SURVEY & CONSTRUCTION OF RAILWAY LINES

Surveying is an activity of making measurements on ground with a view to fix relative position of various important features on the surface of the earth.

1.2 Types of Surveys

1. *Plane Survey :* earth is considered to be a plane
2. *Geodetic Survey* spherical.

1.2.1 Instruments used for Surveying

(1) Instruments for measuring distance :

(a) *Chain :*.

(b) *Tapes :*.

(2) **Instrument for measuring angles :** Prismatic compass.

(3) Leveling Instruments: Leveling instruments are used to determine relative levels of two places,:

Basic principle of leveling :

(a) Dumpy level

1.3 Contours:

1.4. Theodolite

1.4.1 Temporary adjustments of theodolite :

(a) *Leveling :*

(b) *Focusing :*.

1.4.2 Permanent Adjustments of a Theodolite :

Permanent adjustments of a theodolite are those adjustments which are not required to be done daily.

1.4.3 Method of taking observations :

(a) Measurement of Horizontal Angles :

(B) Measurement of Vertical angles :

1.4.4Total Stations :

Now a days, the total Station System is increasingly used for surveying.

A total station is a combination electronic transit and electronic distance measuring device (EDM). With this device, as with a transit and tape, one may determine angles and distances from the instrument to points to be surveyed. With the aid of trigonometry, the angles and distances may be used to calculate the actual positions (x,y, and z or north, east and elevation) of surveyed points in absolute terms.

A standard transit is basically a telescope with cross-hairs for sighting a target; the telescope is attached to scales for measuring the angle of rotation of the telescope (normally relative to north as 0 degrees) and the angle of inclination of the telescope (relative to the horizontal as 0 degrees). After rotating the telescope to aim at a target, one may read the angle of rotation and the angle of inclination from a scale. The electronic transit provides a digital read-out of those angles instead of a scale; it is both more accurate and less prone to errors arising from interpolating between marks on the scale or from mis-recording. The readout is also continuous; so angles can be checked at any time.

The other part of a total station, the electronic distance measuring device or EDM, measures the distance from the instrument to its target. The EDM sends out an infrared beam which is reflected back to the unit, and the unit uses timing measurements to calculate the distance traveled by the beam. With exceptions, the EDM requires that the target be highly reflective, and a reflecting prism is normally used as the target. The reflecting prism is a cylindrical device about the diameter of a soft-drink can and about 10 cm. in height; at one end is a glass covering plate and at the other is a truncated cone with a threaded extension. It is normally screwed into a target/bracket on the top of a pole; the pointed tip of the pole is placed on the points to be surveyed.

The total station also includes a simple calculator to figure the locations of points sighted. The calculator can perform the trigonometric functions needed, starting with the angles and distance, to calculate the location of any point sighted.

Many total stations also include data recorders. The raw data (angles and distances) and/or the coordinates of points sighted are recorded, along with some additional information (usually codes to aid in relating the coordinates to the points surveyed). The data thus recorded can be directly downloaded to a computer at a later time. The use of a data recorder further reduces the potential for error and eliminates the need for a person to record the data in the field.

The determination of angles and distance are essentially separate actions. One aims the telescope with great care first; this is the part of the process with real potential for human error. When the telescope has been aimed, the angles are determined. Only then does one initiate the reading of the distance to the target by the EDM. That takes only a few seconds the calculations are performed immediately.

The total station is mounted on a tripod and leveled before use. Meanwhile, the prism is mounted on a pole of known height; the mounting bracket includes aids for aiming the instrument. The prism is mounted so that its reflection point is aligned with the center of the pole on which it has heen mounted. Although the tip of the pole is placed on the point to be surveyed, the instrument must be aimed at the prism. So it will calculate the position of the prism, not the point to be surveyed. Since the prism is directly above the tip, the height of the pole may be subtracted to determine the location of the point. That may be done automatically.

When the instrument is set up and turned on, it sets itself to be pointing to zero degrees (north) when power is first supplied. The user must then re-set the instrument to zero degree when it is actually pointing north; when there is no secondary battery for back-up, when the battery dies, the instrument must be re-set for zero degrees.

This enables us to get more accurate survey information with much less effort.

1.5 Plane Table and Alidade :

Orientation of Plane Table :

(a) When setting the plane table at a control station

(b) When setting the plane table away from the control station :

1.6 Setting out right angles

(i) *By use of cross-staff :*

(ii) By Optical Square

(iii) *By 3-4-5 method (fig.1.14)*.

