of the supply to the site.

ii) Site sampling

a) Frequency for test other than durability tests

Where the total required batch size for the Contract is less than 5000 m², sampling and testing need not be undertaken. If the material supplied is higher than 5000 m² on-site sampling shall be carried out in accordance with ASTM D4354 at the frequency stated in Table D.2.

Table D.2 – On Site sampling frequency

Batch or order size defined as the lot size	Number of rolls to be sampled representing the lot
The initial 10,000 m ² or part thereof	1
Each subsequent 20,000 m ² or part thereof	1

The representative sample shall be no less than four linear metres along the roll for the full production width but not within two metres of the start or end of the roll.

Identification information including the geogrid supplier, type, batch identification, and details of the order represented by sample, sample date and roll directional markings shall be shown on or attached to the test reports.

b) Frequency for Durability Tests

Random checks on material supplied to project sites once every 5,00,000 sqm. or once in a 3 year whichever is earlier for each manufacturer.

iii) Acceptance

A lot shall be deemed to achieve conformance, if all samples tested comply with the Technical Specification. If a lot fails to achieve conformance, the lot may be re-sampled in accordance with Clause D.2 to verify whether the lot conforms or not. If it still does not conform to the technical specifications, the lot should be rejected.

The geogrid shall not be placed prior to the acceptance as per para D (i) above.

iv) Audit testing During audit testing, samples may be selected from the site and accordingly arrangement for audit testing has to be done, regardless of the quantity of geogrid supplied.

3.0 Specification of Geocomposite Drain to be used behind Bridge Abutment/ Retaining Wall for Railway Bridge- For height up to 10 m. (Specification No. RDSO/2018/GE: IRS-0006 -March 2019)

A) Properties of Geocomposite Drain (Vertical)

The Geocomposite Drain (or Drainage Composite) consisting of a geonet core sandwiched between non-woven geotextile filters on both sides, to be used behind Bridge Abutment/Retaining Wall of Height up to 10m, shall have following properties, when tested as per the latest edition of the test method indicated therein:

Sl. No.	Property	Test Method	Proposed value
I	Composite Drain (Non-woven geotextile on both sides)		
1	Tensile Strength	ASTM D4595-2017	20 KN/m in both MD & CD ($\pm 10\%$)

2	In-plane Water Flow (For i=1, Rigid/Soft Contacts) At 100 kPa (To be tested in lab)	ASTM D4716-2014	1.5 lit/m.sec.
3	Static Puncture Resistance CBR(*)	ASTM D 6241-2014	3000 N
4	Resistance to U.V. Light Weathering (% strength retained in breaking strength) after 500 hrs of exposure	ASTM D4355-2018	Not less than 70% (After unwrapping, the Geocomposite should be installed and covered within a maximum of 14 days)
5	Minimum retained Ultimate Tensile Strength(*)	EN: 12447-2001 and EN ISO: 13438-2004	50% (tested as per Clause B.4 of EN: 13250-2016, for 100 year service life)
II	Core		
1	Material	-	HDPE/Polypropylene/ Polyethylene or combination thereof
III	Filter (Non-woven Geotextile)		
1	Material	-	Polypropylene/Polyamide/Polyethylene, Polyester or combination thereof
2	Type/Structure	-	Non-woven Needle Punched & Mechanically or Thermally bonded type or equivalent
3	Permeability (Perpendicular to Plane)	ASTM D4491-2016	70 lit./m ² .s (Min.)
4	Apparent Opening Size	ASTM D4751-2016	150 Micron (Max.)
5	Puncture Strength – CBR (*)	ASTM D6241-2014	1400 N
6	Resistance to U.V. Light Weathering (% strength retained in breaking strength) after 500 hrs of exposure	ASTM D4355-2018	Not less than 70% (After unwrapping, the Geocomposite should be installed and covered within a maximum of 14 days)

- MD: Machine Direction (Longitudinal to the roll)

- CD: Transverse Direction i.e., 90° to MD, (Across the roll width)
- * Is Minimum Average Roll Value (MARV), which is derived statistically as average value minus two standard deviations.

Note:

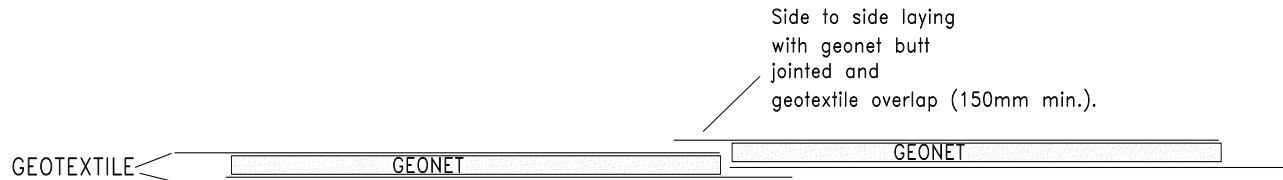
1. The adherence to above listed specification should be checked by testing the samples at IIT, NIT, Government labs or any other NABL accredited lab.
2. Manufacturing of Geosynthetics shall be in accordance with the **manufacturer's QAP** for quality control.
3. The product being supplied by the manufacturer should have been successfully used for similar application (i.e. for drainage behind bridge abutment/retaining wall) at **minimum 3 locations, with minimum 3 years' experience** at one of the locations, with supporting documents as an evidence for satisfactory performance.
4. To ensure proper quality assurance and reproducibility of the product, following stipulations are as under:
 - a) The manufacturer of Geocomposite drain should have ISO: 9001/CE Certification for the product being supplied. The manufacturer of Geo-synthetics should have a well-documented Quality Assurance Procedure (QAP)/Factory Production Control (FPC) Manual, covering every specific product produced on specific production site, which shall be referred/stipulated in the ISO: 9001/CE Certification. The QAP/FPC Manual shall consist of a permanent internal production control system to ensure that product being manufactured conforms to the requisite properties and it addresses following items:
 - i) Produce design requirement and criteria.
 - ii) Acceptance criteria of raw/incoming material and procedures to ensure that these are met.
 - iii) Relevant features of the plant and production process; giving frequency of inspections, checks & tests, together with values/criteria required on equipment and action(s) to be taken when control values or criteria are not obtained.
 - iv) Tests on finished products – Size of the samples and frequency of sampling with results obtained.
 - v) Details of alternative tests and procedures, if any, and their correlation with reference tests.
 - vi) Calibration of equipment having influence on test results.
 - vii) Records to be maintained for various inspections, checks and tests carried out during factory production.
 - viii) Assessment of results of various inspections, checks and tests carried out during factory production; where possible and applicable.
 - ix) System of traceability and control of designs, incoming materials and use of materials.
 - x) Corrective action for non-conforming materials and finished products.
 - xi) Training, job description and responsibility of the personnel involved in the manufacturing process.
 - b) Any subsequent changes in raw materials, manufacturing procedures or the control scheme that affects the properties of a product shall be recorded/revised in the QAP/FPC Manual and certified by the ISO: 9001/CE Certification.

