



भारत सरकार - रेल मंत्रालय
अनुसंधान अभिकल्प और मानक संगठन
लखनऊ - 226 011
EPBX (0522) 2451200
Fax (0522) 2458500

Government of India-Ministry of Railways
Research Designs & Standards Organisation
Lucknow - 226 011
DID (0522) 2450115
DID (0522) 2465310



No. GE/GEN/185-Vol-I

Date: 17.09.2020

All PCEs & CAOs

Indian Railways

MD, KRCL, Belapur Bhawan, Sector-11, CBD Belapur, Navi Mumbai-400614

Chairman and MD, IRCON International Limited, C-4, District Center, Saket, New Delhi-110017

MD, RVNL, Plot No. 25, First Floor, August Kranti Bhawan, Bhikaji Kama Place, RK Puram, New Delhi-110066

MD, DFCCIL, 5th floor, Pragati Maidan, Metro Station Building Complex, Delhi-110001

MD, RITES, RITES Bhawan, 1, Sector-29, Gurugram, Haryana-122001

MD, MRVC, Churchgate Station Building, 2nd Floor, Mumbai-400020

CAO/Const.), Metro Railway, Mumbai & Chennai

Director General, IRICEN Pune

Director General, NAIR, Vadodara

GM(Engg.), Metro Railway, Kolkata

MD/ CONCOR, New Delhi

Chief Project officer, DMRC, NBCC Building, Pragati Vihar, New Delhi

Chief Commissioner of Railway Safety, Lucknow

Sub: "Comprehensive Guidelines and Specifications for Railway formation - Specification No. RDSO/2020/GE: IRS-0004, Sept.-2020"

Ref: Railway Board letter no. 2011/CE-II/Form/Spec dated 14.09.2020.

In compliance to Railway Board's instructions, the Comprehensive Guidelines and Specifications for Railway Formation have been prepared by RDSO by merging of various existing guidelines earlier issued by RDSO from time to time & updating/adding of the recent technical developments in related areas including use of Geosynthetics in railway formation. The Guidelines have been approved by Railway Board vide letter under reference above (copy enclosed).

1. The "Comprehensive Guidelines and Specifications for Railway Formation", Specification no. RDSO/2020/GE: IRS-0004 consists of 10 Chapters and 14 Appendices, covering various aspects for execution of Earthwork in Indian Railway Formation in Construction and Open Line including Design of formation, Slope Stability Analysis, Applications of Geosynthetics in Formation, Quality assurance tests, Fitment of existing formation for 25T axle load (at 100Kmph) & passenger train operation for 160Kmph etc.

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2. It will supersede earlier guidelines/instructions for Earthwork issued by RDSO i.e. "Guidelines for Earthwork in Railway Project" GE: G-1, July 2003, "Guidelines and Specifications for Design of Formation for Heavy Axle Load" GE: G-0014 Nov. 2009, RDSO letter no. RS/G/108/Heavy Axle Load dated 19.10.15/26.10.16 and "Rationalisation of Formation Layer Thickness on Indian Railway Track" Specification No. RDSO/2018/GE: IRS-0004(D) Part-IV, July 2019.

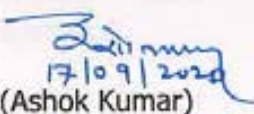
As per instructions of Railway Board in the letter under reference:

3. North Central Railway & Western Railway are requested to carry out field validation for fitment of existing formation for passenger train operations at 160 kmph and South Eastern Railway & East Coast Railway are requested to carry out field validation for fitment of existing formation for 22.9t/25t axle load operation at 100 kmph.
4. Any deviation in the guidelines/specifications based on logic/local conditions can be permitted with approval of PCE/CAO(C) only.

The above mentioned approved Guideline are sent herewith in soft copy for adoption in the field. Provisions in these guidelines will apply to new works. However, the application of these guidelines may be explored in ongoing works also. Any difficulty in adoption of the new specification may please be reported to RDSO. It is also requested that its implementation may please be monitored closely for two years and send feedback to RDSO for improvement, if any.

Soft copy of the Comprehensive Guidelines and Specifications has also been uploaded on RDSO 'Railnet' website (10.100.2.12) under 'Geotechnical Engineering Directorate' under head 'Guidelines and Specifications'. Hard copies shall be sent in due course.

DA: as above.


17/09/2020
(Ashok Kumar)

Exe. Director/Geotech. Engg.

Copy to: PED/CE/P, Railway Board for kind information.

भारत सरकार (GOVERNMENT OF INDIA)
रेल मंत्रालय (MINISTRY OF RAILWAYS)
रेलवे बोर्ड (RAILWAY BOARD)

No. 2011/C15-II/Form/Spec

New Delhi, dated 14.09.2020

Executive Director/GE
RDSO
Lucknow

Sub: **Comprehensive Guidelines and Specification for Railway Formation**
Ref: RDSO's letter no. GE/GEN/185/Vol-I dated 02.07.2020

Vide letter under reference above, the final draft of "Comprehensive Guidelines and Specifications for Railway formation" has been forwarded by RDSO for Board's approval.

Having considered the various recommendations of RDSO regarding the above Guidelines, Competent Authority has approved the above final draft for adoption in Zonal Railways with following decisions on specific issues referred by RDSO -

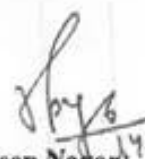
SN	Specific issues/provisions of the guidelines	Board's decision
(i)	Fitment of existing railway formation for 22.9T/25T axle load operations for speed upto 100 kmph and passenger train (19.5T axle load) operation for speed upto 160 kmph assuming 350 mm ballast cushion and 60 kg rail section (Appendix-I)	Approved.
(ii)	Provisions for Gauge conversion/doubling/Cess repair work in case of existing formation (Chapter-9)	Approved.
(iii)	Methods of Formation Rehabilitation (Chapter 10)	Approved.
(iv)	Erosion control of slopes (Chapter 8)	Approved.
(v)	Quality control of Earthwork (Chapter 7)	Approved with following modification. <ul style="list-style-type: none">The note marked as "*" of Table 7.2 to be modified as under: "Additionally this test can also be done by third party (i.e IIT, NIT, Govt. Labs or any NABL approved Lab) having testing facilities, to cross check the results achieved at site. Frequency of testing in this case shall be decided/approved at the level of Chief Engineer (Con). In PSUs, frequency of such tests shall be decided as per existing delegations for testing."In Para 7.4.1.c, in case of PSU, existing provision of Equivalent authority for acceptance criteria shall continue.

SN	Specific issues/provisions of the guidelines	Board's decision
(vi)	Modified checklist of certification of quality of Earthwork in Railway Projects (Appendix-M)	Approved.
(vii)	Para 2.2 (ii) for suitability of subsoil	Approved.
(viii)	Para 2.3.5 for Ground Improvement for expansive soils	Approved.
(ix)	Para 2.4.1 for Use of Geo-composite drain	Approved.
(x)	Para 2.4.4 for Geo-synthetics encapsulated Stone column	Approved.
(xi)	Para 3.4 for Cross Slope of Formation	Approved.
(xii)	Para 3.7 for Soils to be normally avoided	Approved.
(xiii)	Table 3.3 to 3.6 regarding filter criterion	Approved.
(xiv)	Chapter 4 regarding applications of geo-synthetics in railway formation and Appendix C- specification of geo-synthetic products	Approved.
(xv)	Para 5.1 regarding requirement of flatter slope	Approved.
(xvi)	Para 5.1.1 & 5.1.2 regarding provision of berm	Approved.
(xvii)	Appendix B of illustrative Examples for providing minimum thickness of Formation Layers	Approved.
(xviii)	Newly added test procedures for Nuclear Moisture Density Gauge	Approved.
(xix)	Appendix J regarding Proforma for Reporting Unstable Formation	Approved.

RDSO shall circulate the final draft to Zonal Railways/PSUs. Zonal Railways/PSUs shall take necessary action for adoption of above guidelines and for closely monitoring the implementation for a period of two years and to furnish feedback/suggestions to RDSO for improvement, if any.

North Central Railway & Western Railway are nominated for field validation for fitment of existing formation for passenger train operations at 160 kmph and South Eastern Railway & East Coast Railway for field validation for fitment of existing formation for 22.9/25t axle load operation at 100 kmph.

Any deviation to above guidelines/specifications based on logic/local conditions can be permitted with approval of PCE/CAO(C) only.


 (Pradeep Nagar)
 Director Civil Engg. (Plg.)
 Railway Board

Copy for necessary action to:

- (i) PCEs/All Zonal Railway
- (ii) CAO(C)/All Zonal Railway
- (iii) MD/KRCL, RVNL, IRCON, DFCCIL, RITES, MRVC.



**GOVERNMENT OF INDIA
MINISTRY OF RAILWAYS**

**COMPREHENSIVE GUIDELINES
AND
SPECIFICATIONS
FOR
RAILWAY FORMATION**

Specification No. RDSO/2020/GE: IRS-0004

September - 2020

**Geo-technical Engineering Directorate,
Research Designs and Standards Organisation
Manak Nagar, Lucknow – 226011**



FOREWORD

The Railway Track System is an important part of the transportation infra-structure of the country as the Railway plays an important role in the economic growth of the country. Indian Railways has planned to carry higher axle loads as well as higher speeds for increasing through put.


Indian Railway has already decided in 2009 to construct formations for 25T axle load. Further, formation in Dedicated Freight Corridors is being constructed to cater higher axle load of 32.5T. Feeder routes to DFCs are also being strengthened for 25T axle load.

RDSO has been involved with research and standardization of track structure including formation and issued various guidelines on earthwork for railway projects and formation design for heavy axle load i.e., GE:G-1 in July 2003, GE:G-14 in Nov 2009 and other guidelines from time to time covering various geotechnical aspects of track formations. However due to variations in practice in the field over Indian Railways and many changes taken place over a period of time, there is need for comprehensive unified instructions for construction of Railway formation for present and future needs of the traffic. With this view, Railway Board directed RDSO vide letter dated 01.03.2018 & 28.01.2019 to prepare Comprehensive Guidelines covering newly developed aspects like Geo-synthetics, Ground improvement, quality assurance tests, provisions to assess suitability of existing formation for running of 25T axle load and passenger load at 160 kmph of construction/maintenance practices. These Comprehensive Guidelines also cover the latest parameters adopted as per UIC-719 for construction of new formation to meet the requirements of 25 T loading at 100 kmph for goods traffic and 160 kmph speed for passenger traffic.

I am happy to see that after tremendous efforts of Geotechnical Engineering Directorate of RDSO, this "**Comprehensive Guidelines and Specifications for Railway Formation**" could be framed and Railway Board has approved this for implementation on Indian Railways. I am sure that implementation of these guidelines and specifications on Zonal Railways will result in stable and better quality formations fit for running of higher axle load with higher speed viz. 25t & 32.5T axle load and passenger train at 160 kmph. It is particularly appreciable to see the right emphasis on quality control aspects, use of new materials for Railway formation, new field tests to help accelerated construction of formation, check lists and formats through which quality of work can be monitored by Railway field engineers at different levels and will enable engineers to achieve quality of earthwork.

I am sure this "**Comprehensive Guidelines and Specifications for Railway Formation**" will be found very much useful by all sections of Civil Engineers on Indian Railways. Your feedback may be sent directly to PED/ED/GE/RDSO and PED/CE(P)/Railway Board who will be glad to take care of your doubts and suggestions.

Lucknow,
September, 2020


(Sudhir Agarwal)
Spl. Director General (Engg.)
RDSO

PREAMBLE

The existing formation for most of the routes of Indian Railways was constructed by conventional methods and meant to carry lighter axle load with less number of trains and lower speed, as compared to present scenario. Over the years, increase in axle load, speeds and traffic have placed a greater demand on the formation. Unlike replacement of track components and ballast, the rehabilitation /improvement of formation is costly, time consuming and causes traffic disruption. As a result, lot of stretches are continuing under severe speed restrictions over the years.

With an aim to construct the formation for future needs, it was decided in 2009, that the formation on Indian Railways will be constructed for 25T axle load.

Guidelines for earth work in Railway Projects No.GE: G-1, July 2003 and Guidelines & Specifications for design of formation for Heavy Axle Load GE: G-14, November 2009, cater for construction of formation along with other Guidelines i.e. erosion control, widening of formation in gauge conversion etc. Guidelines GE: G-1 were issued for 22.5T axle load mainly, whereas Guidelines GE: G-14 caters for the specification for top layers of the formation for 25T, 30T and 32.5T axle load. There are over-lapping provisions in these two Guidelines and 30T axle load is not envisaged for the future, as 32.5T axle load trains are planned to be run on DFC routes. Thus there was a need for comprehensive unified instructions for construction of Railway Formation for the present and future needs of the traffic.

In view of above, Railway Board vide letter No.2011/CE-II/Form/Spec. dated 01.03.2018 instructed to prepare comprehensive guidelines by merging various existing guidelines regarding earthwork issued from time to time by RDSO and updating with latest technical developments in the related areas with following terms of reference:

- i. To prepare comprehensive Specifications for construction of Railway Formation covering all aspects of execution of earthwork in Construction and Open Line. Various guidelines related to earthwork issued by RDSO should be incorporated as appendices to the specifications.
- ii. The present Guidelines i.e. GE:G-14 contains Guidelines for Construction of Formation for 30T Axle Load in addition to 25T Axle Load and 32.5T Axle Load. The new specifications should contain Provisions for Construction of Formation for 25T and 32.5T Axle Load only as further Standards/Operation are not being contemplated for 30T Axle Load on projects.
- iii. The specification should contain provisions for widening of Formation such as in Doubling and Gauge Conversion projects.
- iv. The specifications should contain methodology for repair of cess, widening of cess/formation in open line maintenance.
- v. The specifications should cover guidelines for formation treatment for existing formation.
- vi. The specifications should contain fitness of type of formation w.r.t. speed.
- vii. The details of modern equipments required for construction and testing of formation in large projects should be incorporated as appendix.
- viii. The testing methodology to adjudge suitability of soil for formation and quality of construction should be incorporated in the specifications.

In addition, there is a need to judge the suitability of existing formation for running of 25T axle load as well as increasing speed of Mail/Express trains to 160 kmph.

Further, as per the instructions of Railway Board vide letter dated 28.01.2019, preparation of this guidelines & specifications was divided into two phases:

First Phase: Specification of Geotextile and Geo-composite drain and Rationalization of Formation Layer thickness

Second Phase: Specification of Geogrid and All the balance items of the comprehensive specification for construction, repairs and rehabilitation of formation.

Specifications for Geotextile, Geogrid, Geocomposite Drain and document on Rationalisation of formation layer thickness have already been issued by RDSO and also incorporated in this Document.

This document apart from covering various aspects for execution of earthwork in Indian Railway Formation, also includes other relevant features such as slope stability analysis, application of Geo-synthetics in formation, ground improvement techniques, quality assurance tests viz. CBR values of subgrade soil, Elastic modulus of compacted layer (E_{v2}) etc. It also covers provisions to judge the suitability of existing formation for running of 25T axle load as well as increasing speed of mail/express trains speed upto 160 kmph.

This comprehensive Guidelines & Specifications supersedes all earlier guidelines/instructions for Earthwork issued by RDSO i.e. Guidelines for Earthwork in Railway Project GE: G-1, July 2003, Guidelines and Specifications for Design of Formation for Heavy Axle Load GE: G-0014 Nov 2009, RDSO letter no. RS/G/108/Heavy Axle Load dated 26.10.16 and Rationalisation of Formation Layer Thickness on Indian Railway Track Specification No. RDSO/2018/GE: IRS-0004(D) Part-IV dated: 25.07.2019.

Vide letter no. 2011/CE-II/Form/Spec dated 14.09.2020, Railway Board has approved this document with minor modifications which have been incorporated in this document.