CHAPTER 2

2 Construction Organisation of the Railway

The works may include :

(i) Survey and construction of new lines,

(ii) Doubling of existing single line section,

(iii) Provision of a 3rd or 4th line of the existing two or three line section,

(iv) Gauge conversion of narrow or metre gauge lines,

(v) Construction of a major or important bridge,

(vi) Important traffic facility works.

2.1 Duties of CAO (Construction)/ or Chief Engineer (Construction)

(i) To provide necessary administrative control for efficient and economical execution of works

(ii) To provide technical direction and support and to ensure that the latest cost effective technology is

(iii) To maintain liaison with the Open Line

(iv) To follow the general policies and.

(v) To exercise necessary budgetary control within the allotment of funds.

(vi) To co-ordinate with the Open line Organisation in matters of training, promotion and placement of personnel.

2.2 Engineering Surveys

2.2.1 Reconnaissance Survey

(i) Ruling gradient.

(ii) Maximum permissible degree of curvature of curves.

(iii) Projected level of traffic.

(iv) Mode of traction such as diesel, electric.

In the course of reconnaissance survey, the following information should be collected :

(i) Topography of the area such as plain, hilly.

(ii) Possible gradients.

(iii) Obligatory points such as intermediate cities, junction points, production centres, river crossings etc.

(iv) Geographical characteristics of the area which may have a bearing on the design of bridge foundations.

(v) Extent of waterway required for rivers and channels.

(vi) Availability of building materials and labour in the area.

(vii) Flood levels- to be ascertained from local residents.

(viii) Value of land.

(ix) Suitable sites of railway stations and yards.

(x) Requirement of special structures such as tunnels & viaducts.

(xi) Feasibility of high banks and deep cuttings.

Techno-Economic Studies.

(i) Optimization of the existing facilities.

(ii) Examination of various alternative schemes.

The study includes :

(i) Study of economic development plan of the catchment area of the project.

(ii) Social development in the area.

(iii) Other factors contributing to railway traffic such as diversion on traffic to and from other routes due to development of other areas/sectors/modes of transport.

(iv) Traffic projection which is likely to become available in future with phases.

(v) Evaluation of existing facilities with a view to optimize the same.

(vi) Development of alternate schemes after taking into consideration the optimization proposals of the existing assets.

2.2.2 Preliminary Engineering-Cum-Traffic Survey (PETS)

2.2.2.2 Report

The Project report should be complied under chapters as indicated below :

(i) Introduction

(ii) Characteristics of the project area.

(iii) Standard of construction

(iv) Route selection.

(v) Project Engineering and cost of construction and proposed schedule of contribution.

(vi) Traffic projections.

Introduction :

Contents of this chapter should be organized under the following sections :

(i) Object of investigation and background.

(ii) Programme and methodology of investigations.

(iii) Special features of investigations.

Characteristics of the Project area :

Contents of this chapter should be organized as under :

(i) Topographical outline of the area and the geological features which may affect the alignment, stability of slopes and cost of construction.

(ii) Climate and rainfall characteristics.

(iii) Environmental characteristics such as pollution, corrosive factors etc. having a bearing on the design of structures and maintenance practices.

(iv) Any schemes being developed by other agencies so as to control the river flow.

(v) Likely interference to outside establishments such as military cantonments, camping ground, communications etc.

Standards of construction :

This chapter should indicate the various standards to be adopted for the constituent elements of the project. These should include the following :

(i) Gauge

(ii) Category of line with maximum speed potential, axle load,

(iii) Ruling gradient with maximum length and load of goods train.

(iv) Curves-Sharpest curvature.

(v) Permanent way-rail section, whether long welded, type and density of sleepers.

(vi) Ballast-type and depth of ballast cushion.

(vii) Fixed structure clearance.

(viii) Stations and their locations, and provision for future stations.

(ix) Residential accommodation-scale and extent of accommodation.

(x) Station machinery.

(xi) Servicing and maintenance facilities.

(xii) Signalling-Standard of signalling.

(xiii) Communication-Scale of communication facilities.

(xiv) Traction-type of traction.

Route Selection :

Project Engineering and cost of construction schedule :

following sub-heads :

(i) Preliminary expenses.
(ii) Land
(iii) Formation
(iv) Bridges
(v) Permanent Way
(vi) Station Building & Residential Quarters.
(vii) Station Machinery :
Running sheds and workshop facilities.
Signalling and interlocking
(viii) Road crossings.
(ix) Equipments.
(x) Rolling stock.
(xi) Special Problems.
(xii) Project organization
(xiii) Rate Analysis
(xiv) Statistical information
(xv) Estimate of cost
(xvi) Investment schedule
(xvii) Construction programme.