- c) Surveillance of QAP/FPC Manual shall be undertaken at least once per year. The surveillance shall include a review of the test plan(s) and production processes for each product to determine if any changes have been made since the last assessment or surveillance. The significance of changes shall be assessed.
- d) Records of all in-house test results, as per QAP/FPC Manual, shall be shown to the purchaser; whenever requested by the purchaser.
- e) Geo-composite Drain shall be manufactured by thermal bonding of filter and core. Melt temperature of the bonding materials must be compatible so that the properties of each material are retained. Adhesion of filter & core using glue/adhesive tape shall not be permitted particularly for this application.
- f) In-plane water flow as per item I (2) of Specification is 1.5 lit/m.sec which is to be tested in lab. For calculating the value of short term flow creep factor is taken as 1.3. Manufactures have to give the test certificate indicating the value of creep factor for their product tested accordingly to ASTM D7931-2018. The value of creep factor of the product should be less than or equal to 1.3 for 100 years design life under 100 kPa pressure. In case the creep factor of a product is greater than 1.3 then in-plane water flow to be tested in lab i.e., 1.5 lit/m.sec as mentioned in specification at I(2) should be increased proportionally.
- g) Geocomposite drain consisting of cusped core shall not be used.

B) Packing, Handling and Installation of Geo-composite Drains (Vertical)

- i) The Geocomposite drain shall be provided in wraps with a protective covering. A tag or other method of identification shall be attached to each wrapped package indicating the following:
 - a) Manufacturer or Supplier Name
 - b) Product Name and Style
 - c) Roll Identification Number
 - d) Lot or Batch Number
- ii) Rolls of Geocomposite drain should not be dragged on the ground and they must be lifted off the ground before moving them.
- iii) Geocomposite drain should be adequately protected from Ultraviolet (UV) exposure during storage at site. The protective wrapping, in which the Geo-composite drain come wrapped from factory, should be kept on till their installation. After unwrapping, the Geo-composite drain should be installed and covered within a maximum of 14 days.
- iv) If stored outside, they should be elevated from the ground surface and adequately covered to protect them from site construction damage, precipitation, UV radiation, chemicals that are strong acids/bases, flames including welding sparks, temperatures in excess of 710C etc.
- v) When Geo-composite drains are assembled on site, the assembly area shall be clean and dry.
- vi) Geocomposite drains shall be capable of being connected longitudinally or laterally into pipe systems or chambers for outflow purpose. Joint parallel to the direction of flow and any exposed edge shall be protected from the ingress of soil by wrapping with a minimum overlap of 150mm or other measures.