Following officers of RDSO (including GE staff as mentioned in the Acknowledgement) have contributed significantly in preparation of the Guidelines:

1. Shri Ashok Kumar, Executive Director/Geotechnical Engineering/RDSO
2. Shri Sameer Singh, Joint Director/Geotechnical Engineering /RDSO
3. Shri S. K. Awasthi, Jt. Director/ Geotechnical Engineering /RDSO
4. Shri S. K. Ojha, Asstt. Research Engineer/ Geotechnical Engineering /RDSO

Valuable suggestions were also received from Shri R. K. Shekhawat, Sr. Professor/IRICEN, Pune on various issues covered in this guideline and incorporating these has led to further improvement of the guidelines.

Lucknow
September, 2020


17/09/2020
(Ashok Kumar)
Exe.Director/Geo-tech.Engg.

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Terminology

Commonly used terms in context of the subject and in this document, with their specific meanings are mentioned as under:

- 1.0 Formation:** In a general way, collectively refers to the layers comprising blanket, prepared subgrade/Subgrade.
- 2.0 Formation Top:** Boundary (interface) between ballast and top of blanket or prepared subgrade/Subgrade (where blanket layer is not provided).
- 3.0 Track Foundation:** Constitutes ballast, blanket, Prepared subgrade/Subgrade, which is placed / exist below track structure to transmit load to subsoil.
- 4.0 Cess:** Portion at top of formation level, extending from toe of ballast to edge of formation.
- 5.0 Ballast:** Crushed stones with desired specifications placed directly below the sleepers.
- 6.0 Blanket:** Blanket is a layer of coarse, granular material of designed thickness & specification provided over full width of formation between subgrade and ballast.
- 7.0 Prepared Subgrade:** In case of two layer system, it is provided over the subgrade and below the blanket layer with a view to economise the thickness of blanket layer.
- 8.0 Sub-grade:** It is the upper part of Railway Embankment constructed by borrowed soil of suitable quality upto bottom of blanket/prepared subgrade. It is divided into top layer and lower layer (fill).
- 9.0 Subsoil:** The existing soil below natural ground level.
- 10.0 Cohesive Subgrade:** Subgrade constructed with soils having cohesive behaviour i.e., shear strength is predominantly derived from cohesion of the soil is termed as cohesive subgrade. Normally, soils having particles finer than 75 micron exceeding 12% exhibit cohesive behaviour.
- 11.0 Cohesionless Subgrade:** Subgrade constructed with cohesion-less, coarse-grained soils i.e., shear strength is predominantly derived from internal friction of the soil are termed as cohesion-less subgrade. Normally, soils having particles finer than 75 micron less than 5% exhibit cohesion-less behaviour.
- 12.0 Dispersive Soil:** Dispersive soils are those, which normally deflocculate when exposed to water of low salt content. Generally, dispersive soils are clays which are highly erosive and have high shrink and swell potential. These soils can be identified by Crumb, Double Hydrometer, Pin Hole and Chemical Tests.
- 13.0 Unstable Formation:** It is yielding formation with continued settlement including slope failure, which requires excessive maintenance efforts.
- 14.0 Shear Strength:** Shear strength of soil is its ability to resist shearing at a shearing surface (plane) under direct stress (vertical pressure)
- 15.0 Soil Pressure Units, equivalence:** 1 Pascal (Pa) = 1 N/m² and 1 Mega Pascal (MPa) = 1 N/mm²

$$100 \text{ kPa} = 10 \text{ t/m}^2 = 1 \text{ Kg/cm}^2 = 1/10 \text{ N/mm}^2 = 1/10 \text{ MPa}$$

16.0 Deformation Modulus (E_{v2}) : It is modulus of elasticity (also deformation) in the second cycle of loading in the cyclic plate load test. It is determined by cyclic Plate Load Test on top of compacted blanket layer/prepared subgrade/Embankment fill in accordance with DIN:18134-2012 (Ref :Appendix-H).

17.0 Geosynthetic: A planar product manufactured from polymeric material used with soil, rock, earth, or other geotechnical engineering related material as an integral part of a man-made project, structure, or system.

18.0 Geogrid:Geogrid is a planar, polymeric structure consisting of a regular open network of integrally connected tensile elements, which may be linked by extrusion, bonding or interlacing. They have open grid like configuration with large apertures between individual ribs.

19.0 Geotextile: Geotextiles are planar and permeable members which are used in contact with soil/rock and/or any other geotechnical material for civil engineering applications. They are basically textiles manufactured from synthetic fibers.

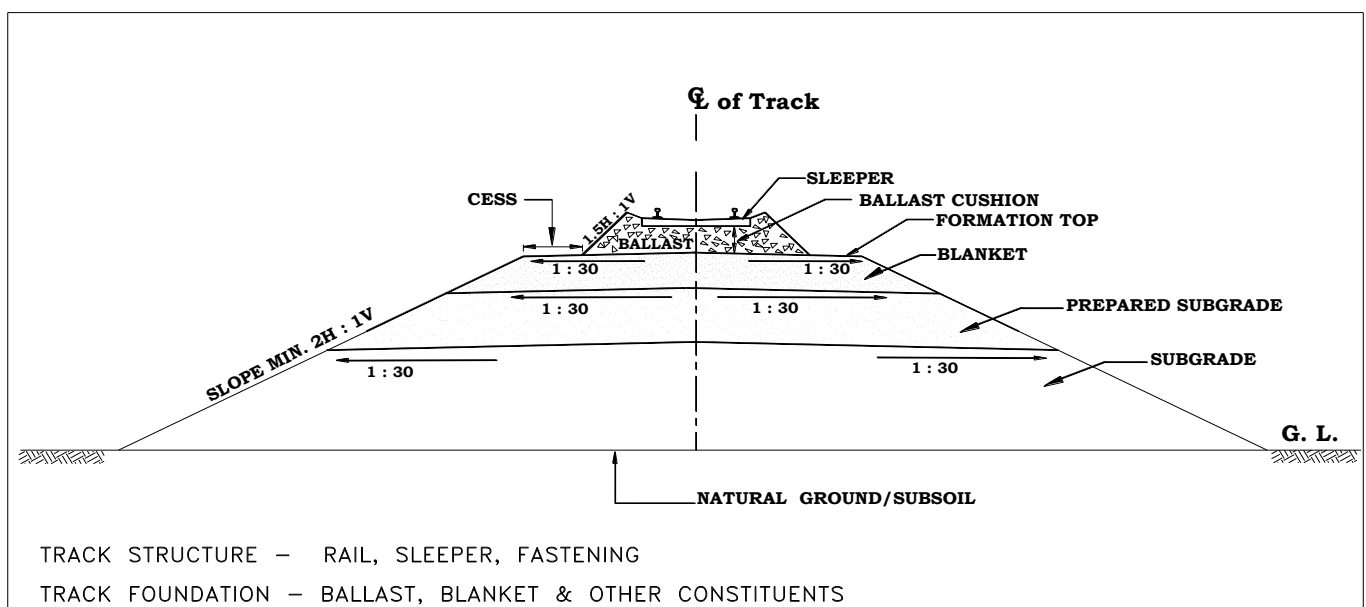
20.0 Geonet: A geosynthetic consisting of integrally connected parallel sets of ribs overlying similar sets at various angles for planar drainage of liquids or gases.

21.0 Geocomposite Drain: Geocomposite drains, consisting of a geonet bonded with non-woven geotextile layer(s) on one or both sides are used for drainage

22.0 Pre-Fabricated Vertical Drain (PVD): A geocomposite consisting of geotextile cover and drainage core installed vertically into soil to provide drainage for accelerating consolidation of soils. Also known as band or wick drain.

23.0 Formation components:

Formation comprises of granular layer (blanket) over prepared subgrade and subgrade. General profile of formation given below.



Typical cross-section representing formation component

CHAPTER-1

SOIL EXPLORATION & SURVEY

Objectives of constructing a stable formation can only be achieved if soil exploration, as envisaged in **“Indian Railways Code For The Engineering Department”** (Engineering Code) Paras 409, 425 and 528, is undertaken in right earnest and precautions are taken to design embankment & cutting against likely causes which could render it troublesome during service. Adequate provision for soil surveys & explorations at different stages, as per requirements of the terrain, should be made in the project estimates to cover the cost for this activity.

1.1 Objectives of Soil Exploration:

Main objectives of soil survey and exploration work are:

- a) To determine soil type with a view to identify their suitability for earthwork and to design the foundation for other structures.
- b) To avoid known troublesome spots, unstable hill sides, swampy areas, soft rock areas, peat lands, etc.
- c) To determine method of handling and compaction of subgrade.
- d) To identify suitable alignment for Embankment and cutting from stability, safety, economy in construction and maintenance considerations.
- e) To identify suitable borrow areas for desired quality and quantity of subgrade and blanket material.
- f) To determine depth of various strata of sub-soil and bedrock level.
- g) To determine ground water table position and its seasonal variation and general hydrology of the area such as flood plains, river streams, etc.
- h) To determine behaviour of existing track or road structure nature and causes of geo-technical problems in them, if any.

1.2 Soil survey and exploration/investigation for construction projects should be carried out in following three stages:

1.2.1 During Reconnaissance Survey

- a) The main objective of soil survey during Reconnaissance is to collect maximum surface and sub-surface information without drilling exploratory boring/ test pits to avoid obviously weak locations such as unstable hillsides, talus formation/scree (accumulation of broken rock debris, as at the base of a cliff or other high place), swampy areas, peat grounds, very soft rocks or highly weathered rocks, etc.
- b) At the reconnaissance stage, available data from geological and topological maps and other soil surveys done in the past, existing soil profiles in nearby cuts, quarries are scrutinized. Water table is recorded from local observation and inquiry. The involved soils are classified by visual examination and if necessary, few field/ laboratory tests are conducted for this purpose.
- c) Survey reports available from other Departments/Agencies such as Geological Survey of India, Ministry of Road Transport and Highways, Central Board of Irrigation and Power, CPWD, State Irrigation, PWD, etc. can be acquired to

obtain information on the accessibility, geology and soils, subsurface information, etc.

- d) Areas of prospective borrow soil and blanket material should also be surveyed to give idea of quality and quantity of materials to be used for construction of Railway Embankment.
- e) Above collection of data should be incorporated in the Feasibility Report required to be submitted as per **"Indian Railways Code For The Engineering Department"** (Engineering Code) Paras 555 and 576 in chapter of Project Engineering under heading of formation (para 528 of Engineering Code).
- f) The data and information collected during survey should be presented in suitable format such as graphs, bar charts or in tabular or statement form.

1.2.2 During Preliminary Survey

- a) Primary objective of preliminary exploration is to obtain sufficient subsurface data to permit selection of the type, location and principal dimensions of all major structures and estimation of earthwork and design of formation. The scope of preliminary survey is restricted to determination of depths, thickness and composition of each soil stratum, location of rock and ground water and also to obtain appropriate information regarding strength and compressibility characteristics of various soil strata.
- b) As stated in Para 409 of **"Indian Railways Code For The Engineering Department"**, the field work in Preliminary Survey includes a compass traverse along one or more routes with transverse and longitudinal levels to prepare an L- section of routes proposed. This fieldwork shall also cover a soil survey by sampling at suitable intervals in order to obtain a fair idea of the soil classification and characteristics of soils on proposed routes. Testing of disturbed soil samples is usually adequate; however core drilling will be necessary in rocks. This will help in determining the thickness of the blanket layer on different sections and total quantity of blanket material to be required.
- c) Exploratory boring with hand/ auger samplers and soil sampling should be undertaken along the alignment and soil samples also should be collected from borrow pit area, at an interval of 500 meter or at a closer interval, wherever change of soil strata occurs. The boring should be done upto 1.5 to 2.0 m depth below existing ground level. In case of Embankments more than 4m height and embankments with problematic substrata, the boring should be taken down to a depth equal to twice the height of Embankment. Samples should be collected from each stratum found in each boring.
- d) Bore logs are prepared based on laboratory test results of disturbed samples obtained by auguring or split spoon sampler. Particle size distribution, soil classification and index properties of the soils are determined from laboratory tests.

- e) In case of soft clays and sensitive clays, in-situ vane shear tests should be conducted to determine its shear strength and depth of underlying compressible clay layer. Undisturbed samples should also be collected to know actual moisture content, natural dry density and shear and consolidation parameters of the soil.
- f) Geo-physical investigations for bedrock profile, sub-surface strata and soil properties are required to be carried out for foundation of major structures such as bridges. Methods such as Seismic Refraction Method (IS: 1892-1979) (Reaffirmed 2016), Standard Penetration Test (IS: 2131- 1981) (Reaffirmed 2016), Dynamic Cone Penetration Test (IS: 4968-1976) (Reaffirmed 2016) etc., will be required to be carried out to ascertain constituents of substrata and their properties and design foundation of such structures. In alluvial strata, deep auger boring upto 6m may be deployed for subsurface exploration and sampling.
- g) The data and information collected during survey should be presented in suitable format such as graphs, bar charts or in tabular or statement form.

1.2.3 During Final Location Survey

- a) During Final Location survey, detailed investigations are done at locations where important structures viz. high embankment, deep cuttings, major bridges etc. are to be located and where weak sub-soil, swampy ground, marshy land exist. Undisturbed soil samples with the help of deep auger sampler or Split spoon samplers are collected for conducting detailed tests viz. shear strength tests & consolidation test to design safe and economical structure and predict settlements. However, if some tests during preliminary survey are deficient, the same should also be covered.
- b) Assistance may be taken from Geologists, in case of rocky strata, known unstable hill slopes, earthquake prone area and geological fault.
- c) Detailed subsoil exploration is necessary to check stability of structures against failure and to predict anticipated settlement. Bores are made along alignment normally at 200 m to 300m apart in case of uniform type of soil and closely spaced in critical zones. Soil samples within the boreholes are obtained at every change of stratum and interval not exceeding 1.5 m. In case of sandy and gravely soils, Standard Penetration Test may be adequate, as taking out samples in these types of strata is difficult.
- d) Besides classification tests, soil samples should be tested for shear strength and consolidation properties. In case of very soft clays, vane shear test should be conducted for each boring site. Free swell index test should also be carried out in case of expansive soil and organic contents of soil should be determined if soil is suspected to be having large organic contents.
- e) Availability of naturally occurring source of blanket material conforming to the laid down specification shall be explored during the survey. Sources of blanket material of specified quality and its availability around the project site needs to be located to assess its realistic costs for inclusion in project estimates. The source identification should cover various logistics involved in its utilization.

- f) The data and information collected during survey should be presented in suitable format such as graphs, bar charts or in tabular or statement form.

1.2.4 The availability of borrow soil sources shall be explored during the survey. As formation design will primarily depend upon the type of the soil being used in construction, it is essential that soil classification and assessment of bearing capacity is done during soil exploration.

The results of soil exploration shall be reviewed and finally approved at the level of the CAO/Construction as this will be the basis of further design. In case of PSUs the powers of PCE/CAO shall be exercised at appropriate level of authority as nominated by CMD/MD of the PSU.

1.3 Soil Survey & Exploration for Gauge Conversion, Doubling & Rehabilitation Work

For these projects, additional information required will be as follows:

1.3.1 A statement listing out problematic stretches on existing track should be prepared/obtained after scrutiny of gang charts for identifying locations requiring frequent attention, having unsatisfactory TRC results, past history of stretches having failure like slips, subsidence, pre-mature ballast recoupmnt, ballast penetration etc.