2.2.3 Final location Survey

Final location survey is carried out to set out the finally selected alignment based on the preliminary survey. It shall be based on a theodolite traverse which should be approximately as close as possible to the centre line to be finally adopted. Following are the main features of the Final location survey.

(i) The survey operations should be sufficiently comprehensive for the preparation of detailed plans and sections and estimated cost of the line.

(ii) Details of rivers, streams and bunds and irrigation work in the vicinity of the projected line should be collected.

(iii) In case of the alignment passing through hilly terrain, geological characteristics of the country should be investigated for examining the stability of banks and cuttings.

(iv) Systematic soil sampling at suitable intervals be done for classification of soils to decide the methodology of construction as well as need for blanketing or other treatment.

(v) The centre line finally located should be marked by pegs at every 20 metres and at every 100 metres a large peg should be used which should be serially marked indicating their chainage.

(vi) Masonry pillars should be built at the tangent points of curves and along the centre line at intervals of not less than 500 metres.

(vii) Curves should be defined both by degree and radius in metres.

(viii)Apex angle (deflection angle) formed by the intersection of tangents should, if practicable, be observed and if not be calculated.

(ix) Transition curves : Transition curves should be provided at the start of the curve and between two curves of different curvatures.

(x) Gradient : Gradient should be defined by the distance in which a rise or fall of one metre occur per 100 metres.

(xi) All lines should be graded with due regard to the possibility of additional intermediate stations to be constructed at a later date.

(xii) Sharp changes of gradient should be avoided, particularly on curves. All sharp changes of gradient should be eased off by vertical curves.

(xiii)Compensation for curves on gradients : All gradients should be compensated for curvature if the ruling gradient would otherwise be exceeded. The compensation to be allowed should be 0.04 percent per degree of curvature for broad gauge.

(xiv)Bench Marks : Bench marks should be left at intervals of not more than one kilometer along the line and at sites of important bridges.

(xv) Datum : Datum to which all levels should be referred is the mean sea level as adopted for the Great Trigonometrically Survey of India.

(xvi)Compass bearings : Compass bearings of each tangent should be taken at every curve in level country. In hilly terrain, it will be sufficient to take such bearings at about 2 or 3 places in kilometer.

(xvii) Plans, Sections and Designs for Works : A set of plans and sections should consist of :

(a) General Map of the country traversed.

(b) Index map, scale 2.5 km. to I cm.

(c) Index plan and sections, scale 0.5 km. to I cm. horizontal and 10 metres to I cm. vertical.

(d) Detailed plans and sections, scale 50 metres to I cm. horizontal and 5 metres to I cm. vertical.

(e) Plans and cross section of rivers.

(f) Plans of station yard.

(g) Detailed drawing of structure.

(h) Plans of junction arrangements.

On the plans should be shown all features in detail of the country within a distance of 100 metres on each side of the centre line of railway and the boundaries of village lands. Boundaries of different kind of cultivation, forest, pasture, etc. should also be marked on the plan. The following details should be shown which lie within a distance of 300 metres from the centre line :

(i) Rivers requiring opening of 12 m or more.

(iii) Important roads with bridges.

(iv) Canal and large tanks.

(v) Outline of villages and towns.

(vi) State boundaries, Division and Districts.

(vii) Hill peaks and other important features.

(viii) Survey of India Stations.

(ix) Reserved forests.

(x) Camping grounds, rifle range.

(xi) Industrial units.

2.3 Development of Railway Projects :

If the line shows potential, a PETS (Preliminary Engineering-Cum-Traffic Survey) is taken up to determine the cost, potential earnings and rate of the projects.

If on the basis of PETS, it is decided to go ahead with the project, the Project Report is sent to Planning Commission:

(1) If the project cost is below Rs. 50 crores, the work is included in the Railway Budget with the approval of Railway Minister.

(ii) If the work cost over Rs. 50 Crores, the case is put up before the Expanded Board consisting of the members of Railway Board, Secretary (Expenditure), Ministry of Finance, Secretary, Programme Implementation and Secretary, Planning Commission and once their recommendations are available, the case is put up to the Cabinet Committee of Economic Affairs for their approval.

After their approval is received, the work is included in the Railway Budget.

Once the Budget is passed by Parliament, the work is taken as sanctioned and thereafter the final location survey is taken up.

CHAPTER 3

NEW LINES, GAUGE CONVERSION AND DOUBLING PROJECTS

3.1 New LINES - Policy

A new railway line is required to be constructed normally in a new area for one or more of the following considerations.

(i) Strategic and political considerations

(ii) Development of backward area.

(iv) Connecting new trade centres.