Geocomposite jointing and overlap

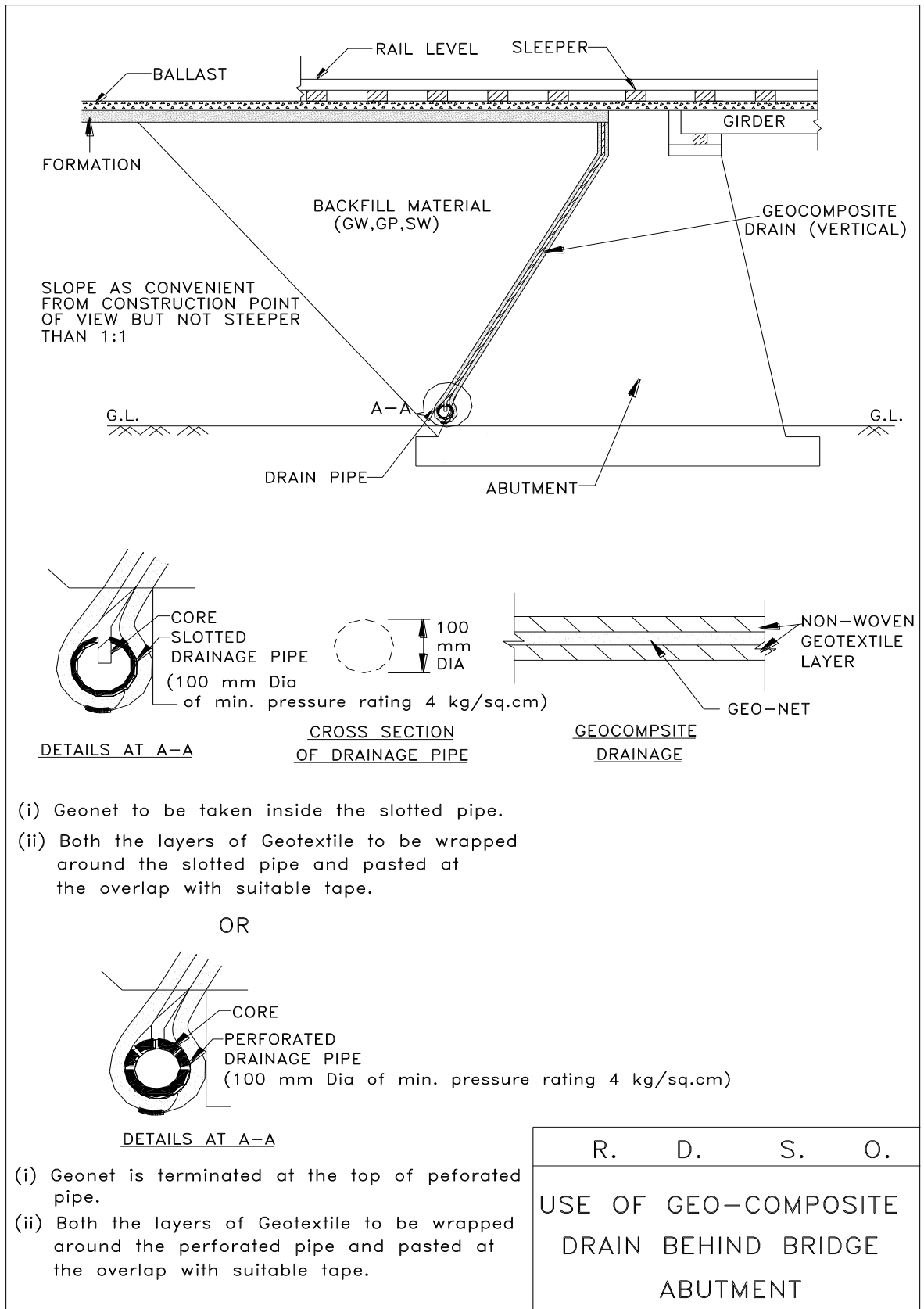


Overlap of Geocomposite drains

- (vii) Care must be taken to ensure that large stones are not allowed in the soil & large projections abutment surface to damage the surface of the geotextile filter.
- (viii) In case of use behind Bridge Abutment or Retaining Wall, slotted pipe can be provided for horizontal drainage at bottom, by placing Geonet inside slot and both layers of geotextile to be wrapped around the slotted pipe & pasted at the overlap with suitable tape. Or perforated pipe can be provided for horizontal drainage at bottom, by placing Geonet is terminated at the top of perforated pipe and both layers of geotextile to be wrapped around the perforated pipe & pasted at the overlap with suitable tape.
- (ix) A diagram showing GeoComposite Drain behind bridge abutment is shown below.

C) Measurement for Payment of Geo-composite Drain (Vertical)

The Geocomposite drain shall be measured in square metres, with no allowance for overlapping at transverse & longitudinal joints. The contract unit rate for the accepted quantities of Geo-composite drain shall be in full compensation for furnishing, preparing, hauling and placing Geo-composite drain including all labour, freight, tools, equipment and incidentals to complete the work as per specifications.



Use of Geocomposite drains behind bridge abutment

4.0 Specification for Geo-composite drain to be used at the base of the Embankment"- for height of embankment upto 8m, for Railway Formation (Specification No. RDSO/2018/GE: IRS-0004 Part-II)

A) Properties of Geocomposite Drain (Horizontal)

In case of embankments over weak/fine grained sub-soils (which are mostly soft clays) and having water table at higher level, it is a good practice to provide a "separator-cum-drainage layer" of sand at the ground level to provide adequate drainage path for the water coming from sub-soil (reducing excess pore water pressure in embankment and thereby increasing its' stability) and to prevent fouling of subgrade by the fine grained subsoil.

For reducing the thickness of "drainage-cum-separator layer of sand" at the base of embankment, Geo-composite Drain (or Drainage Composite) consisting of a geonet core sandwiched between non-woven geotextile filters on both sides can be laid with cross slope of 1 in 30. Such geo-composite drain is sandwiched between two sand layers of thickness 75mm each.

The specification of geo-composite Drain shall be as listed below when tested as per the latest edition of the test method indicated therein. These specifications are for embankments of height up to 8m when laid over weak/fine grained sub-soils.

S. No	Property	Test Method	Value
I	Composite Drain (Non-woven geotextile on both sides)		
1	Tensile Strength	ASTM D4595-2017	20 KN/m in both MD & CD ($\pm 10\%$)
2	In-plane Water Flow (Min.) (For $i=1.0$, Soft/Soft Contacts) At 200 kPa (To be tested in lab)	ASTM D4716 - 2014	0.45 lit/m.sec.
3	Static Puncture Resistance CBR(*)	ASTM D6241-2014	3000 N
4	Resistance to U.V. Light Weathering (% strength retained in breaking strength) after 500 hrs of exposure	ASTM D4355-2018	Not less than 70% (After unwrapping, the Geocomposite should be installed and covered within a maximum of 14 days)
5	Minimum retained Ultimate Tensile Strength(*)	EN: 12447-2001 and EN ISO: 13438-2004	50% (tested as per Clause B.4 of EN: 13250-2016, for 100 year service life)
6	Resistance to Installation damage { % retained of In-plane Water Flow (Min.) (For	ASTM- D5818-2018	90%

	i=1.0, Soft/Soft Contacts) At 200 kPa (To be tested in lab)}		
II	Core		
1	Material	-	HDPE/Polypropylene/ Polyethylene or combination thereof
III	Filter (Non-woven Geotextile)		
1	Material	-	Polypropylene/Polyamide/ Polyethylene, Polyester or combination thereof
2	Type/Structure	-	Non-woven Needle Punched & Mechanically or Thermally bonded type or equivalent
3	Permeability (Perpendicular to Plane)	ASTM D4491-2016	70 lit./m ² .s (Min.)
4	Apparent Opening Size	ASTM D4751-2016	150 Micron (Max.)
5	Puncture Strength – CBR (*)	ASTM D6241 – 2014	1400 N
6	Resistance to U.V. Light Weathering (% strength retained in breaking strength) after 500 hrs of exposure	ASTM D4355-2018	Not less than 70% (After unwrapping, the Geocomposite should be installed and covered within a maximum of 14 days)

- MD: Machine Direction (Longitudinal to the roll)
- CD: Transverse Direction i.e., 90° to MD, (Across the roll width)
- * Is Minimum Average Roll Value (MARV), which is derived statistically as average value minus two standard deviations.

Note:

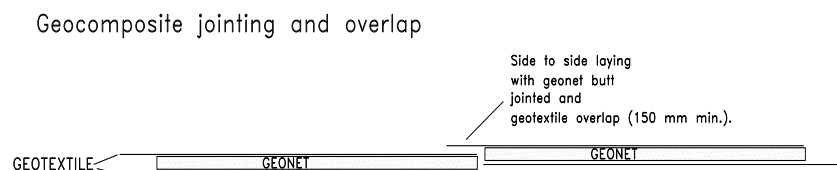
1. The adherence to above listed specification should be checked by testing the samples at IIT, NIT, Government labs or any other NABL accredited lab.
2. **Manufacturing of Geosynthetics shall be in accordance with the manufacturer's QAP for quality control.**
3. The product being supplied by the manufacturer should have been successfully used for similar application (i.e., Geo-composite Drain at base of the Embankment) at minimum 3 locations, **with minimum 3 years' experience at one of the locations, with supporting documents as an evidence for satisfactory performance.**
4. To ensure proper quality assurance and reproducibility of the product, following stipulations are as under:
 - i) The manufacturer of the Geo-composite Drain should have ISO: 9001/CE Certification for the product being supplied. The manufacturer of Geo-synthetics should have a well-documented Quality Assurance Procedure (QAP)/Factory Production Control (FPC) Manual, covering every specific product produced on

specific production site, which shall be referred/ stipulated in the ISO: 9001/CE Certification. The QAP/FPC Manual shall consist of a permanent internal production control system to ensure that product being manufactured conforms to the requisite properties and it addresses following items:

- i) Produce design requirement and criteria.
 - ii) Acceptance criteria of raw/incoming material and procedures to ensure that these are met.
 - iii) Relevant features of the plant and production process; giving frequency of inspections, checks & tests, together with values/criteria required on equipment and action(s) to be taken when control values or criteria are not obtained.
 - iv) Tests on finished products – Size of the samples and frequency of sampling with results obtained.
 - v) Details of alternative tests and procedures, if any, and their correlation with reference tests.
 - vi) Calibration of equipment having influence on test results.
 - vii) Records to be maintained for various inspections, checks and tests carried out during factory production.
 - viii) Assessment of results of various inspections, checks and tests carried out during factory production; where possible and applicable.
 - ix) System of traceability and control of designs, incoming materials and use of materials.
 - x) Corrective action for non-conforming materials and finished products.
 - xi) Training, job description and responsibility of the personnel involved in the manufacturing process.
- ii) Any subsequent changes in raw materials, manufacturing procedures or the control scheme that affects the properties of a product shall be recorded/revised in the QAP/FPC Manual and certified by the ISO: 9001/CE Certification.
 - iii) Surveillance of QAP/FPC Manual shall be undertaken at least once per year. The surveillance shall include a review of the test plan(s) and production processes for each product to determine if any changes have been made since the last assessment or surveillance. The significance of changes shall be assessed.
 - iv) Records of all in-house test results, as per QAP/FPC Manual, shall be shown to the purchaser; whenever requested by the purchaser.
 - v) Geo-composite Drain shall be manufactured by thermal bonding of filter and core. Melt temperature of the bonding materials must be compatible so that the properties of each material are retained. Adhesion of filter & core using glue/adhesive tape shall not be permitted particularly for this application.
 - vi) In-plane water flow as per **item I (2)** of Specification is 0.45 lit/m.sec which is to be tested in lab. For calculating the value of short term flow creep factor is taken as 1.3. Manufactures have to give the test certificate indicating the value of creep factor for their product tested accordingly to ASTM D7931-2018. The value of creep factor of the product should be less than or equal to 1.3 for 100 years design life under 200 kPa pressure. In case the creep factor of a product is greater than 1.3 then in-plane water flow to be tested in lab i.e., 0.45 lit/m.sec as mentioned in specification at I(2) should be increased proportionally.
 - vii) Geocomposite drain consisting of cusped core shall not be used.

B) Packing, Handling and Installation of Geo-composite Drains (Horizontal)

- i) The Geo-composite drain shall be provided in wraps with a protective covering. A tag or other method of identification shall be attached to each wrapped package indicating the following:
 - a) Manufacturer or Supplier Name
 - b) Product Name and Style
 - c) Roll Identification Number
 - d) Lot or Batch Number
- ii) Rolls of Geo-composite drain should not be dragged on the ground and they must be lifted off the ground before moving them.
- iii) Geo-composite drain should be adequately protected from Ultraviolet (UV) exposure during storage at site. The protective wrapping, in which the Geo-composite drain come wrapped from factory, should be kept on till their installation. After unwrapping, the Geo-composite drain should be installed and covered within a maximum of 14 days.
- iv) If stored outside, they should be elevated from the ground surface and adequately covered to protect them from site construction damage, precipitation, UV radiation, chemicals that are strong acids/bases, flames including welding sparks, temperatures in excess of 710C etc.
- v) When Geo-composite drains are assembled on site, the assembly area shall be clean and dry.
- vi) Geo-composite drains shall be capable of being connected longitudinally or laterally into pipe systems or chambers for outflow purpose. Joint parallel to the direction of flow and any exposed edge shall be protected from the ingress of soil by wrapping with a minimum overlap of 150mm or other measures.



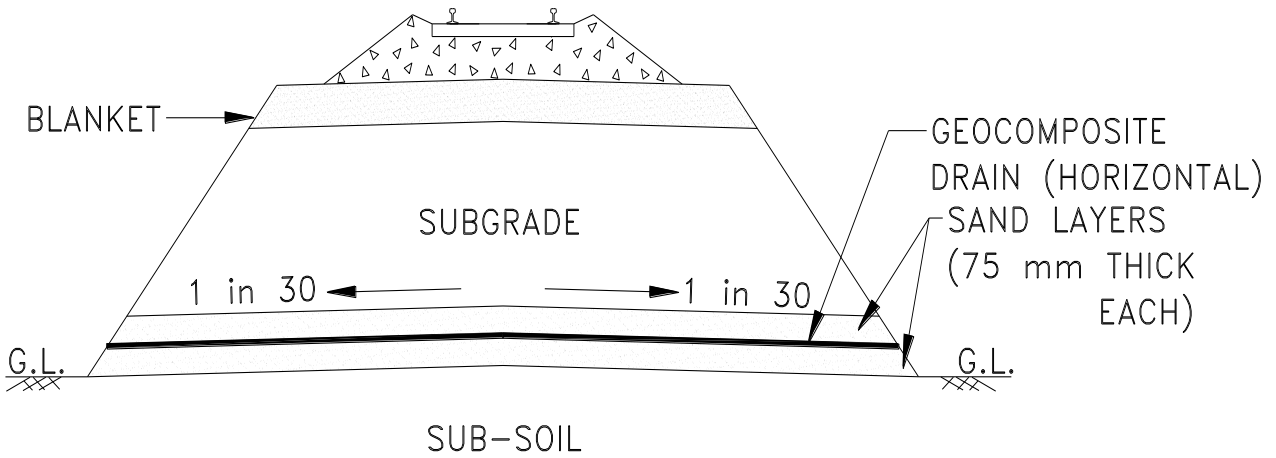
Showing overlap of Geo-Composite Drain

- vii) Care must be taken to ensure that large stones are not allowed in sub soil & subgrade soil to damage the surface of the geotextile filter.
- viii) The water coming from the Geo-Composite Drain can be disposed off by providing side drain along the embankment.
- ix) A diagram showing Use of Geo-Composite Drain in bank over soft subsoil is shown below.