1.3.2 Failure of existing formation is accompanied by signs of distress/instability. 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 below:

Table: 1.1 Recommended Scheme for soil exploration and data collection & testing

S. No.	Symptoms	Type of failure	Recommended Scheme for soil exploration and data collection	Soil testing
1	2	3	4	5
1	i) Embankment settlement - loss of longitudinal profile ii) Heaving of soil beyond toe iii) Leaning of telegraph posts, trees, etc. on the embankment and at the toe	Base failure	i) Recording of embankment profiles and ballast profile in x-section ii) Undisturbed sampling iii) Field tests- Vane shear DCP/SPT	i) Classification tests ii) Consolidation tests iii) Natural moisture content and Natural dry density tests. iv) Peak and residual shear strength tests
2	i) Flattening of Embankment/ slope ii) Bulging of slope	Slope failure	i) Recording of embankment profile and x-section of ballast profile.	i) Classification and swell tests ii) Peak and Residual Shear

	<p>surface.</p> <p>iii) Longitudinal cracks on cess/slopes</p> <p>iv) Leaning of OHE masts</p>		<p>ii) Survey and recording of surface cracks</p> <p>iii) Undisturbed sampling</p>	<p>strength tests</p> <p>iii) Natural moisture content and Natural dry density tests.</p>
3	<p>i) Soil heaving on cess and on slopes</p> <p>ii) Ballast penetration exceeding 30 cm below formation</p> <p>iii) Excessive – cross level variations</p>	Subgrade failure (by shear)	<p>i) Recording of embankment profile and ballast penetration profiles inside subgrade</p> <p>ii) Collection of data</p> <p>a. Track geometry variations</p> <p>b. Excessive maintenance inputs</p> <p>c. Quantum of ballast recoupment</p> <p>d. Speed restrictions imposed</p> <p>iii) Undisturbed and Disturbed soil samples below the ballast penetration</p>	<p>i) Classification and swell tests</p> <p>ii) Shear strength tests</p> <p>iii) Natural Moisture content and Natural Dry Density tests</p> <p>iv) CBR test</p>
4	<p>i) Fouling of ballast with subgrade fines</p> <p>ii) Ballast penetration below formation – 30 cm or less</p> <p>iii) Impaired drainage</p> <p>iv) Excessive cross level variations in Monsoon</p> <p>v) Hard running during summer</p>	Subgrade failure (by mud pumping)	<p>i) Recording of embankment profile and ballast penetration inside subgrade</p> <p>ii) Collection of data –</p> <p>a. Track geometry variations</p> <p>b. Excessive maintenance inputs</p> <p>c. Speed restrictions imposed</p> <p>iii) Undisturbed & Disturbed soil samples from below the ballast penetration</p>	<p>i) Classification and swell tests</p> <p>ii) Shear tests</p> <p>iii) Natural Moisture Content and Natural Dry Density tests</p> <p>iv) CBR Test</p>
5	<p>i) Reduced cess & denuded slopes- loss of soil/absence of vegetation.</p> <p>ii) Formation of</p>	Erosion failure of Slopes leading to ballast penetration	<p>i) Recording of embankment profile</p> <p>ii) Undisturbed soil samples</p>	<p>i) Classification tests</p> <p>ii) Field crumb test for soil dispersivity</p> <p>iii) Pinhole test</p>

	rills/ gullies and pot holes on slopes & on cess	and slope Failure		iv) Double hydrometer tests v) Natural Moisture Content and Natural Dry Density tests
6	i) Cut slope failures ii) Choked side drains iii) Seepage of water iv) Saturated subgrade	Failure of Cuttings	i) Recording of profile side slope, longitudinal drain sections, HFL and Ground water table ii) Cross-section and Ballast penetration profile iii) Undisturbed soil sample	i) Classification of soils ii) Natural Moisture Content and Natural Dry Density tests iii) Lab. Shear tests

Note: *a) In practice generally more than one type of failure is encountered.
b) Recommended scheme and soil tests are for general guidance.*

1.3.3 Frequency of soil sampling shall depend on the extent and type of problems in the troublesome stretches. However, samples should be taken at 500m intervals for determination of natural dry density and soil type only where no formation problem is reported.

1.3.4 In order to ensure proper bonding of earthwork and soil compatibility behaviour of old and new earthwork, samples of soils from mid-slope of existing bank at about 1 m depth and 500m length or closer intervals should be collected and tested for particle size, natural moisture content, natural dry density and consistency limits.

1.3.5 In case of doubling, where existing formation is troublesome as described in Para 1.3.2 above, soil investigation shall be planned for remedial measures to be undertaken before execution of doubling work and additional possibility of construction of new line away from centre line of the existing track may also be explored in such cases.

1.4 Soil Classification system as per Indian Standard 1498 is also explained in brief in Appendix: L for reference.

CHAPTER-2

SUITABILITY OF SUBSOIL & GROUND IMPROVEMENT TECHNIQUES

2.1 General

Field tests are required to be conducted on sub-soil strata, i.e. Plate load test for determination of Elastic Modulus in second cycle of loading (E_{v2}), Standard Penetration test to determine N-value, and Unconfined Compression Test or Vane Shear Test to determine unconfined compressive strength or undrained cohesion, c_u . If any of these parameters, as specified in following para do not meet with specified requirement then ground improvement needs to be undertaken.

2.2 Suitability of sub-soil

Strengthening of sub soil, including in cutting shall be required when;

- (i) E_{v2} value less than 20 MPa, or
- (ii) Undrained cohesion (c_u) < 25 kPa, only for soils having particles finer than 75 microns exceeding 12%, or
- (iii) N-value < 5,

In such cases Ground Improvement Techniques mentioned below can be adopted. However, these are suggestive in nature and depend on site conditions before implementing these techniques, proper planning and investigation is required.

2.3 Ground Improvement Techniques/ Methods for Soft soil

Soil at a construction site may not always be totally suitable for supporting structures in its natural state. In such a case, the soil needs to be improved to increase its bearing capacity and decrease the expected settlement. These techniques can be adopted to improve the ground strength on which the Embankment/fills is constructed.

2.3.1 Removal and replacement of weak sub-soil

Soil replacement is one of the oldest and simplest methods for Ground improvement. The foundation condition can be improved by replacing poor soil (e.g. organic soils and medium or soft clay) with more competent materials which can improve the bearing capacity of subsoil.

The removal and replacement may be required even in 'cutting' areas where the naturally occurring soils are found to be of low shear strength. Subsurface drainage may have to be introduced in most of such areas. Excavation and replacement can be carried out for soft soil up to the depth of 1.5 to 2 m as per site condition.

2.3.2 Preloading

The preloading technique is a simple and economical method for accelerating consolidation railway fills on soft clays, since; the material can stay in place and need not be relocated. Preloading is especially attractive when fill material is subsequently used on the same project for site preparation.

For low Embankment over soft compressible soil where the poor ground is of limited thickness (short drainage path) or is capable of compressing rapidly under the load of

excess preload fill due to presence of sand lenses, preloading may be resorted. Preloading of soft soils is based on the consolidation concepts, whereby pore water is squeezed from the voids until the water content and the volume of the soil are in equilibrium under the loading stresses imposed by the surcharge. This is usually accompanied by gain in shear strength of soil. To a certain extent, the primary consolidation under final loading can be achieved during construction and hence post construction settlement reduces.

The pre-loading technique takes two forms:

- i) Overloading
- ii) Stage construction

(i) Overloading

In the overloading process, a surcharge (overload) is placed temporarily on the ground and after a pre-determined time lapse, the intended structure can be built with occurrence of little or no additional settlement. The ratio of surcharge load to design load is known as overload coefficient. The charge is normally a uniformly distributed surface load which is placed prior to the construction of the intended structure. A part or the entire surcharge may be removed before the construction commences, depending on the requirements. The magnitude of the surcharge load and its duration of application are determined by the conventional settlement calculations. The settlement which occur under overloading results in an increase in the undrained shear strength of the clay. The principle of overloading method is shown in fig-2.1.

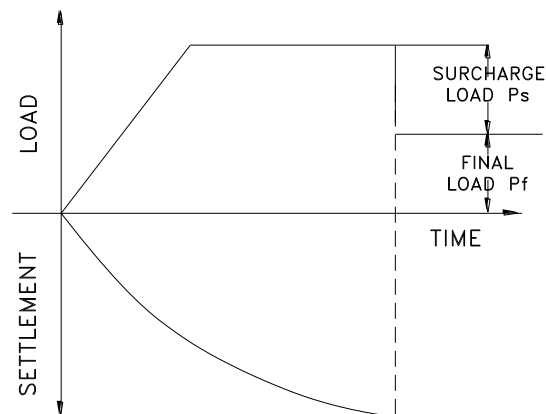


Fig-2.1: Principle of overloading

(ii) Stage Construction (Improvement of Shear Parameters)

This technique enhances the bearing capacity of the sub-soil and provides the site for construction of Embankment up to the design height in the phases/stages, with a designed strength of the soil & calculated waiting period for the next loading after the previous loading.

Stage construction is employed mainly as a means of gradually increasing the shear strength of soft clay which would otherwise be inadequate to carry the

intended Embankment load. In stage construction, advantage of increase in shear strength of sub-soil strata due to consolidation by surcharge load of Embankment is taken into account. Work on next stage filling can be permitted only after it is ascertained that the strength gain needed for building the next stage has been reached. The principle of stage construction method is shown in Fig-2.2 below-

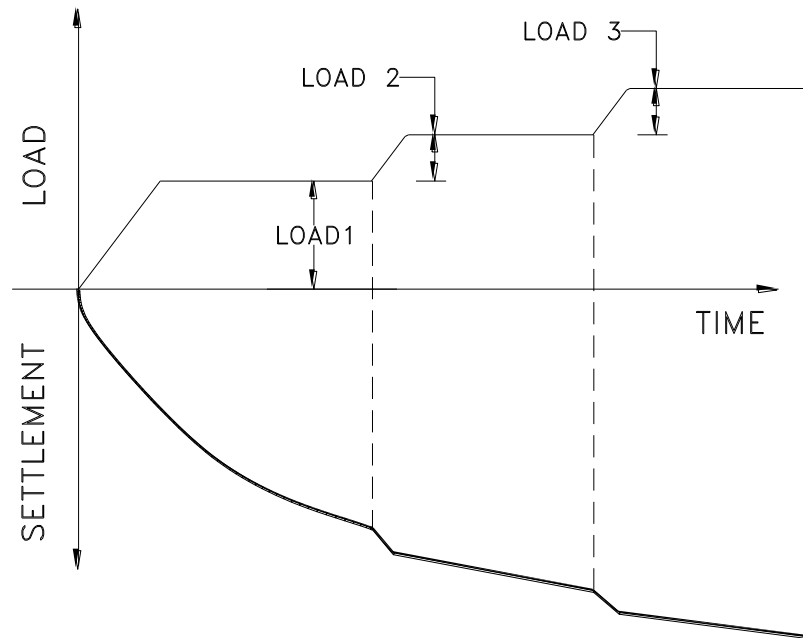


Fig-2.2: stage construction method

Theoretical basis of design using stage construction method, solved practical examples and instrumentation scheme for monitoring the behavior of Embankment on soft soil are covered in "RDSO Guidelines on Soft Soils-Stage Construction Method (Guideline No: GE:G-5)-April 2005".

2.3.3 Ground improvement using Vertical drains

Because of low permeability the consolidation settlement of soft clay takes long time to complete. Wherever in such case if preloading is not sufficient, to shorten the consolidation time vertical drain are installed together with preloading. Vertical drain are artificially created drainage path which are inserted in soft clay In order to accelerate the process of consolidation settlement for the construction of structure.

The Sand drain is one of such method being used for this purpose.

Sand drains (Fig-2.3) are constructed by driving down casing or hollow mandrels in to the soil and then the holes are filled with sand and casing is taken out. When the surcharge is applied on the ground surface the pore water pressure in the soil increases and the drainage in vertical and horizontal direction starts. Process of dissipation of excess pore water pressure created by loading is accelerated and hence the settlement rate. Top of sand drain are connected to granular sand blanket to allow the pore water to flow out.

Now days mostly **PVD** are being used for this purpose as they are easy to install and less time consuming. PVD have been explained in para 2.4 Stabilization & Ground Improvement Methods Using Geosynthetics of this chapter.

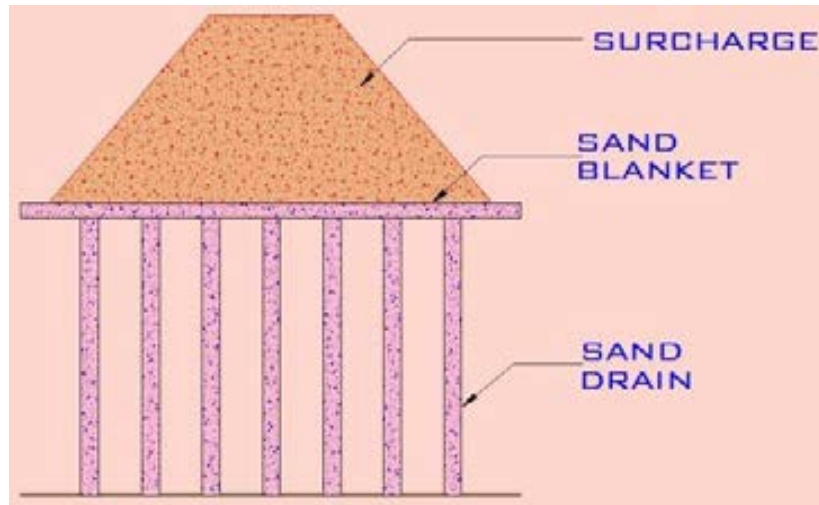


Fig-2.3 Ground improvements using sand drain

2.3.4 Ground improvement using Stone Columns

Stone column method of ground improvement is an efficient method of improving the strength parameter like bearing capacity and it also reduces the consolidation settlement time. Stone column consist of compacted crushed stone or well graded gravel of 75 mm to 2mm size and can be extended through the most compressible strata that contribute the settlement to foundation. The stone should be chemically inert, hard and resistant to breakage.

Stone column will transmit some load to soil by shear stress and end bearing but the predominant load transfer mechanism is due to the lateral bulging into the surrounding soil. Generally, column bulging will be closer to the top of column where the over burden pressure is lowest thus distributes the stresses at the upper portion of the soil profile rather than transferring the stresses in to the deeper layer, thus causing the soil to support it. Along with this rapid consolidation due to accelerated dissipation of pore water pressure into the drainage path formed by stone column. Due to this combined effect construction can be started soon after instillation of stone column completed.

Stone column provides rapid consolidation and immediate increase in shear strength hence there is no waiting period is required (such as in case of ground improvement by PVD/sand drain) and construction of embankment can be begin soon after the installation up to full height with non-compressible fill without further stage construction.

Subsurface conditions for which stone columns are generally not suited include sensitive clays and silts (sensitivity is > 4) which lose strength when vibrated and also where suitable bearing strata for resting the toe of the column are not available under the weak strata.

Stone column can be installed by Non-Displacement method (Fig-2.4) or by Displacement method. In case of displacement installation, the soil is laterally displaced while making the hole due to driving of tube or a casing, while in case of non-displacement method soil is taken out during boring. Compacted crushed coarse aggregate of various sizes fed in to the hole created and on top of stone column a clean medium to coarse sand layer is laid; it should be exposed to atmosphere at its periphery for dissipation of pore water pressure.

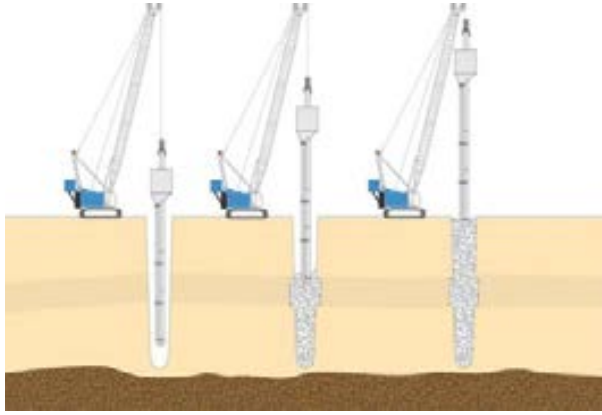


Fig- 2.4: Ground improvement using stone column

2.3.5 Ground Improvement for expansive soils using CNS material

Using a layer of Cohesive Non-Swelling soil (CNS) is one of the effective methods of ground improvement in expansive soils area. CNS layer shall be provided below the bottom layer of Embankment fill in case of Embankment and below subgrade/prepared subgrade level in case of cuttings, of suitably designed thickness and width, compacted to 97% of MDD at optimum moisture content (OMC). The width of treatment should be extended minimum 3.0m beyond the toe line on both sides. The CNS material possesses the property of cohesion of varying degree and non-expanding type clay minerals such as illite and kaolinite, having low plasticity with liquid limit not exceeding 50 percent.