(v) To shorten the existing rail lines.

3.2 Construction of new lines.

The main works involved in constructing a new line are as follow :

1. land acquisition.
2. Earthwork and bridges.
3. Station building, staff quarters and other allied facilities, including ballasting of track.
4. Opening of section for traffic.

3.3 Categories of lines and standard of construction

(i) Group 'A' For projected speed of 160 kmph.

(ii) Group B For projected speed of 130 Kmph

(iii) Group C Suburban sections

(iv) Group D where the sanctioned speed is 100 kmph.

(v) Group E Other sections of branch lines

Two more routes namely D (Special) and E(Special) have been

3.4 Land acquisition

The minimum land to be arranged should cater for the following :

(i) Width of formation :

(ii) Side slope :

(iii) Width of beams : The usual width of beam is kept as 3 metres.

(iv) Borrow pits :

3.5 Earthwork for formation

A formation (embankment) is normally preferred:

Gauge	**Type of formation**	**Width of formation (m)**	
		Single line	**Double line**
BG	Embankment	6.10	10.82
	Cutting	5.40	10.21
MG	Embankment	4.88	8.84
	Cutting	4.27	8.23

Some of the points with regard to specification of earthwork are given below :

(i) Earthwork is normally done in layers of about 30 cm depth so that earth is well compacted.

(ii) Mechanical compaction is to be done after each layer with the help of Sheep foot roller' to obtain 90% of maximum dry density at optimum moisture content.

(iii) A shrinkage allowance of 5% is made from the final cross section for consolidation in case of mechanical compaction. In other cases when mechanical compaction is not done, this shrinkage is 10%

(iv) A blanket of about 1 metre thickness is provided at the top of the embankment except where the soil is granular and as per specification of the blanketing material.

(v) In areas where there are cutting and embankments both, the earth from the cuttings should be used for the embankments up to an economical lead. The economical limit of moving the earth in the longitudinal direction is determined by 'Mass-haul Curve'.

(vi) For early execution of earthwork, the sections is normally divided in different convenient zones; Tenders are invited for each zone separately so that work can simultaneously progress in all the zones.

3.6 Bridges

The bridges as required to be designed as per the standard of loading approved for the line. Depending upon the topography of the country and the type of stream to be crossed, hume pipe culverts, R.C.C. Slab bridges, plate girders or PRC girder bridges or steel bridges are designed.

3.7 Service buildings and Staff Quarters

Service buildings are the buildings like Station Buildings/Power stations, etc,.

3.8 Plate laying or Track Linking

1. *Tram line method :* In this method, a temporary line known as 'tram line' is laid by the side of proposed track for taking the track materials to the site. This method can be useful in flat countries, where laying of a tram line on the natural ground may be comparatively easier. This method is however, seldom used in actual practice.

2. *American method :* In this method, rails and sleepers are first assembled in the base depot and pre-assembled track panels.

3. *Telescopic method :* This method is widely used on Indian Railways. In this method, the rails, sleepers and other fittings are taken to the base depot and unloaded. The track materials are then taken to the rail head and track linked and packed.

(i) *Unloading of materials :* The track materials are taken to the base depot and the same unloaded with the help of 'material gang' and are taken from the base depot with the help of dip lorry.

(i) *Linking of track :* Once the track materials are unloaded, the track is linked with the help of linking gangs. Following procedure is normally adopted :

(ii) *Packing of track :* The track is then thoroughly packed with the help of beaters by 'Packing in-gangs.' The following aspects should be checked.

(iii) *Ballasting of track :* The ballast is normally spread in the railway lines after the embankment has settled well and atleast two monsoon has passed over it.

3.8.1 Requirement of track materials for I km. of B.G. track

1. **Rails :** The standard rails are of 13 metre length for B.G. and 12 metre length rails for B.G.

No. of rails per km for B.G. = 77x2 = 154
Wt. of 52 kg. rails per km = 52x1000x2 kg.
= 104 Metric tones

2. **No. of sleepers :** The number of sleepers depend upon the sleeper density. Assume sleeper density as M + 7, where M is the length of rail in metres.

No. of sleeper per rail =13+7 = 20

No. of sleeper per km. = 77 x20 = 1540

3. **Fitting & fastenings :**

(i) No. of fish plates per km, = 2x Number of rails per km
= 2x 154 =308

(ii) No. of fish bolts = 4x No of rails per km
= 4x154 = 616

(iii) No. of bearing plates = No. of sleeper x 2
= 1540x2 =3080

(iv) Number of dog spikes = No. of sleepers x 4
= 1540 x 4 =6160

Note : The requirement of track materials for M.G. can also be calculated using the same method.