C) Measurement for Payment of Geo-composite Drain (Horizontal)

The Geo-composite drain shall be measured in square metres, with no allowance for overlapping at transverse & longitudinal joints. The contract unit rate for the accepted quantities of Geo-composite drain shall be in full compensation for furnishing,

preparing, hauling and placing Geo-composite drain including all labour, freight, tools, equipment and incidentals to complete the work as per specifications.



Use of Geo-Composite Drain in bank over soft subsoil

FIELD COMPACTION TRIAL OBSERVATIONS & COMPUTATION SHEETS
COMPACTION EQUIPMENT DATA
TABLE -D-1

Project.....

Location.....

Date.....

Item		Roller - 1	Roller -2	Roller -3
Type of Roller				
Gross weight (tonnes)				
Drum Dimension (Roller Type)	Width (mm)			
	Diameter (mm)			
Foot (Sheep foot Type)	Type			
	Number			
	Length (mm)			
	Area (mm ²)			
Contact Area (cm ²) (Sheep foot/Pneumatic Tyred/Vibratory Plate Type)				
Tyre Inflation Pressure(Kg/cm ²)				
Nominal Amplitude(mm)				
Frequency(Hz)				
Dynamic Force(Kg)				
Operational Speed(Kmph)				
Static Linear Loads(Kg/cm)				
Contact Pressure(Kg/cm ²)				
LIST OF EQUIPMENT FOR FIELD TRIALS/MONITORING				
S.No.	Equipment	No. Reqd.	No. available	
1.	Field density apparatus complete: a) Sand replacement b) Core cutter with dolly and hammer	4 Sets 4 Sets		
2.	Balance: a) Electronic balance – 20 kg capacity (with 2.0 gm Least Count) b) Electronic balance – 500 gm capacity (with 0.1 gm Least Count)	1 Set 1 Set		
3.	Straight edge 300mm long	4 Nos.		
4.	Frying Pan	1 No.		
5.	Containers plastic (about 500g capacity)	8 Nos.		
6.	Enamel plates: 6 inch dia. 8 inch dia. 10 inch dia.	10 Nos. 3 Nos. 3 Nos.		
7.	Uniform clean sand (Ottawa Sand) (bags of 50 Kg)	10 Bags		
8.	Measuring tape (3M/5M)	1 No.		
9.	Measuring tape (15 M/30M)	1 No.		
10.	Kerosene oil stove	1 No.		
Signature of Monitoring Official _____ Name _____ Designation _____ Date _____		Signature of Project Official _____ Name _____ Designation _____ Date _____		

**FIELD COMPACTION TRIAL OBSERVATION
TABLE- D-2**

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 _____

FIELD COMPACTION TRIAL OBSERVATION **TABLE- D-3**

Project _____ Location: _____ Date _____
 STRIP No. _____ OMC _____ % MDD _____ gms/cc Volume of core cutters: _____ C.C.

No. of roller passes	Location of the Ramp	In-situ bulk density					Moisture content				Dry density of soil	Percent of MDD	Remark
		Core cutter No.	Wt. Of empty core cutter (gm)	Wt. of wet soil with core cutter (gm)	Wt. of wet soil (gm)	Bulk density of soil (gm/cc)	Container No.	Wt. of wet soil (gms)	Wt. of dry soil (gms)	Moisture content (%)			
1	2	3	4	5	6	7	8	9	10	11	12	13	14
4	1												
	2												
	3												
	4												
6	1												
	2												
	3												
	4												
8	1												
	2												
	3												
	4												
10	1												
	2												
	3												
	4												
12	1												
	2												
	3												
	4												
14	1												
	2												
	3												
	4												

Signature of monitoring official _____
 Name _____
 Designation _____
 Date _____

Signature of project official _____
 Name _____
 Designation _____
 Date _____

FIELD COMPACTION TRIAL-COMPUTATION SHEET
TABLE- D-4

Project_____

Location_____

S. No	Lift thickness (mm)	Moisture content %	Dry density of soil(gm/cc)						Remarks
			Nos. of the roller passes						
			4	6	8	10	12	14	
1.	225								
2.	300								
3.	375								
4.	450								