The properties of CNS material are defined below (Ref- IS 9451: 1994):

Grain Size Distribution

Clay (less than 2 micron) : 15-20 %

Silt (0.06 mm to 0.002 mm) : 30-40 %

Sand (2 mm to 0.06 mm) : 30-40%

Gravel (greater than 2 mm) : 0-10%

Liquid Limit : >30 but less than 50

Plasticity Index : >15 but less than 30

Swelling Pressure : <10kN/m²

Unconfined Compression strength : >10kN/m²

The thickness of CNS materials required for balancing the different swelling pressures are as follows:

Table-1

Swelling Pressure of Soil (KN/m²)	Thickness of CNS Materials (cm) (Min)
50 to 150	75
150 to 300	85
300 to 500	100

In case naturally occurring, soil do not meet the parameters of CNS soil, same can be produced by blending suitable combination of locally available materials. Such artificial CNS should satisfy all the parameters of CNS soil.

2.4 Stabilization & Ground Improvement Methods Using Geo-synthetics

Some of the ground improvement methods (list is not exhaustive), wherein geo-synthetics are used, are as under:

2.4.1 Use of Geo-composite drain for Construction of new embankment over soft subsoil

In case of embankments over weak/fine grained sub-soils (which are mostly soft clays) and having water table at higher level (shallow depth), it is a good practice to **provide a “separator-cum-drainage layer” of Geo-composite drain layer**, sandwiched between two layers of sand of about 75mm thickness (**Fig-2.5**), 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. Alternatively, a 1000mm thick sand layer can be provided. Its thickness may be varied depending on the bank height, characteristics of sub-soil and water table. The sand layer to be used in both the cases should be clean medium to coarse sand with minimum permeability of the order of 10^{-5} m/second.

Specification for Geo-composite drains to be used at the base of the Embankment for Railway Formation, for Embankment height upto 8m (Specification No. RDSO/2018/GE: IRS-0004-Part-II) is given in **APPENDIX-C**. These specifications have been issued to Zonal Railway/PSU’s initially for trial purpose. On satisfactory performance report from the field, the mandating of its usage will be decided.

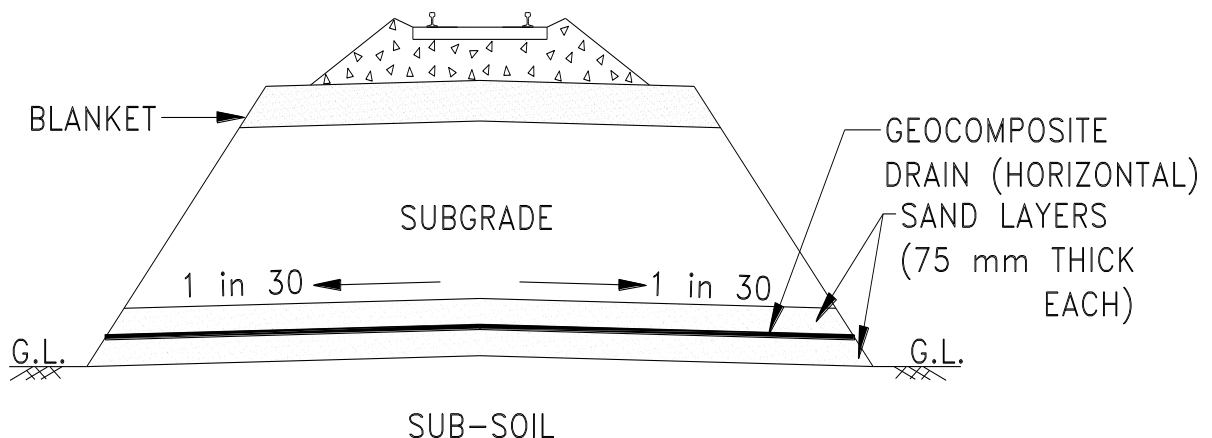


Fig- 2.5: Use of Geo-Composite Drain in bank over soft subsoil

2.4.2 Use of Geocell

Geocell is another form of Geosynthetics used as basal mattress in embankments for ground improvement [Fig-2.6(a)].

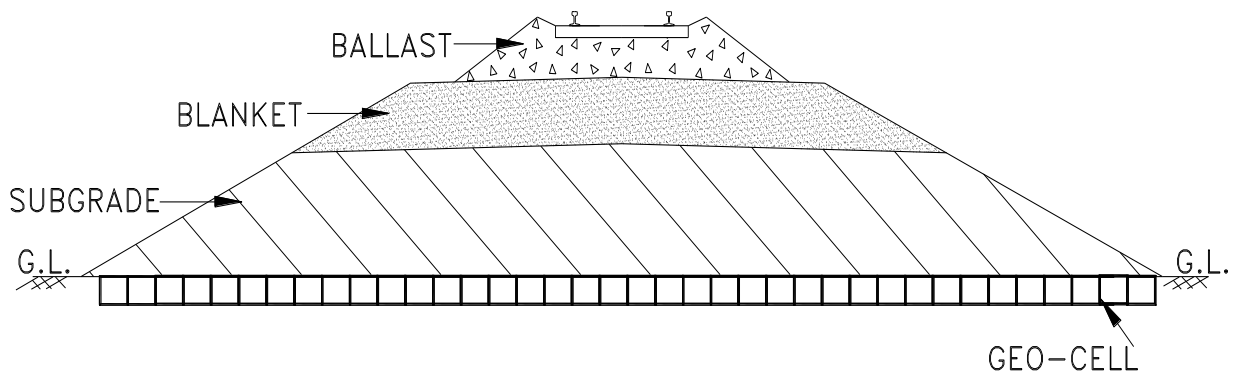


Fig-2.6(a): Application of Geocell for ground improvement

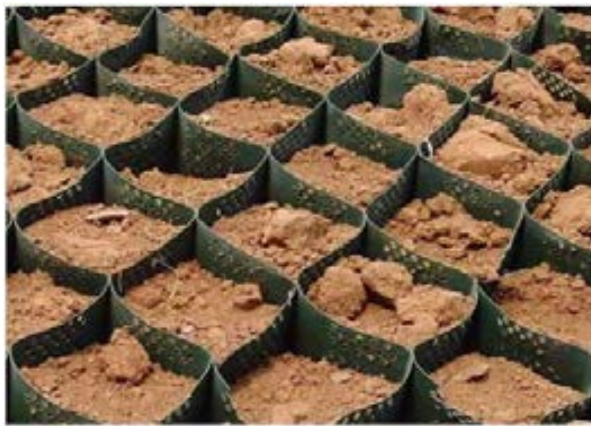


Fig-2.6(b): Geocell and it's applications

Geocell is a three dimensional honeycomb like cellular structure, consisting of a regular open network of synthetic strips, linked by extrusion or adhesion or other methods [Fig-2.6(b)]. On site, the Geocell sections are fastened together and placed directly on the subsoil or on a Non-woven Geotextile filter placed on the subgrade surface and propped open in an accordion-like fashion with an external stretcher assembly.

They are then filled with various infill materials, such as soil, sand, aggregate or recycled materials and then compacted using vibratory compactors.

When the soil contained within Geocell is subjected to pressure, it causes lateral stresses on cell perimeter walls. The 3D zone of confinement reduces the lateral movement of soil particles while vertical loading on the contained infill results in high lateral stress and resistance on the cell-soil interface. This increases the shear strength of the confined soil, which creates a stiff mattress/slab to distribute the load over a wider area, reduces punching of soft soil, increases shear resistance and bearing capacity and decreases deformation. Confinement from adjacent cells provides additional resistance against the loaded cell through passive resistance, while lateral expansion of the infill is restricted by high hoop strength. Compaction is maintained by the confinement, resulting in long-term reinforcement.

In Railway Embankment applications, Geocell can improve the load support capacity of soft subsoil. It is often recommended for swampy conditions where the ground water is close to the surface.

2.4.3 Use of Prefabricated vertical drain (PVD):

Prefabricated vertical drains consist of channelled synthetics core wrapped in Non-woven geotextile fabric known as filter (Fig-2.7). Prefabricated Vertical drains are used where preloading alone is not sufficient.

Prefabricated Vertical drains in soft clay accelerate the primary consolidation of clay since they bring about rapid dissipation of excess pore water pressure. Therefore, the structures or Embankments can be put to use earlier than it would be possible otherwise. The accelerated rate of gain in shear strength of clay enables the loads to be applied more rapidly than would otherwise be possible.

The effectiveness of Prefabricated Vertical drains depends mainly on the engineering properties of soils, namely, soil permeability and coefficient of consolidation and their variations in space and time. They are, however, ineffective in organic soils and highly stratified soils.

For installation, PVD is placed into steel mandrel and the mandrel is pushed into the ground to the determined depth with a mast mounted on back hoe. Anchor plate is attached to the wick material to hold it in place as mandrel is removed. Then the PVD is cut off a little above the ground (Fig-2.7). Top of PVD drain are connected to granular sand blanket to allow the pore water to flow out.

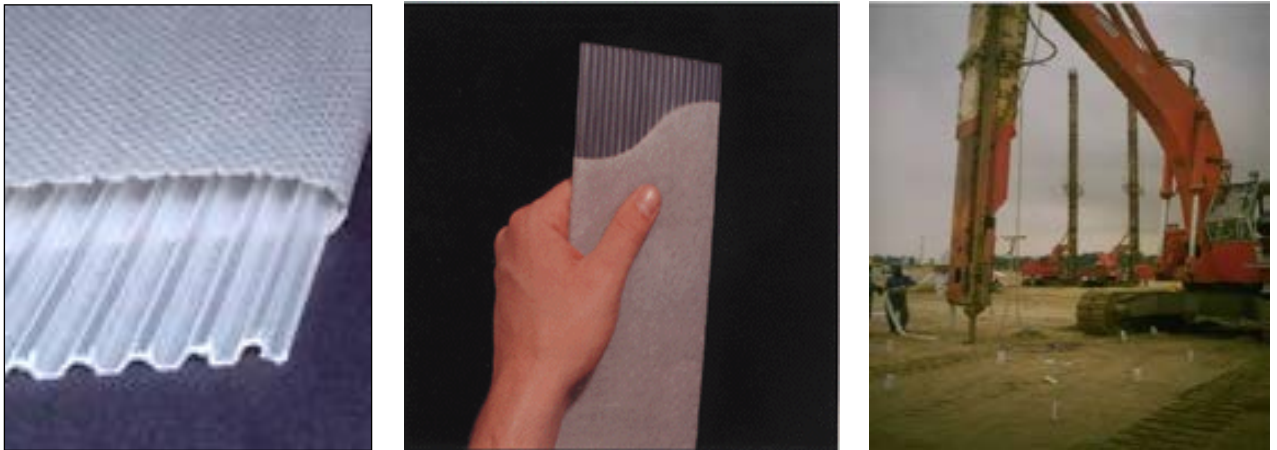


Fig-2.7: PVDs and their Installation

2.4.4 Geosynthetic encapsulated Stone column:

When stone columns are installed in soft clays, over a period of time, the gaps in the stones are filled by soft clays which decrease the load carrying capacity and lead to increase in the vertical deformation. Also, soft clay can provide a limited lateral pressure. To overcome this problem, the idea of placing a Geosynthetic (geotextile/geogrid) encasement around the granular material has been developed recently. By this, the granular material that wants to expand sideways is not only restricted by the cohesive soil, but also by the Geosynthetic reinforcement (Fig-2.8). The encapsulation in geosynthetics makes stone column more ductile than normal stone column. The specifications of geogrid and geotextile included in Appendix-C will not be applicable in this case. It can be suitably designed with suitable type of geosynthetics.

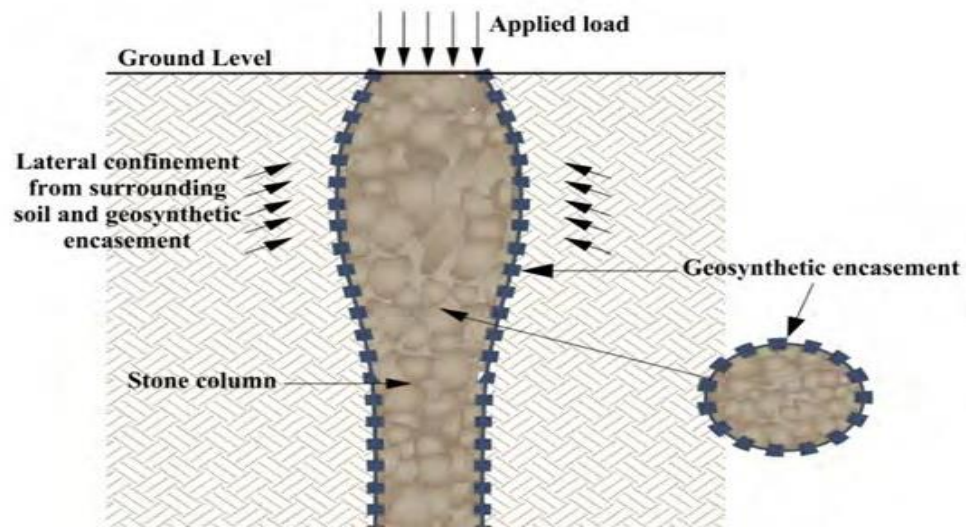


Fig-2.8: Geosynthetics Encapsulated Stone column

Note: All the above methods are suggestive in nature and final methodology to be adopted will depends on site condition and topography, soil type, drainage condition etc.

CHAPTER-3

DESIGN OF FORMATION & SPECIFICATIONS FOR FORMATION LAYERS

3.1 General

Formation comprises of Blanket and, Prepared subgrade/Subgrade. Depending upon techno-economic considerations, it can be Single layer or Two-layer construction as shown in Fig-3.1 & 3.2 below. For construction of a new line, it is important to ensure that the track bed layers (Blanket/Prepared subgrade/Subgrade) have the appropriate mechanical characteristics and are of adequate thickness. For Indian Railway Formation, it has been stipulated & described in detail in Para 3.10 of this Chapter.

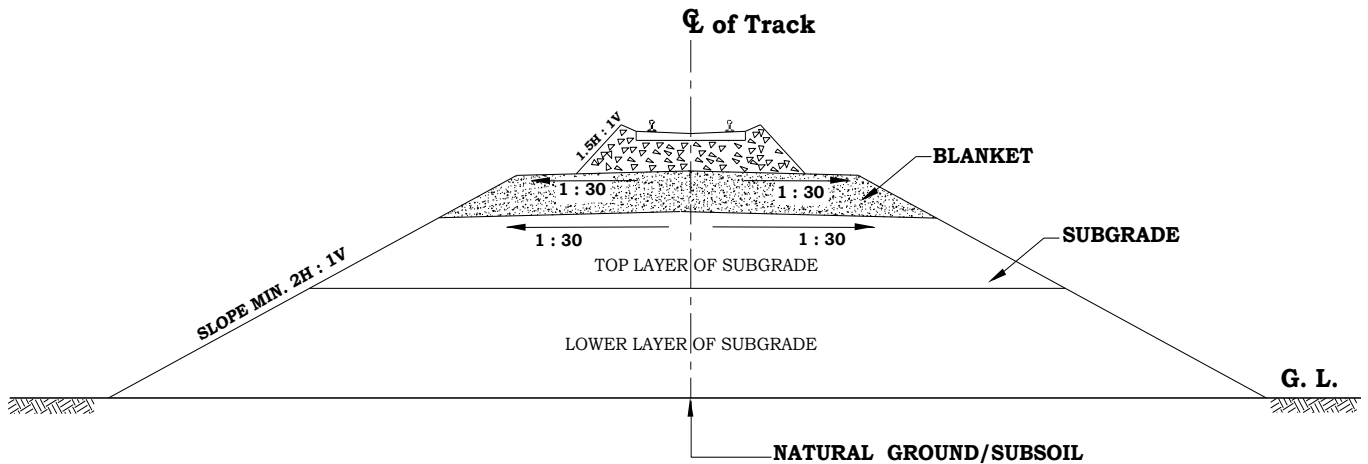


Fig-3.1: Single layer construction

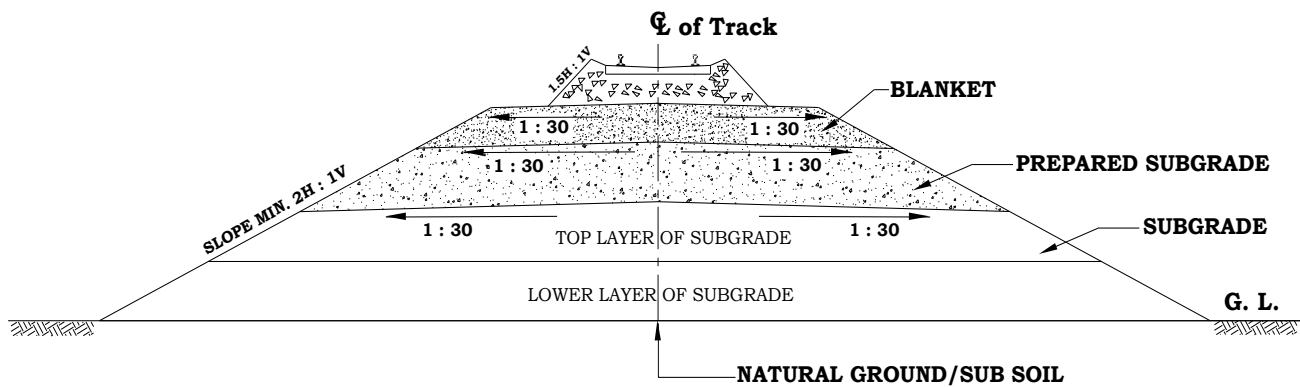


Fig-3.2: Two layer construction

3.2. Pressure on Formation and sub-soil

As good design practice, typical values for the maximum pressure on formation at bottom of ballast should not exceed 0.3MN/m^2 or 3 kg/cm^2 , and the pressure on sub-soil should not exceed 0.1MN/m^2 or 1 kg/cm^2 generally.

3.3 Top Width of Formation

- a) It should be adequate enough to accommodate tracks laid with concrete sleepers and standard ballast section (minimum 35cm depth) and have minimum cess width of 90cm on either side.
- b) Additional Width of formation will have to be provided to cater for increase in extra widening of ballast shoulder and extra clearances required on curves.

It shall be regulated/provided in accordance with extant instructions as per Indian Railway Schedule of Dimensions (IRSOD) & Indian Railway permanent Way manual (IRPWM).

3.4 Cross Slope of Formation

Top of formation should have a cross slope of 1 in 30 from centre of formation towards both sides for single line/multiple line in new construction. In case of doubling or multiple line construction work in existing lines, the cross slope of 1 in 30 should continue from the edge of existing formation towards cess/drain side (single slope) to avoid any stagnation of water between two tracks. However, if the cross slope of existing embankment is steeper than 1 in 30 due to any reason, the configuration of 1 in 30 cross slope shall be maintained in the new line while ensuring proper drainage conditions at the same time so as to avoid any stagnation of water in between tracks, by adopting appropriate measures as per site conditions.

Further elaboration on drainage is given in **Chapter 6 for Execution of Earthwork.**

3.5 Erosion Control System

The design should provide for a suitable and cost-effective erosion control system considering soil matrix, topography and hydrological conditions. Further elaborations given in **chapter-8 (Erosion control of slopes).**

3.6 Borrow Pits

It will be necessary to keep borrow pits sufficiently away from the toe of the embankments as far as possible at the extreme of Railway land but normally not less than 3m plus height of the embankment to prevent base failures due to lateral escapement of the soil. Existing borrow pits, close to the toe of bank may be filled or its depth should be taken into account in analysing slope stability of the bank.

3.7 Soils to be normally avoided

- a) There are some soils, which are normally unsuitable for construction of formation as listed below:
 - i) Organic clays, organic silts, peat, chalks, marl, dispersive soils and soil containing soluble material (e.g. rock salt or gypsum).
 - ii) Poorly graded sand and gravel with $C_u < 2.0$, should not be used to safeguard against liquefaction. Generally, most liquefiable soils as falling in gradation zone as indicated in the Fig-L1 of Appendix-L & having coefficient of uniformity, $C_u < 2$ shall not be used. (Reference Sketch given in Appendix-L).
 - iii) Clays and Silts of high plasticity (CH & MH) in top 3m of Embankment.

- iv) Shales and soft rocks which become muddy after coming into contact with water.
- b)** There may be some typical situations in construction of formation & cuttings, where it is not possible to avoid conditions as given below, for economical or any other reason, then Railway may decide special investigations and other measures to formulate suitable scheme of construction.
 - i) Cuttings passing through unsuitable soils as defined in para 3.7 (a).
 - ii) Construction of embankment on subsoil of unsuitable types of soils.

3.8 Blanket Layer

3.8.1 Need and functions of Blanket Layer

- a) It reduces traffic-induced stresses to a tolerable limit (i.e. threshold stress) on the top of subgrade, thereby, prevents subgrade failures.
- b) It prevents penetration of ballast into the subgrade and also prevents upward migration of fine particles from subgrade into the ballast under adverse conditions, during service. This prevents mud pumping by separating the ballast and subgrade soil.
- c) It results in increased track modulus and thereby reduces the track stresses & deformations.
- d) It facilitates drainage of surface water and reduces moisture variations in subgrade, thereby reducing track maintenance problems.
- e) It facilitates dissipation of excess pore water pressure developed in subgrade on account of cyclic loading and leads to increase in shear strength of subgrade soil.

3.8.2 Blanketing Material

It is difficult to get natural 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 pug mill, wet mix plant, crusher etc. However, if naturally available material conforms to the specifications, the same can also be used. The type of blanket material to be used whether natural or manufactured (mechanical crushing and/or blending) may be indicated clearly before start of the work and should be indicated in tender document. Some Typical methods used for mechanised production of blanket material are given in **Appendix-A**.

Decisions to use natural blanket material or manufactured blanket material shall be taken on the basis of site conditions or final location survey report.

3.8.3 Requirement of Blanket Layer

- a) The provision of blanket layer shall not be needed when formation/earth fill embankment have:
 - i) Rocky beds except those, which are very susceptible to weathering e.g. rocks consisting of shale and other soft rocks, which become muddy after coming into contact with water.

- ii) Soils conforming to specifications of Blanket layer as given in Table 3.3 to 3.6.
- b) For other conditions, the system of layered construction of embankment (Single layer/ Two layer) shall normally be followed.

3.9 Soil Quality

For Design of Railway Formation, the soils for their use in Indian Railway Embankment have been grouped based on percentage of fines present in the soil, as given below:

Description of Soil Quality Class

Description w.r.t. Fine-Particles (size less than 75 micron)	Soil Quality Class,
Soils containing fines > 50 %	SQ1
Soils containing fines from 12% to 50%	SQ2
Soils containing fines < 12%	SQ3

3.10 Specifications and Thickness of Formation Layers:

(A) The Railway Formation may be constructed with Single Layer System or Two Layer System based on availability of local soils/materials and on economic considerations. The thickness of the prepared sub-grade and blanket layer has been rationalized based on UIC-719R calculation for ballast cushion of 350 mm. The specifications and thickness of Blanket layer, Prepared subgrade, Subgrade (Top Layer & Lower layer) and Sub-Soil are tabulated for Single layer system and Two-layer system for 25T and 32.5T Axle load as below: -

Table-3.1: For 25 T Axle Load

S. No.	Soil type Category in Sub-grade	Prepared Sub-grade		Recommended Blanket Thickness (mm)	Remarks
		Soil Type	Thickness (mm)		
1.	SQ1	SQ1*	--	550	Single layer
2.	SQ1	SQ2	500	400	Two layer
3.	SQ1	SQ3	500	300	Two layer
4.	SQ2	SQ2*	--	400	Single layer
5.	SQ2	SQ3	350	300	Two layer
6.	SQ3	SQ3*	--	300	Single layer

* Subgrade soil is continued upto blanket layer

Table-3.2: For 32.5 T Axle Load

S. No.	Soil type Category in Sub-grade	Prepared Sub-grade		Recommended Blanket Thickness (mm)	Remarks
		Soil Type	Thickness (mm)		
1.	SQ1	SQ1*	--	700	Single layer
2.	SQ1	SQ2	500	550	Two layer
3.	SQ1	SQ3	500	450	Two layer
4.	SQ2	SQ2*	--	550	Single layer
5.	SQ2	SQ3	350	450	Two layer
6.	SQ3	SQ3*	--	450	Single layer

* Subgrade soil is continued upto blanket layer

(B) Formation for 25T axle load

Table 3.3: Specification and Thickness of Formation Layers for 25T axle load: Single layer system

Layers	Specification	Thickness
<u>Blanket</u>	i) $C_u > 7$ and C_c between 1 and 3. ii) Fines (passing 75 microns) : 3% to 10% iii) Minimum soaked CBR value ≥ 25, (Soil compacted at 100% of MDD * in Lab) iv) Los Angeles Abrasion value $< 40\%$ v) Field Compaction : Min. 100% of MDD * in field trial vi) Minimum $Ev_2^{**} = 100$ MPa vii) Size gradation – within specified range (as table-3.7) or should lie more or less within enveloping curves (as Fig-3.8) viii) Filter criteria (***Optional) should be satisfied with sub-grade layer as given below: Criteria-1: $D_{15}(\text{blanket}) < 5 \times D_{85}(\text{sub-grade})$ Criteria-2: $D_{15}(\text{blanket}) > 4 \text{ to } 5 \times D_{15}(\text{sub-grade})$ Criteria-3: $D_{50}(\text{blanket}) < 25 \times D_{50}(\text{sub-grade})$	30 cm over SQ3 sub-grade 40 cm over SQ2 sub-grade 55 cm over SQ1 sub-grade
<u>Sub-grade</u> Top Layer	SQ1/SQ2/SQ3 soil SQ1 soils (To be used only with dispensation of PCE/ CAO) i) For SQ2/SQ3 soil, $CBR \geq 6$ (soil compacted at 98% of MDD *) ii) For SQ1 soil, $CBR \geq 4$ soil compacted at 98% of MDD *	100 cm

Table 3.4: Specification and Thickness of Formation Layers for 25T axle load: Two layer system

Layers	Specification	Thickness
<u>Blanket</u>	i) $C_u > 7$ and C_c between 1 and 3. ii) Fines (passing 75 microns) : 3% to 10% iii) Los Angeles Abrasion value < 40% iv) Minimum soaked CBR value ≥ 25, (soil compacted at 100% of MDD * in lab) v) Field compaction: 100% of MDD* in field trial vi) Minimum $E_{v_2}^{**} = 100$ MPa vii) Size gradation – within specified range (as table-3.7) or should lie more or less within enveloping curves (as fig.-3.8) viii) Filter criteria (***Optional) should be satisfied with prepared sub-grade layer as given below: Criteria-1: D_{15} (blanket) < $5 \times D_{85}$ (prepared sub-grade) Criteria-2: D_{15} (blanket) > 4 to $5 \times D_{15}$ (prepared sub-grade) Criteria-3: D_{50} (blanket) < $25 \times D_{50}$ (prepared sub-grade)	30 cm over SQ3 Prepared Sub-grade 40 cm over SQ2 Prepared Sub-grade
<u>Prepared Subgrade</u>	SQ2/SQ3 i) CBR ≥ 8 (soil compacted upto 98% of MDD *) ii) Plasticity Index ≤ 12 iii) Field Compaction : Min. 98% of MDD * iv) Minimum $E_{v_2} = 60$ MPa	50 cm over SQ1 fill 35 cm over SQ2 fill
<u>Subgrade</u> Top Layer	SQ1/SQ2/SQ3 (SQ1 soils (To be used only with dispensation of PCE/ CAO) i) CBR ≥ 5 (soil compacted at 97% of MDD *) for SQ2/SQ3 soils ii) For SQ1 soil, CBR ≥ 4 (soil compacted at 97% of MDD *) iii) Field Compaction : Min. 97% of MDD * iv) Minimum $E_{v_2} = 30$ MPa (for SQ1) 45 MPa (for SQ2/SQ3)	50 cm
Lower layer (fill)	SQ1/SQ2/SQ3 soil (+) i) CBR ≥ 3 (soil compacted at 97% of MDD *) ii) Field Compaction : Min. 97% of MDD *	As per Embankment height

Ground Soil/Sub-soil Strata	i) Undrained Cohesion of soil (c_u) ≥ 25 KPa (only for soils having particles finer than 75 micron exceeding 12%) ii) E_{v2} (determined from PLT) ≥ 20 MPa iii) N (determined from SPT) ≥ 5 Ground Improvement is required, if any of the above parameters not complied with	--
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* MDD mentioned in above table

a) For determination of CBR - MDD achieved in Lab,

b) For field compaction - MDD achieved in field compaction trials which should not be less than 98% of MDD in lab.

** E_{v2} is Modulus of deformation **(Para 2.0 of Appendix-H)**

*** With the application of Non-woven Geotextile as a separator layer below the blanket, filter criteria will not be required or mandatory.

+ No dispensation of PCE/CAO required for use of SQ1 soil in Lower layer (fill) of Subgrade.