Computed by_____

Name _____

Designation_____

Date _____

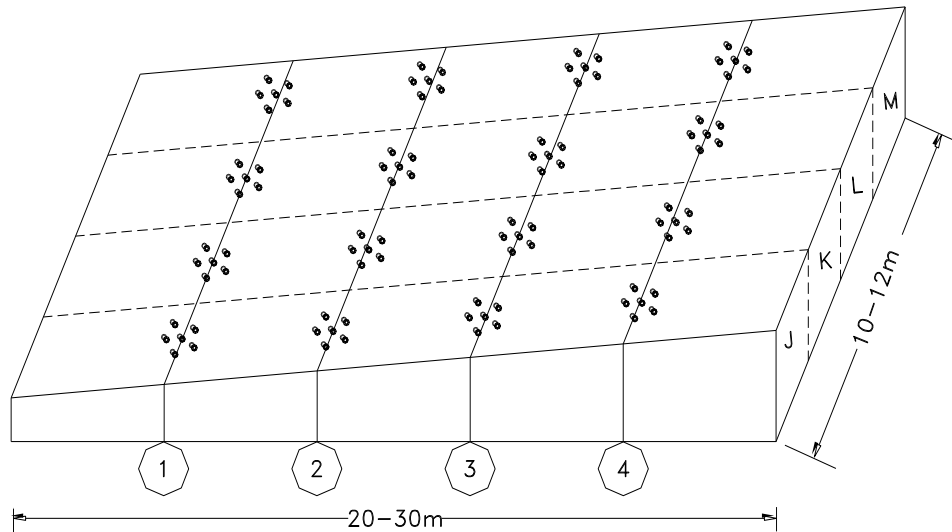
Checked by _____

Name_____

Designation_____

Date_____

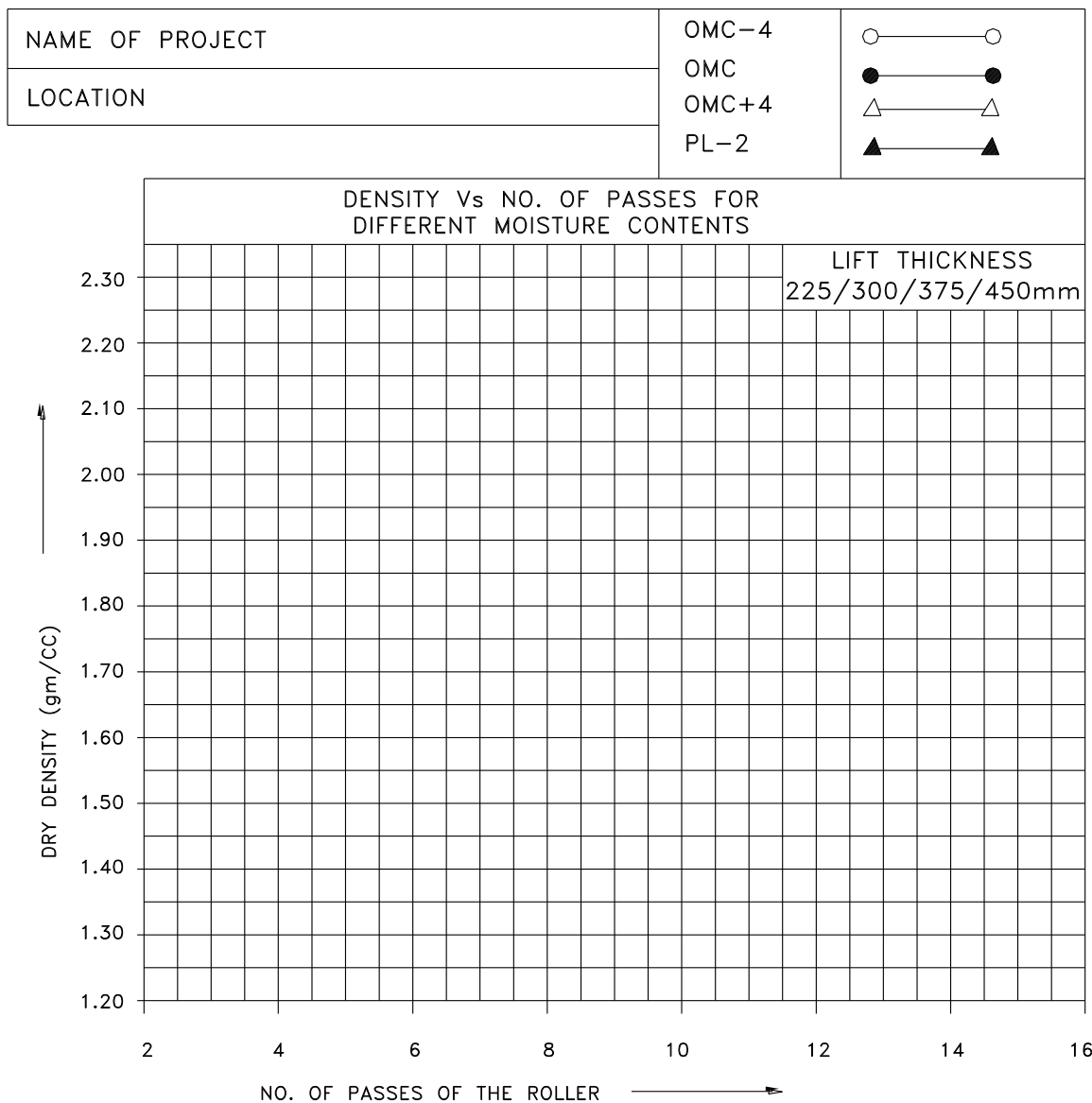
Fig -D-1



RAMP OF EARTH FOR COMPACTION TRIALS IN THE FIELD

• SAMPLING	—	J	K	L	M
• MOISTURE CONTENT (%) (WITH VARIATIONS OF $\pm 2\%$)	—	OMC-4	OMC	OMC+4	PL-2
• SAMPLING POINTS	—	J ₁ , J ₂ , J ₃ , J ₄ ; K ₁ , K ₂ , K ₃ , K ₄ ; L ₁ , L ₂ , L ₃ , L ₄ ; M ₁ , M ₂ , M ₃ , M ₄ ,			
• THICKNESS IN MM.	—	225, 300, 375 & 450			
• NO. OF TIMES FOR OBSERVATIONS	—	6(SIX), (AFTER INTERVAL OF 4,6,8,10,12 & 14 PASSES OF ROLLER)			
• TOTAL NO. OF OBSERVATIONS	—	4x4x6 = 96			

Fig – D-2



OFFICIALS – IN – CHARGE	QUALITY CONTROL OFFICIALS
SIGNATURE _____	SIGNATURE _____
NAME OF OFFICER _____	NAME OF OFFICER _____
DESIGNATION _____	DESIGNATION _____
DATE _____	DATE _____

Fig- D-3	
NAME OF PROJECT	LIFT
LOCATION	225mm 300mm 375mm 450mm
NOTATION <div style="display: flex; align-items: center; margin-bottom: 5px;"> ○ — ○ </div> <div style="display: flex; align-items: center; margin-bottom: 5px;"> ● — ● </div> <div style="display: flex; align-items: center; margin-bottom: 5px;"> △ — △ </div> <div style="display: flex; align-items: center;"> ▲ — ▲ </div>	
MOISTURE CONTENT Vs MAX.DRY DENSITY FOR VARIOUS LIFT THICKNESS	
<div style="display: flex;"> <div style="flex: 1; text-align: center; padding-right: 10px;"> <p style="transform: rotate(-90deg); margin: 0;">↑</p> <p style="margin: 0;">MAX.DRY DENSITY (gm/cc)</p> </div> <div style="flex: 4;"> </div> </div> <div style="display: flex; justify-content: space-between; margin-top: 10px;"> 8 10 12 14 14 18 20 22 </div> <div style="text-align: center; margin-top: 5px;"> <p>MOISTURE CONTENT (%) →</p> </div>	
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 _____

Modern Equipment's for Earth Work

The details given below are based on the information available in the public domain and the list is not exhaustive. There may be many manufactures / suppliers of these equipment's and many such similar equipment's.

1.0 Compactors/Rollers

1.1 Slope Compactors

(a) Slope Compactor Vibratory Roller (Double Drum) Rope Start

Slope compactor vibratory roller (Double drum) with Hydraulic drive can work on slope of 1:2 to 1:1.5, a pair of compactors works on Counter Balance Principle have to be linked via wire rope pulley (i.e. two compactors (One at the top and other at bottom of the slope), supported on loaded truck at the top). The two compactors with individual operator have to operate Single lever simultaneously in downward and upward direction from two ends of slope. One of the Slope Compactor Vibratory Roller (Double Drum) Rope Start in operation is given below for illustration.



Fig-E1: Slope Compactor Working with counter balance Method

(b) Slope Vibratory Roller

Slope Vibratory Compactor is a unique attachment which can be attached to any Excavators/Backhoes/Long Reach. This attachment is specially designed for various applications like Railway track extension /Canal / Dam Slope Compaction and sloping surface where compaction is required. This attachment is capable of reaching surfaces where normal compactors cannot reach and can-do deep compaction than an ordinary compactor.

On Steep Slopes, slushy and most difficult terrains, where the normal Roller would easily swamp down, Slope Vibratory Compactors can easily work. These rollers work on the double vibratory principle that provides superior compaction.



Fig-E2: Slope Vibratory Roller



Fig-E3: Working of Slope Vibratory Roller

(c) Slope Vibratory Compactor

Slope Vibratory Compactor is an attachment to normal excavators. The major advantage of this compactor is that it can compact 360 degrees for a height of 2m to 17m depending on size of excavator and attachment length.



Fig-E4: Slope Vibratory Compactor

1.2 Vibrating Plate Compactors:

The vibratory plate compactor is power-engines, walk-behind equipment that imparts powerful vibratory compaction effort to loose materials, by transmitting vibration through the vibrating plate which generates power from the single rotor in vibration case. A plate compactor works by vibrating or driving a flat metal plate against the ground over and over. This flat plate helps to compress and smoothen out the rough and uneven dirt. Plate compactors work best on granular soil, such as sand and gravel. These vary in weight from 100 kg to 2 tonne with plate areas between 0.16 sqm and 1.6 sq cm. Smaller versions are manually guided and therefore suitable for compacting small or awkwardly shaped areas. They usually

travel at about 0.7 km/h. They are classified in terms of mass divided by the area of the base in contact with the ground.



Fig-E5: Vibrating Plate Compactor

1.3 Small Width Vibratory Roller for Compaction of Earthwork in Gauge Conversion Work and Narrow Width Portion

Proper compaction in the widened portion of embankment is difficult to achieve with conventional means of compaction like ramming & hand rollers. The small width vibratory roller is to achieve the desired compaction in widening of embankment in narrow width portion, from MG to BG in Gauge Conversion Works.



Fig-E6: Small Width Vibratory Roller (Drum width 90 cm)

1.4 Walk behind Vibratory Roller

Walk behind Double Drum Vibratory Roller is modern compact design for use in a wide range of compaction application. Hydraulic with integrated travel control eases the operating effort required for movement. Walk behind Roller has the vibratory source located in the drum which provides maximum compaction and traction performance.



Fig-E7: Walk behind Roller

1.5 Vibratory Rollers with Latest Techniques:

Even some latest techniques have been developed in World Railways, where vibratory roller includes the machine to directly determine the vibration modulus as parameter for the dynamic stiffness of the soil. There is continuous optimization of amplitude and compaction energy which reduces loosening in upper layers on uniform and granular material types.

1.6 Double Drum Vibratory Roller:

Double Drum Vibratory rollers are used primarily to compact paving materials & their surface layer. It can also be used for the compaction of small and medium-sized foundations, sub-foundations and filling materials. These machines have two steel drums that vibrate via an internal, eccentric mechanism, which often can be adjusted to vary the frequency and amplitude of the vibratory action.



Fig-E8: Double Drum Vibratory Roller

Few Models Of The Double Drum Vibratory Rollers Manufactured In India



Fig-E8.1 Delivers excellent mat density, good visibility and comfort, fuel efficiency with Eco-mode & good water spray system



Fig-E8.2
(Solid drum type & excels on a variety of asphalt mix designs as well as other granular materials)

1.7 Single Drum Vibratory Roller:

Single Drum Vibratory Roller which is widely used in the construction to compact the granular layer. It ensure smooth surface after the application and therefore, used for the bridges, patching, footpath and landscaping applications. These machines have one steel drum that vibrates via an internal, eccentric mechanism, which often can be adjusted to vary the frequency and amplitude of the vibratory action.



Fig-E9: Single Drum Vibratory Roller

Few Models Of The Single Drum Vibratory Rollers Manufactured In India



Fig-E9.1: (Drum Type & used for better gradeability)



Fig-E9.2: (Available in Standard, Drum & Pads + Drum type & used for better gradeability & breaking clods)



Fig-E9.3: Vibratory Rollers(Drum Type & used for better gradeability)

2.0 Heavy Machinery for Railway Embankment Construction: Rail Road construction equipment's are found in a wide variety ranging from the very heavy equipment to portable and lighter equipment. This modern and heavy construction equipment makes the construction job easier and quicker. Also the work done by heavy machinery is of good quality. The heavy machines make possible a lot of tasks to be completed safely reliably and time saving that cannot be carried out manually properly.

2.1 Backhoe:

Backhoe comprises a bucket on the end of an articulated boom, set on a pneumatic tyred or crawler tractor unit. The boom, bucket arm and bucket are usually controlled by hydraulic rams. Back-acters operate by digging towards the machine in an arc from a small distance above the surface on which the machine stands to a position vertically below the outer edge of the machine. The maximum depth of excavation is related to the length of the boom and machines with depth capacities between 2.6 and 6 m are in common use. Long reach machines with nominal reach and depth capacities up to 18 to 14m respectively are also available. Buckets are available for back-acters in different sizes up to 3cum,

depending on the power of the machine and the use. Loading is generally carried out by lifting the bucket and swinging the boom away from the working face to the awaiting haulage vehicle. Alternatively, material can be dumped adjacent to the machine.