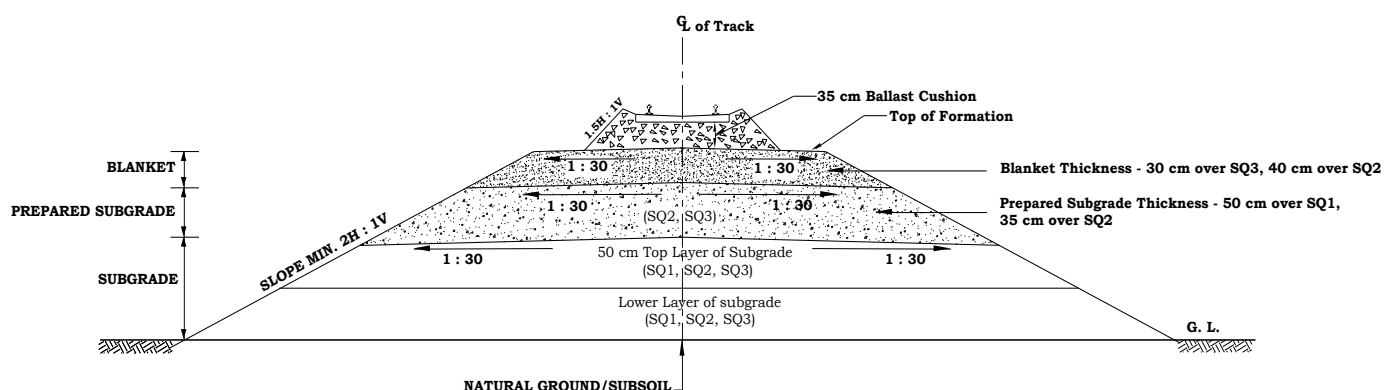


Fig-3.5: Track Formation for Two layer system (for 25 T Axle load)

(C) Formation for 32.5T Axle load

Table 3.5: Specification and Thickness of Formation Layers for 32.5T axle load: Single layer system

Layers	Specification	Thickness
Blanket	i) $C_u > 7$ and C_c between 1 and 3. ii) Fines (passing 75 microns) : 3% to 10% iii) Size gradation within specified range as specified in Table 3.7 or should lie within enveloping curves given in fig 3.8. iv) Los Angeles Abrasion value $< 40\%$ (v) Minimum CBR value ≥ 25 (Soil compacted at 100%)	45cm over SQ3 sub-grade 55cm over SQ2 sub-grade 70cm over SQ1 sub-grade

	<p>of MDD * in Lab.)</p> <p>(vi) Field Compaction: 100% of MDD * in field trial</p> <p>(vii) Minimum $E_{v2}^{**} = 120\text{Mpa}$</p> <p>(viii) Filter Criteria (***Optional) should be satisfied with subgrade layer, as given below :</p> <p>Criteria-1: $D_{15}(\text{blanket}) < 5 \times D_{85}(\text{sub-grade})$</p> <p>Criteria-2: $D_{15}(\text{blanket}) > 4 \text{ to } 5 \times D_{15}(\text{sub-grade})$</p> <p>Criteria-3: $D_{50}(\text{blanket}) < 25 \times D_{50}(\text{sub-grade})$</p>	
<u>Subgrade</u>		100 cm
Top Layer	<p>SQ1/SQ2/SQ3 soil</p> <p>(SQ1 soils (To be used only with dispensation of PCE/ CAO)</p> <p>i) $\text{CBR} \geq 6$, for SQ2/SQ3 soil compacted at 98% of MDD *)</p> <p>ii) $\text{CBR} \geq 4$, for SQ1 (soil compacted at 98% of MDD *)</p> <p>iii) Field Compaction : Min. 98% of MDD*</p> <p>iv) Minimum $E_{v2}^{**} = 45 \text{ MPa}$ (for SQ1 soil)</p> <p style="text-align: center;">60 MPa (for SQ2/SQ3)</p>	
Lower layer (fill)	<p>SQ1/SQ2/SQ3 soil (+)</p> <p>i) $\text{CBR} \geq 3$ (soil compacted at 97% of MDD*)</p> <p>ii) Field Compaction: min 97% of MDD*</p>	As per Embankment height
Ground Soil/Sub-soil	<p>i) Undrained Cohesion of soil (c_u) $\geq 25 \text{ KPa}$ (only for soils having particles finer than 75 micron exceeding 12%)</p> <p>ii) E_{v2} (determined from PLT) $\geq 20 \text{ MPa}$</p> <p>iii) N (determined from SPT) ≥ 5</p> <p>Ground Improvement is required, if any of the above parameters not complied with</p>	--

* MDD mentioned in above table

a) For determination of CBR - MDD achieved in Lab,

b) For field compaction - MDD achieved in field compaction trials which should not be less than 98% of MDD in lab.

** E_{v2} is Modulus of deformation (**Para 2.0 of Appendix-H**)

*** With the application of Non-woven Geotextile as a separator layer below the blanket, filter criteria will not be required or mandatory.

+ No dispensation of PCE/CAO required for use of SQ1 soil in Lower layer (fill) of Subgrade.

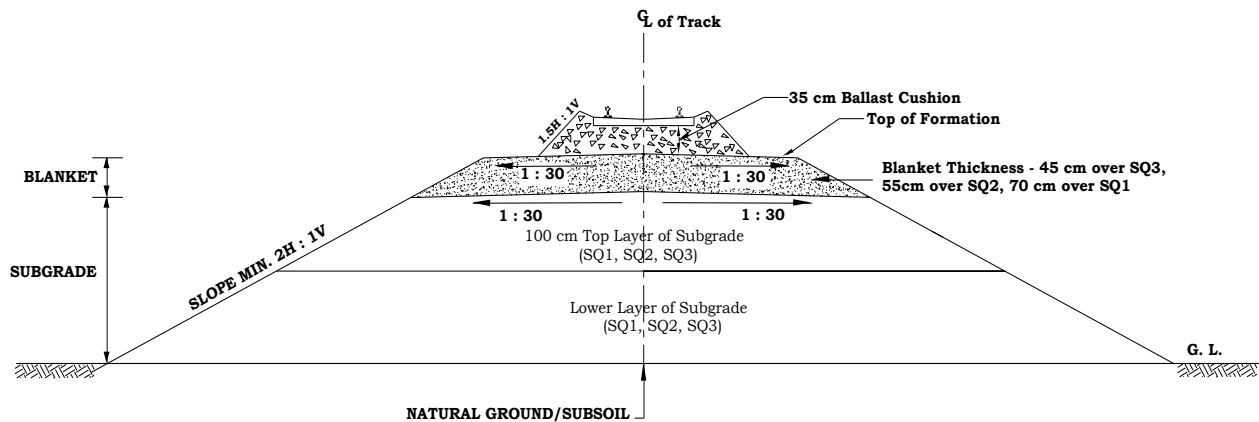


Fig-3.6: Track Formation for single layer system (for 32.5 T Axle load)

Table 3.6: Specification and Thickness of Formation Layers for 32.5T axle load: Two layer system

Layers	Specification	Thickness
<u>Blanket</u>	i) $C_u > 7$ and C_c between 1 and 3. ii) Fines (passing 75 microns) : 3% to 10% iii) Size gradation – within specified range as given in Table 3.7 or should lie within enveloping curves as given in Fig. 3.8 iv) Los Angeles Abrasion value < 40% (v) Minimum soaked CBR value ≥ 25 (Soil compacted at 100% of MDD* in Lab.) (vi) Field Compaction: 100% of MDD* in field trial (vii) Minimum $E_{v2}^{**} = 120\text{MPa}$ (viii) Filter Criteria (***Optional) should be satisfied with subgrade layer, as given below : Criteria-1: $D_{15}(\text{blanket}) < 5 \times D_{85}(\text{prepared sub-grade})$ Criteria-2: $D_{15}(\text{blanket}) > 4 \text{ to } 5 D_{15}(\text{prepared sub-grade})$ Criteria-3: $D_{50}(\text{blanket}) < 25 \times D_{50}(\text{prepared sub-grade})$	45cm over SQ3 prepared subgrade 55cm over SQ2 prepared subgrade
<u>Prepared Subgrade</u>	SQ2/SQ3 Soil i) $\text{CBR} \geq 8$ (soil compacted at 98% of MDD*) ii) Field Compaction : Min. 98% of MDD* iii) Plasticity Index ≤ 12 iv) Minimum $E_{v2} = 60\text{ MPa}$	50 cm over SQ1 fill 35 cm over SQ2 fill
<u>Subgrade</u> Top layer	SQ1/SQ2/SQ3 Soil (SQ1 soils (To be used only with dispensation	50 cm

Lower layer (fill)	of PCE/ CAO) i) CBR ≥ 5 (soil compacted at 97% of MDD *) for SQ2/SQ3 soil ii) CBR ≥ 4 , for SQ1 (soil compacted at 97% of MDD *) iii) Field Compaction : Min. 97% of MDD* iv) Minimum $E_{v2}^{**} = 30$ MPa (for SQ1 soil) 45 MPa (for SQ2/SQ3) SQ1/SQ2/SQ3 Soil (+) i) CBR ≥ 3 , (soil compacted at 97% of MDD*) ii) Field Compaction : Min. 97% of MDD*	As per Embankment height
Ground Soil/Sub-soil Strata	i) Undrained Cohesion of soil (c_u) ≥ 25 KPa (only for soils having particles finer than 75 micron exceeding 12%) ii) E_{v2} (determined from PLT) ≥ 20 MPa iii) N (determined from SPT) ≥ 5 Ground Improvement is required, if any of the above parameters not complied with	--

* MDD mentioned in above table

a) For determination of CBR - MDD achieved in Lab,

b) For field compaction - MDD achieved in field compaction trials which should not be less than 98% of MDD in lab.

** E_{v2} is Modulus of deformation **(Para 2.0 of Appendix-H)**

*** With the application of Non-woven Geotextile as a separator layer below the blanket, filter criteria will not be required or mandatory.

+ No dispensation of PCE/CAO required for use of SQ1 soil in Lower layer (fill) of Subgrade.

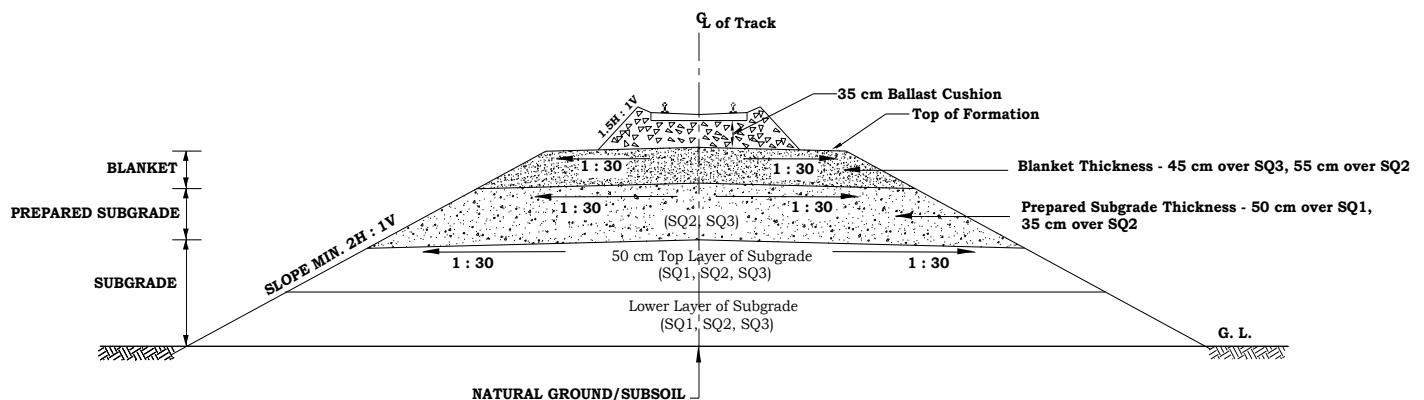


Fig-3.7: Track Formation for Two layer system (for 32.5 T Axle load)

Table-3.7: Gradation Percentage of Blanket Material

SL	IS Sieve Size	Percent Passing (by weight)
1.	40 mm	100
2.	20 mm	80 – 100
3.	10 mm	63 – 85
4.	4.75 mm	42 – 68
5.	2 mm	27 – 52
6.	600 micron	13 – 35
7.	425 micron	10 – 32
8.	212 micron	6 – 22
9.	75 micron	3 – 10

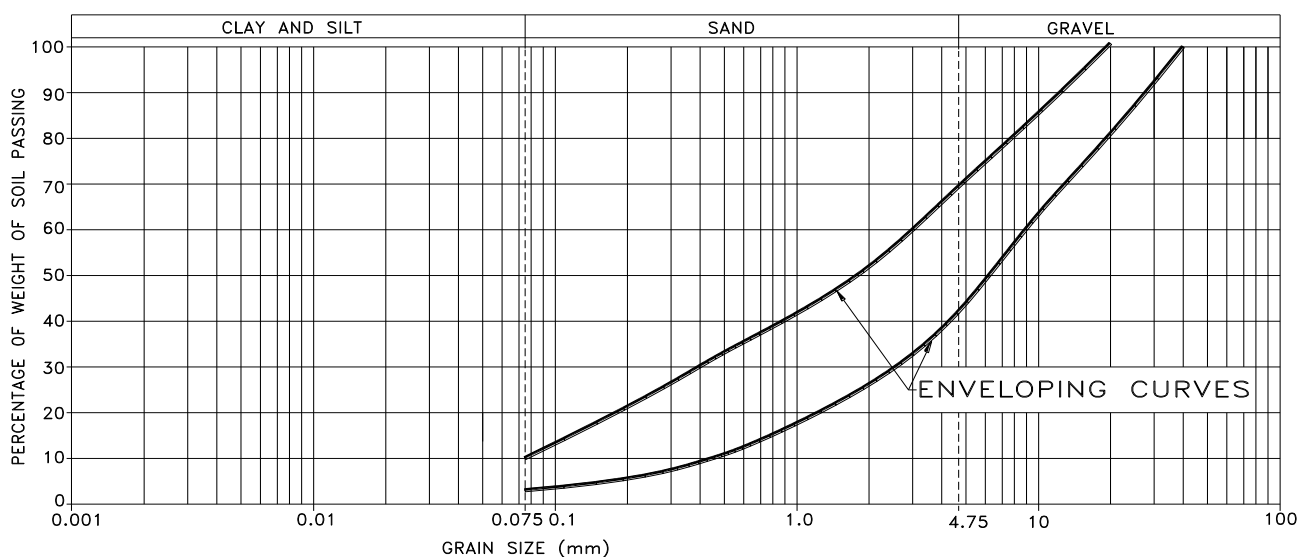


Fig-3.8: Enveloping Curves for Blanket Material

- (D)** When the subgrade/prepared subgrade is of SQ1 or SQ2 category soil (in table 3.3 to 3.6), a suitable non-woven geo-textile **layer may be used as “separator layer”** on the top of subgrade to prevent upward migration of the fines from subgrade/prepared subgrade causing contamination of blanket layer on top of it and also to prevent penetration of coarse particles of layer on top of subgrade into soft/fine grained particles of sub-grade below. Specifications of Non-Woven Geotextile to be used as **“separator layer”** given in APPENDIX-C.
- (E)** Design of formation, including adoption of single layer or two layer system, and use of SQ1 soil (in top layer of subgrade) as given in above paras shall be decided by PCE/CAO (Con) on the basis of soil investigation.

In case of the projects being executed by PSUs, the powers of PCE/CAO shall be exercised at appropriate level of authority as nominated by CMD/MD of the PSU.

- (F) In case of cutting also, blanketing shall be provided as required & as specified in this Para 3.10, based on the type of soil just below the blanket.

3.11 Height of Embankment and Formation Layer thickness:

- i) Minimum height of embankment above ground level or highest flood level (HFL) whichever is higher should not be less than **one meter** to ensure proper drainage and avoid trespassing.
- ii) Total required thickness of formation layers as specified in **Para 3.10** for blanket, prepared sub-grade & Subgrade-Top Layer, should be provided/ensured uniformly in embankment/cutting for effective stress dispersal.
- iii) The specification of soil strata below the ground level (GL) must be ascertained from the results of soil exploration.
- iv) For effective stress dispersal, required total uniform thickness of formation layer (Blanket, Prepared sub-grade & Subgrade/Top Layer) shall be ensured in cuttings as well as in embankments, even where embankment height is less than about 1.5m or total uniform required thickness. It is further explained as below:
 - a) **For Embankment (where height of embankment is less than required total uniform thickness):** If the specification of sub-soil meets the required specification of blanket/prepared subgrade/subgrade-top layer, upto required total depth of uniform thickness below ground level, then there will be no need of excavation, else the excavations will be done below ground level as per the requirement, to satisfy the provision of total uniform thickness for effective stress dispersal. Detailed description & few examples are as given in **APPENDIX-B**.
 - b) **For Cutting:** If the specification of sub-soil does not meet the required specification of blanket/prepared subgrade/subgrade-top layer i.e. total required uniform thickness, below the proposed level of excavation in cuttings, the excavation level for cuttings shall be enhanced to the level so as to satisfy the total required uniform thickness requirement. Detailed description & few examples are as given in **APPENDIX-B**.
- v) Suitable drainage arrangement shall be ensured.

CHAPTER-4

APPLICATIONS OF GEOSYNTHETICS IN RAILWAY FORMATION

4.1 General

Geo-synthetic is a generic term which includes different synthetic products used in Geotechnical Engineering applications. Geo-synthetics are available in a wide range of forms and materials.

They can be utilized to solve various issues related to railway roadbed stabilization, like drainage, filtration, reinforcement, separation, erosion control etc. The raw materials used in the manufacturing of Geosynthetics are polymers, which are non-biodegradable.

4.2 Functions of Geo-synthetics

A properly designed Geosynthetic can serve various functions; some of them are as given below:

4.2.1 Separation

A Geosynthetic placed at the interface between two dissimilar geotechnical materials (fine and coarse grained soils) functions as a Separator when it prevents intermixing of two soil types to maintain integrity of each material under the applied loads (**Fig-4.1**). Non-woven geotextile layer is commonly used for separation, in Railway formations, and it provides filtration and drainage also.

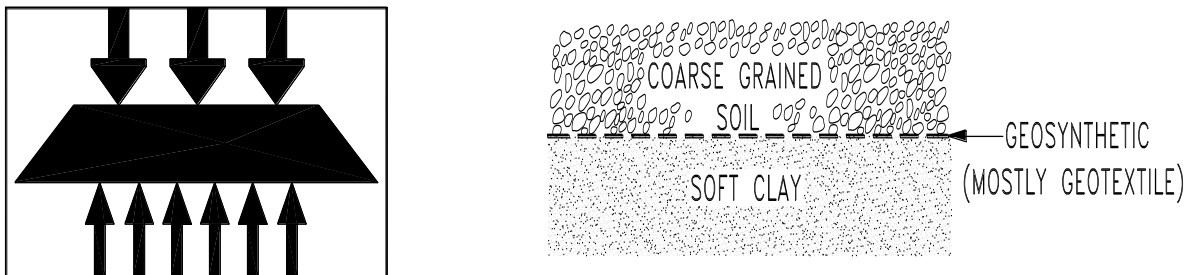


Fig-4.1: Separation

4.2.2 Filtration

In this function, the geosynthetics allows passage of fluids from the soil in either direction while simultaneously prevents the uncontrolled passage of soil particles (**Fig-4.2**). The pore size of the geosynthetic (mostly non-woven geotextile) is chosen to aid against their blocking, binding and clogging. Non-woven geotextile layer is commonly used for filtration in Railway formations and it normally partnered with Separation.

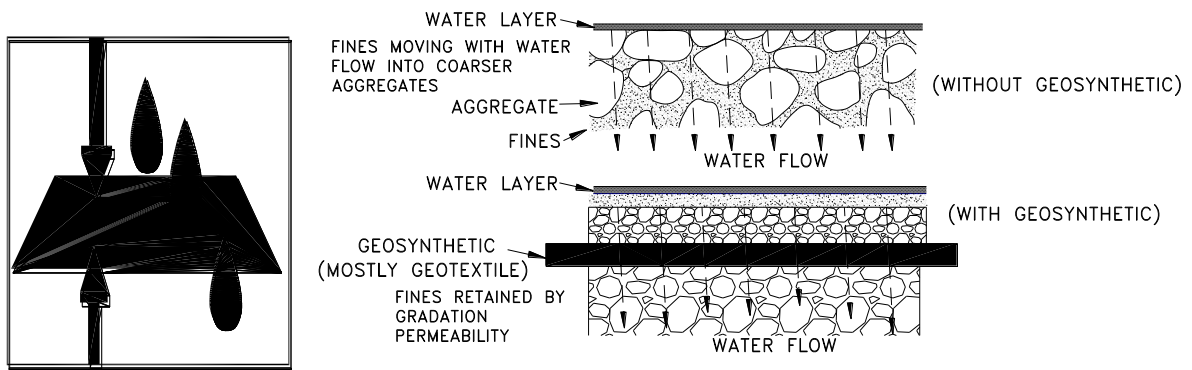


Fig-4.2: Filtration

4.2.3 Drainage

In this function, the Geosynthetic collects the fluid and transports it in its own plane [Fig-4.3 (a) & (b)]. This function is facilitated due to in-plane permeability of the geosynthetic (called "transmissivity") being far more than permeability across the plane (called "permittivity"). Non-woven geotextile or Geocomposite drains are commonly used for drainage in Railway formations.

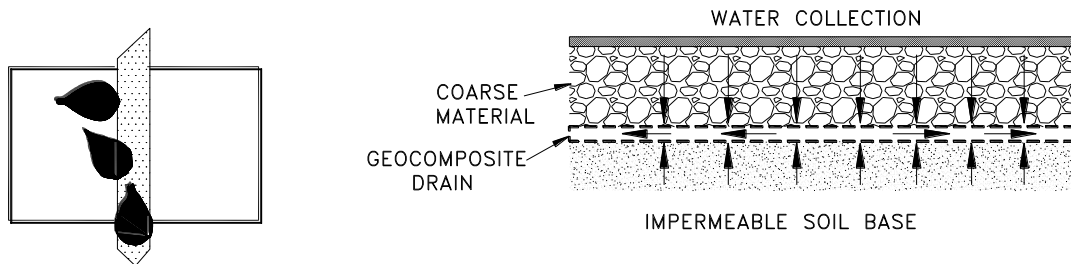


Fig-4.3(a): Drainage in Basal Layer

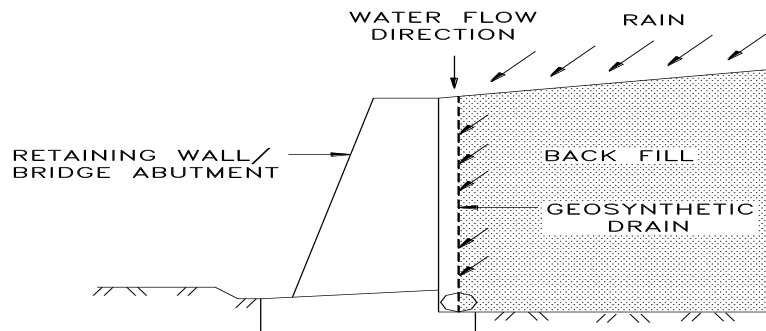


Fig-4.3(b): Drainage behind Bridge Abutment/Retaining Wall

4.2.4 Reinforcement

Geogrid can be used for reinforcement at the bottom of ballast or at the bottom of blanket or within the blanket, which by its reinforcing/interlocking mechanism forms

a semi rigid mat that helps in reducing the stresses on the layer below. This can be used to reduce the required blanket thickness.

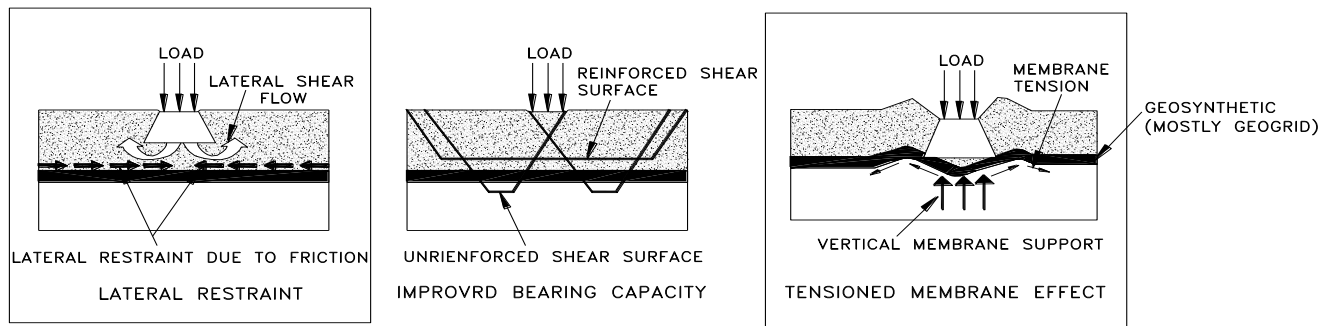


Fig-4.4: Reinforcement of Layers in Embankment

4.3 Types of Geosynthetics

There are various types of Geosynthetics, as under:

- i) Geotextiles
- ii) Geogrids
- iii) Geonets
- iv) Geomembranes
- v) Geocomposites
- vi) Geocell &
- vii) Others

Geosynthetics which are/can be used in Railway formations are described in brief, as under:

4.3.1 Geotextile

Geotextiles are planar and permeable members which are manufactured from synthetic fibers, yarns, filaments, tapes etc. The polymers used in manufacturing geotextiles are Polypropylene, Polyester, High Density Polyethylene and Polyamide (nylon) or a combination thereof, but a large majority of geotextiles are made from Polypropylene.

Generally two types of geotextiles are used commonly, as given below:

(i) Woven Type

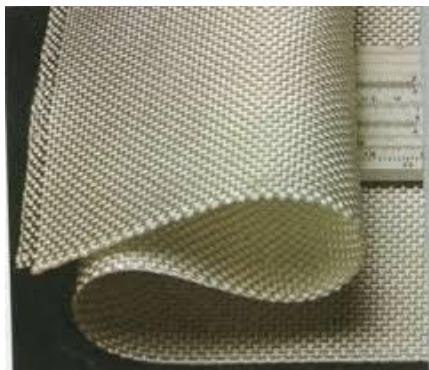




Fig-4.5 : Woven Geotextiles

These geotextiles are woven by interlacing two or more sets of yarns, fibers, filaments, tapes or other elements (Fig-4.5). These threads are generally woven straight and parallel to each other. Woven textiles exhibit high tensile strength, high modulus, high permeability and low elongation.

(ii) Non-woven Type

Non-woven geotextiles are manufactured in the form of sheet or web of directionally or randomly oriented fibres (Fig-4.6), produced by mechanical and/or thermal and/or chemical bonding. Non-woven geotextiles have high permeability and high elongation characteristics. In Railway application it acts as a separator, drainage material, and filter.

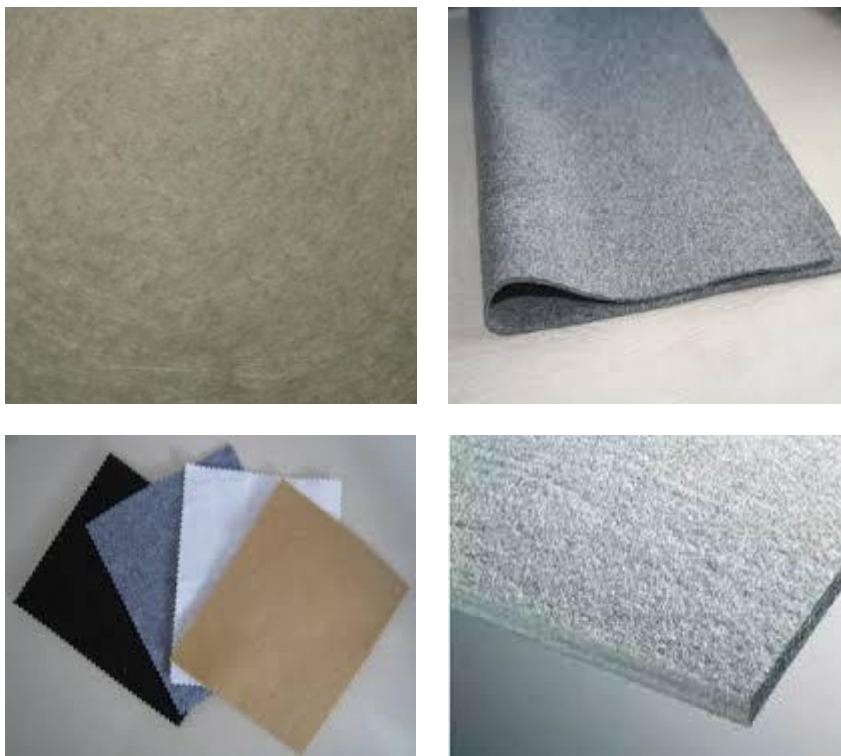


Fig-4.6 : Non-woven Geotextiles

4.3.2 Geogrid

Geogrid is a planar, polymeric structure consisting of a regular open network of integrally connected tensile elements, which may be linked by extrusion, bonding or interlacing. They have an open grid like configuration with large apertures between individual ribs. The key feature of all geogrids is that the apertures are large enough to allow soil communication, or strike through, from one side of the geogrid to the other. Geogrids have relatively high strength, high modulus and low-creep-sensitive polymers.

Geogrids provide uniform distribution of loads over a larger area by increasing stiffness of base, as the same resists flexural deformation.

Woven types of geogrids are manufactured by weaving together polypropylene coated polyester fibers into longitudinal & transverse ribs and joining the crossovers by knitting or intertwining before protecting the entire unit by a subsequent coating (**Fig-4.7**). Extruded types of geogrids are produced by extruding polymers and by stretching uniaxially or biaxially extruded integral structure (**Fig-4.8**). Bonded geogrid is produced by bonding, usually at right angles, two or more sets of strands or other elements (**Fig-4.9**).



Fig. 4.7 Woven Geogrid



Fig. 4.8 Extruded Geogrid

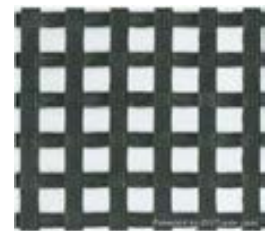


Fig. 4.9 Bonded Geogrid

Following types of geo-grids are generally available in the market:

- (i) **Geogrid with one axis:** Also known as mono-oriented geogrids, it is a planar grid, which possesses a much higher strength in one direction than in the other direction (**Fig-4.10**).
- (ii) **Geogrid with two axes:** Also known as bi-oriented geogrids, it is a planar grid, which possesses similar strength in both ortho direction i.e. longitudinal & transversal (**Fig-4.11**).



Fig-4.10 Geogrid with one axis



Fig-4.11 Geogrid with two axes



Fig-4.12 Geogrid with three axes

- (iii) Geogrid with three axes:** A recent addition to the geogrid family, this product is having ribs in triangular pattern or other shapes. These geogrids are manufactured from a punched polypropylene sheet oriented in multiple, equilateral directions to form triangular apertures. (**Fig-4.12**).

4.3.3 Geocomposite

Geocomposite a generic name used to define a geosynthetic product consisting of a combination of two or more geosynthetic materials. The application areas of geocomposites are numerous and growing steadily. The geocomposites used for Raiway formations, are as following:

(i) Geocomposite Drain

Geocomposite drains, consisting of a geonet bonded with non-woven geotextile layer(s) on one or both sides are used for drainage from a basal layer in case of embankments and for drainage behind retaining walls and/or bridge abutments.

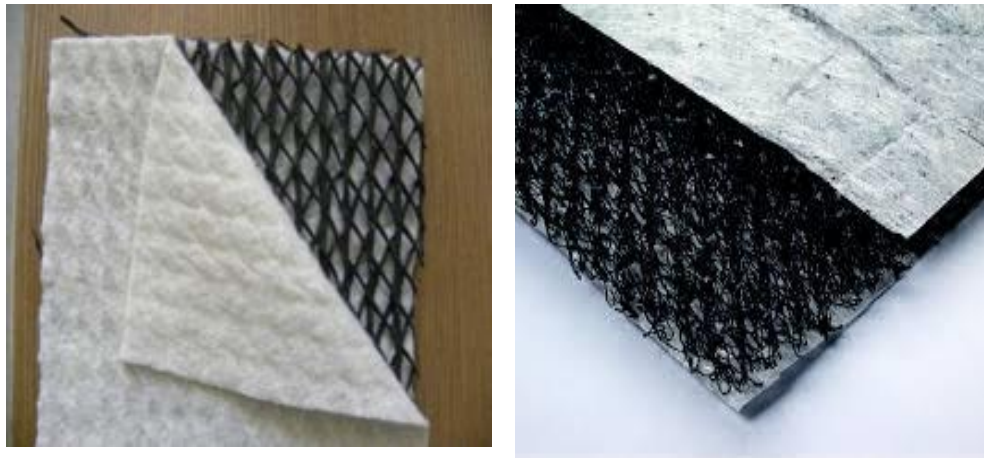


Fig-4.13 Typical Geocomposite Drains

(ii) Prefabricated Vertical Drains (PVD)

Prefabricated Vertical Drains (PVDs) are a geocomposites consisting of a synthetic filter jacket surrounding a plastic core. Normally they are manufactured in rolls of 200-300 m length and are inserted into ground to required depths using special drain stitcher rigs.