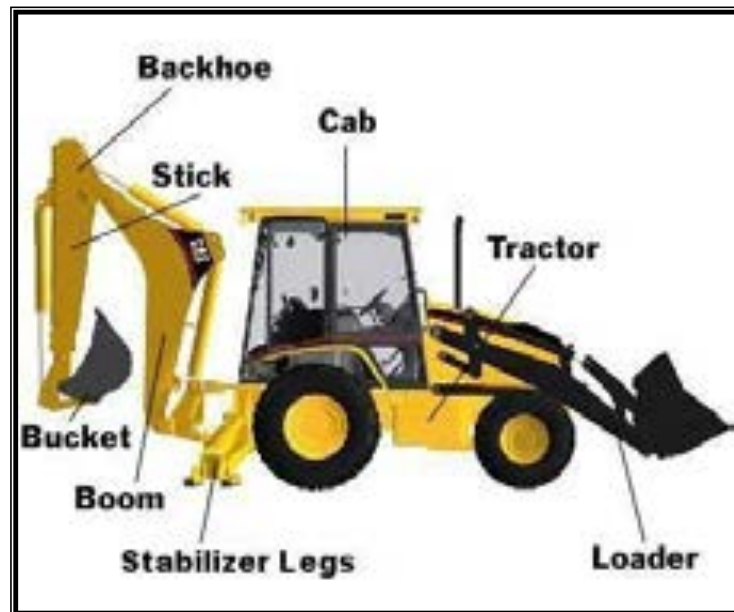


Fig-E 10: Backhoe

2.2 Face, Front or Loading Shovel:

Face, front or loading shovel is constructed in a similar manner to a back-acter except the boom; bucket arm and bucket operate in the opposite direction, i.e. up and away from the machine. Generally used for excavating faces upto about 8m high and stockpiles. Buckets are available in different sizes upto 4cum (heaped) depending on the power of the machine. Loading is carried out in a similar manner to the back-acter, although some machines have bottom dump buckets to increase the speed of loading. It is useful in excavating soils, weak rocks and blasted rocks from faces in cutting etc. some larger excavators can be converted from back-acters to face shovels.



Fig-E 11: Shovel



Fig-E 12: Crawler Hydraulic Excavator with Face Shovel

2.3 Forward Loader:

Forward loader consists of a pneumatic tyred or crawler tractor at the front of which is mounted a wide bucket that can be moved in a vertical plane. Excavation is carried out by driving the machine towards and the bucket into the material; the bucket is then turned and lifted upwards, thus catching and excavating the material. The hauling vehicle is loaded by driving the loader to and emptying the bucket into the body of a vehicle. Loaders are generally used to excavate the materials at and for a distance above ground level and can be used to push or haul material in the bucket over a short distance. Modern loaders have hydrostatically powered buckets and the smaller units may be equipped with back-acters (i.e. backhoe loader)



Fig-E 13: Forward Loader

2.4 Excavator:

Excavators are heavy construction equipment consisting of a boom, dipper, bucket and cab on a rotating platform known as the "house". The house sits atop an undercarriage with tracks or wheels. They are a natural progression from the steam shovels and often mistakenly called power shovels. These machineries are used for various earthwork purposes such as excavation of earth and loading etc.



Fig-E14: Excavator

2.5 Graders:

Graders are used for levelling the surface during earthwork in embankments and providing blanket surface before spreading ballast and laying track. Graders are

used to spread fill and finely trim the subgrade. They consists of a blade which can rotate in a circular arc about a sub horizontal axis and which is supported beneath a longitudinal frame joining the front steering wheels and the rear drive wheels. The front wheels are generally articulated whilst the rear wheels are set in tandem beneath the motor and control units. The blade is used to trim and redistribute soil and therefore graders usually operate in the forward direction.



Fig-E15: Grader

2.6 Dumpers:

Dump trucks or dumpers generally vary in size from 1 to about 80 tonne capacity. Large capacity machines are also available but are generally used in mines, quarries or open cast sites. In recent years articulated dump trucks with capacities upto 35 tonne have become popular as they are versatile and are especially suitable for hauling on softer sub grades. The speed of tipping is increased over a road lorry by the absence of a tailgate. Small dumper units are available for work on small sites and mounted dump trucks are also available with load capacities upto about 20 tonne.



Fig-E 16: Dumper

2.7 Dozers:

Bulldozer also called Dozer, powerful machine for pushing earth or rocks, used in road building, farming, construction, and wrecking, is a tractor equipped with affront pusher blade, which can be raised and lowered by hydraulic rams. An angle

dozer has a blade that is capable of being set an angle to push material sideways whilst the tractor moves forward. The tractor unit is usually mounted on crawler tracks thus allowing it to travel over and push off a wide variety of ground conditions although wheel mounted units is available. Blades are manufactured in a variety of styles but are all of heavy duty construction with a hardened steel basal leading edge driven into the ground to cut and push the material to be excavated. Dozers have a wide variety of roles including excavating soils and weak rocks, ripping moving excavated material over short distances spreading materials, trimming earthworks and acting as a pusher to boost the effective power of scrapers and other plants. Wide ranges of crawler units are available ranging from 45 to 575 kW.



Fig-E 17: Dozer

2.8 Scraper:

A scraper is a machine used for moving or removing dirt, gravel and any other unnecessary material from the surface. Scraper can excavate load and deposit material in one cycle and may be towed or self-propelled. It consists of a centrally mounted bowl, the bottom, leading edge of which can be controlled. Both towed and self-propelled scrapers are effectively articulated between the front motorized or towing unit and the bowl and larger self-propelled scraper may second engine mounted on the rear.



Fig-E 18: Scraper

**Typical Compaction Characteristics for natural soils & rocks (Ref: BS: 6031
(latest version))**

Material (1)	Major divisions (2)	Sub groups (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 Grid roller not less 180 kg per 100 mm of roll 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.
Coarse-grained soils	Gravel sand, gravelly soils	Well graded gravel and gravel/sand mixture: little or no fines Well graded gravel/ sand mixtures with excellent clay binder Uniform gravel: little or no fines Poorly graded gravel and gravel/sand mixtures: little or no fines Gravel with excess fines, silty gravel, clayey gravel, poorly graded gravel/ sand/clay mixtures	Grid roller over 540 kg per 100mm of roll Pneumatic tired over 2000 kg per wheel Vibratory plate compactor over 1100 kg/sq.m. of base plate Smooth wheel roller Vibratory roller Vibro-rammer Self-propelled tamping roller	3 to 12 depending on type of plant	75 to 275 depending on type of plant	