4.3.4 Geocell

Geocell is a three dimensional honeycomb like cellular structure, consisting of a regular open network of synthetic strips, linked by extrusion or adhesion or other methods.

4.4 Scope of Use of Geosynthetics In Railway Embankments

The decision on use of geosynthetics shall be taken based on the techno-economic considerations for every site of work, with the approval of PHOD in Open Line and Construction departments of Zonal Railways and equivalent officer in PSUs.

Considering the various functionalities provided by the geosynthetics, they have been used or can be used for following applications related to Railway Embankments:

- a) Construction of new Embankment with fine grained soils
- b) Ground Improvement in case of soft sub-soils
- c) Construction of new Embankment over soft subsoil
- d) Reduction in thickness of blanket layer
- e) Rehabilitation/Strengthening of weak/unstable formation
- f) Drainage behind Bridge Abutment/Retaining Wall.

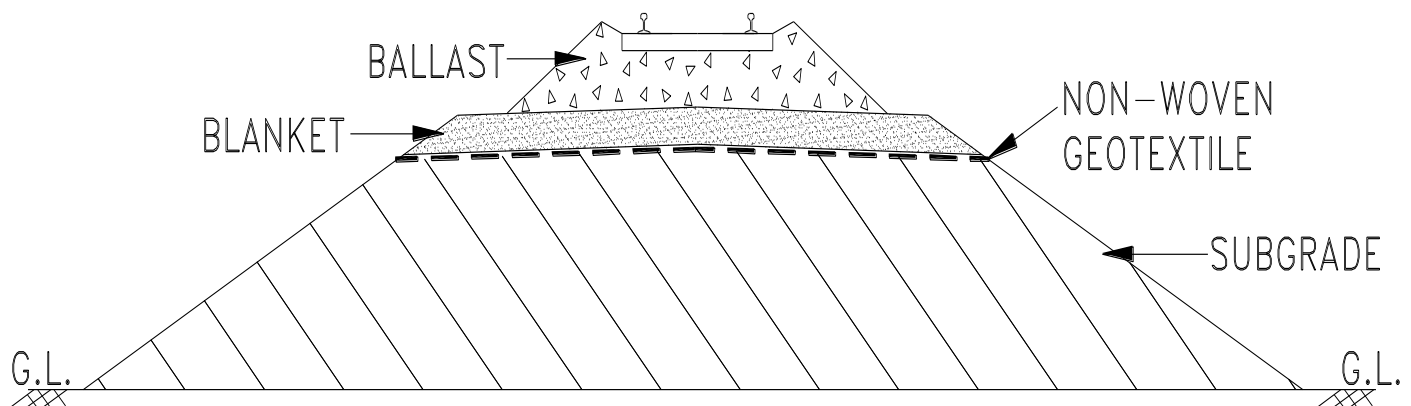
4.4.1 Construction of new Embankment with fine grained soils

As given in Para 3.10, a non-woven Geo-textile layer is required to be used as “separator layer” in the following cases:

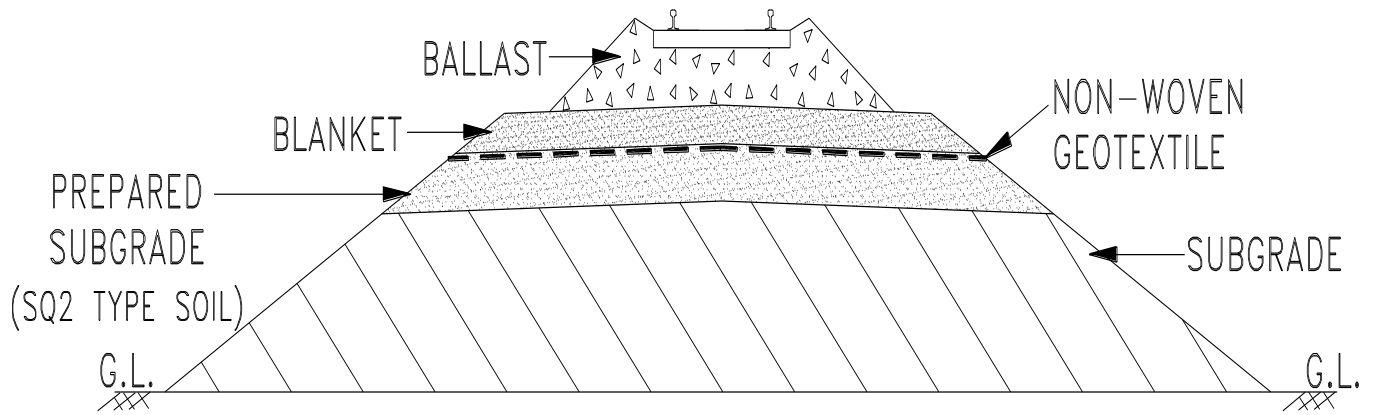
- (a) Below blanket layer, if SQ2 soil is used in prepared sub-grade in two layer system.
- (b) Below blanket layer, if SQ1 or SQ2 soil is used in sub-grade in single layer system.

RDSO has developed the Specification for Non-woven geotextile to be used as separator/filtration in Railway formation. The specifications have been issued to **Zonal Railway/PSU's for trial application initially so as to improve upon the specifications based on its satisfactory performance, before its general adoption.**

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) is given in **APPENDIX -C.**



**Fig-4.14 (a): Use of non-woven geotextile for fine grained soil
(In Single Layer System)**



**Fig-4.14 (b): Use of non-woven geotextile for fine grained soil
(In Two Layer System)**

4.4.2 Ground Improvement in case of soft sub-soils

For construction of embankment over soft sub-soils (which are mostly soft clays), the sub-soil/ground has to be improved for –

- Reducing the consolidation time (which otherwise can be very long spanning months/year) & associated settlement so that bank can be constructed in faster time; and
- To increase the bearing capacity/ shear strength of the sub-soil so that the bank constructed over it is stable.

For faster consolidation & associated settlement, Prefabricated Vertical Drain (PVD) can be used. To improve the load support capacity of soft subsoil, Geocell is another form of Geosynthetics which is used as a basal mattress in embankments for ground improvement. For detailed description, **Chapter-2 (Suitability of Subsoil & Ground Improvement Techniques)** can be referred.

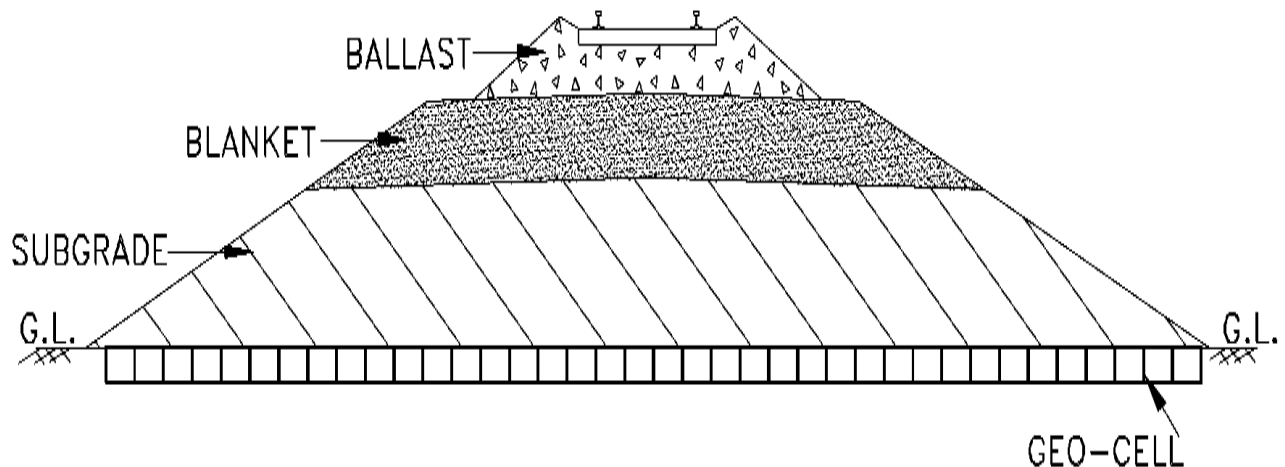


Fig-4.15: Use of Geocell as basal mattress for Ground improvement in soft subsoil

4.4.3 Construction of Embankment over soft subsoil

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 Geocomposite drain layer, sandwiched between two layers of sand of about 75mm thickness (**Fig-4.16**), 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. Alternatively, a 1000mm thick sand layer can be provided. Its thickness may be varied depending on the bank height, characteristics of sub-soil and water table. The sand layer to be used in both the cases should be clean medium to coarse sand with minimum permeability of the order of 10^{-5} m/second.

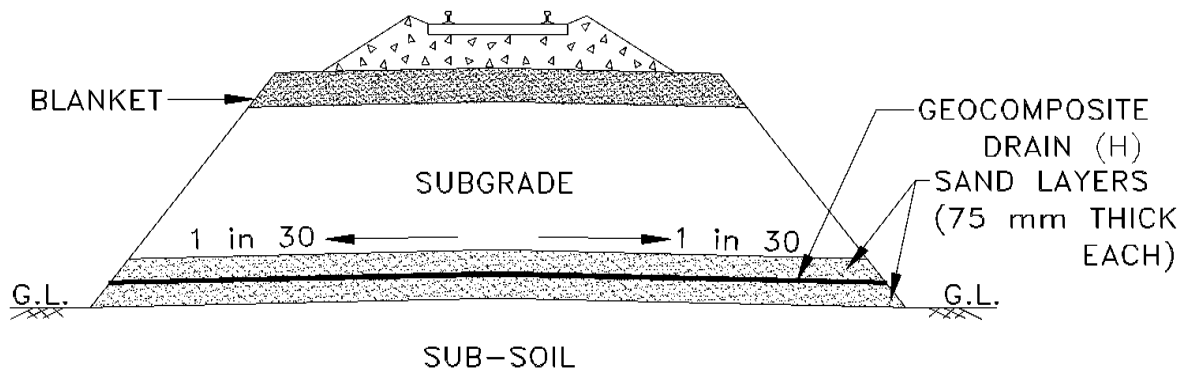


Fig-4.16: Use of Geosynthetic (Geocomposite drain-horizontal) in embankment over soft subsoil

RDSO has already developed the Specification for Geocomposite Drain (Horizontal) at the base of the Embankment (for embankment height upto 8m). The specifications have been issued to Zonal Railway/PSU's for trial application initially so as to improve upon the specifications based on its satisfactory performance, before its general adoption.

Specification of Geocomposite Drain to be used at base of the Embankment (Specification No. RDSO/2018/GE: IRS-0004- Part-II, March 2019) is given in **APPENDIX -C**.

4.4.4 Reduction in thickness of blanket layer

To reduce the thickness of the Blanket Layer (which is costly granular material obtained by quarrying or mining) in case of new constructions or for formation rehabilitation, on techno-economic considerations and/or to reduce the adverse impact on environment due to quarrying/mining, geogrid can be used. (**Fig-4.17**)

RDSO has developed the Specifications for Geogrid to be used as Reinforcement/Stabilisation for Railway Formation. The specifications have been issued to Zonal Railway/PSU's for trial application initially so as to improve upon the specifications based on its satisfactory performance, before its general adoption.

Specifications for Geogrid to be used as reinforcement/stabilisation for Railway Formation (Specification No. RDSO/2018/GE: IRS-0004- Part-III, February 2020) is given in **APPENDIX -C**.

Zonal Railways and Construction units must submit the design of reinforced formation layer to RDSO along with design methodology for use and selection of Geo-grid with minimum specifications as prescribed by RDSO for its approval.

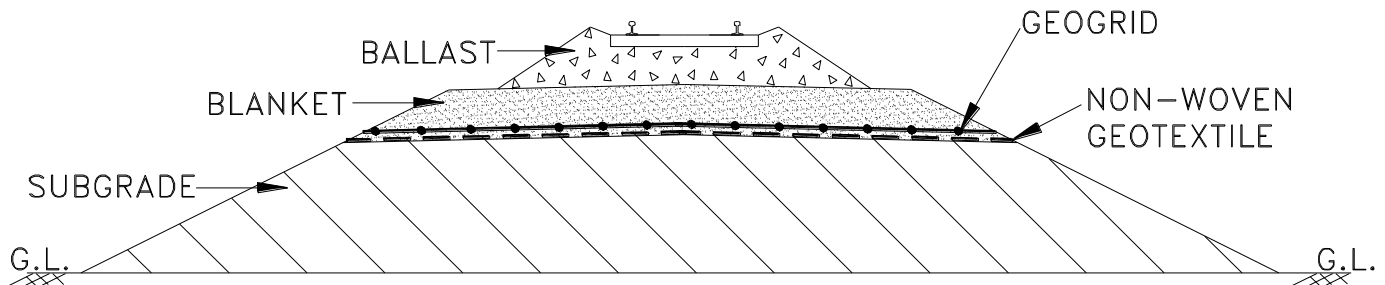


Fig-4.17: Use of geogrid for reduction of blanket layer thicknesses

4.4.5 Rehabilitation/Strengthening of weak/unstable formation

The weak/unstable formations are mostly those formations where subsoil and/or 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 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, will reduce 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.

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 along with deep screening work by Ballast Cleaning Machine (BCM), with additional provision in machine for laying of Geogrid/Geotextile. **(Refer Para 10.5, Chapter 10).**

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.

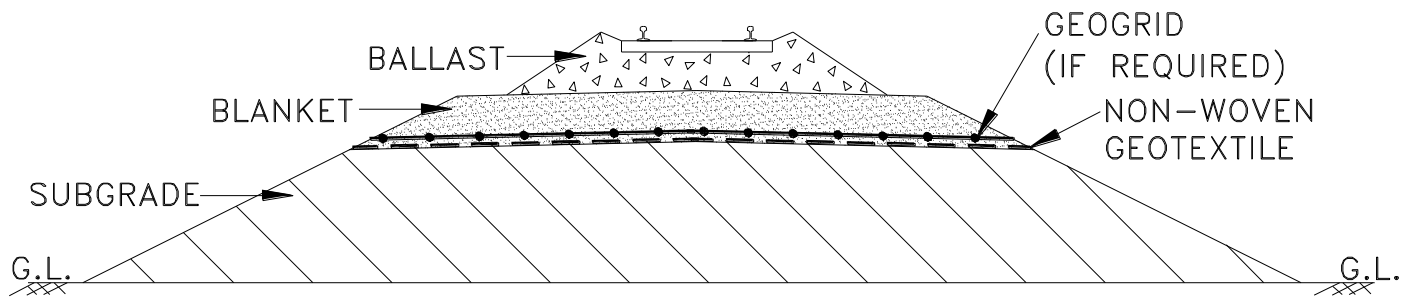


Fig-4.18: Rehabilitation/Strengthening of weak/unstable formation using geogrid & non-woven geotextile

4.4.6 Drainage behind Bridge abutment/Retaining wall

Geocomposite drain (Vertical) can replace the 600 mm thick natural graded filters (consisting of different sizes of boulders and gravels), provided behind bridge abutment and/or retaining walls for drainage, in places where availability of graded filter material is matter of concern. It also eliminates the need for weep holes in bridge abutment and/or retaining walls. The stages in installation of such a synthetic drain are shown in Fig-4.19.

RDSO has developed the Specification for Geocomposite drain (vertical) to be used behind the Bridge Abutment/Retaining wall for drainage purpose. The specifications have been issued to Zonal Railway/PSU's for trial application initially so as to improve upon the specifications based on its satisfactory performance, before its general adoption.

Specification for Geocomposite drains to be used behind Bridge Abutment/Retaining wall (Specification No. RDSO/2018/GE: IRS-0006, March-2019) is given in **APPENDIX-C**.





Fig 4.19: Installation of Geocomposite Drain