3.9 Doubling of railway lines (fig .3.1)

Doubling of railway line means construction of an additional line

(i) *Engineering-cum-Traffic survey :*

(ii) *Specification of work :* While executing the work, it is necessary to clearly understand the standard of construction and specifications to be followed

(iii) *Land acquisition :* Extra land, if necessary, for the double line station yard, bridges, etc. is acquired, wherever the existing land is not adequate for this purpose.

(iv) *Earthwork :* Earth work is done for double line, by widening the existing formation.

(v) *Bridges :* The existing bridges are extended to suit the double line.

(vi) *Plate laying :* Rails, sleepers and fastenings are collected in track depots established for the projects. Normally such depots are situated at each railway station.

(vii) *Opening for Goods Traffic & Ballasting :* As soon as construction work is completed, the line is opened for goods traffic at restricted speed.

(viii) *Opening the line for passenger Traffic :* Once the line is properly packed, the same is opened for Passenger traffic after obtaining Commissioner of Railway Safety's sanction.

3.10 Gauge Conversion

'Gauge Conversion Projects' are basically aimed to provided uniform gauge for smooth and fast flow of traffic either due to strategic reasons or on account of operating considerations.

3.10.1 Uni-Gauge policy of Indian Railways

The problems of having multi gauge in a country are well known.

3.10.2 Benefit of adopting B.G. (1676 mm) as Uniform Gauge

Uni gauge system is beneficial to the Rail users, Railway administration as well as to the Nation. The benefits of Uni gauge system are as follows :

(i) *No transport bottlenecks:*
(ii) (ii) *No transshipment hazards :*

(iii) *Provisions of alternate routes:* By uni-gauge policy, alternate routes will be available for free movement of traffic

(iv) *Better turn round :* There will be better turn round of wagons and locomotives and their usage will improve the operating ratio.

(v) *Improved utilisation of track :* There will be improved utilization of track and reduction in working expenses of the railway.

(vi) *Balanced economic growth :* The areas presently served by M.G would receive an additional fillip and this will lead to removal of regional disparities and help in balanced economic growth.

(vii) *No multiple tracking works :* The uni gauge project will eliminate need for some of the traffic facilities and multiple tracking works, which will offset to certain extent the cost of gauge conversions.

(viii) *Better transport infra-structure :* Some of the areas served by M.G have the potential for becoming highly industrialized and skilled man power is also available. The uni Gauge policy will help in providing these areas a better transportation infrastructure.

(ix) *Boosting Investor's Confidence :* With liberalization of economic policy, Uni gauge project of Indian Railways has played a significant role. It will help in boosting investor's confidence that their goods will be distributed throughout the country in time and without any hindrance.

3.10.3 Execution of Gauge Conversion projects

1. Details of various field works normally involved in Gauge Conversion:

Table 3.1 : Field works for gauge conversion projects

Nature of work	Brief detail of works
1. Civil Engg. Works	Engineering-cum traffic survey; land acquisition. Earthwork for widening of formation; Extension of minor bridges, Extension and Strengthening or rebuilding of major Bridges of PSC slabs or steel girders; P.Way Work consisting of supply and spreading of ballast And layout of rails, sleepers and fastenings Including points & Crossings and all connected works
2. Electrical works	Modification to high tension crossings; Augmentation of power Supply; wiring of new Structures; Modification to LT and HT installation; Shifting of flooded light masts.
3.Signalling works :	Erection of signals at new locations; Interlocking of points; Track circuiting; Relay racks installation; Wiring & Testing works

II *Planning of Works :* Detailed planning is.

III *Speed potential :* Two rounds of packing by light track Tampers like Phooltas or Chinese tampers are required to make the track fit for 50 kmph. This is further supplemented by two more rounds of packing by Heavy-on-track Tie Tamping Machines for making the track fit for 100 kmph.

3.10.4 Details of civil Engineering works of gauge conversion projects (Fig .3.2)

1. *Engineering-cum-traffic Survey ;* The survey is done to examine the technical feasibility of the proposal and the economical aspects of the same.

2. *Land acquisition :* The land required for converting the track from M.G. to B.G. is assessed; Extra land, if necessary is acquired as per extent procedures laid down in land acquisition act.

3. *Earth work :* Earth work is done on either side of existing formation to increase its width from 4.88 m (16ft.) to 6.10 m (20ft.) in case of embankments and from 4.27 m (14ft.) to 5.49 m in case of cuttings. These width of formation are for single line tracks.

4. *Bridges and Culverts :* The existing bridges and culverts are extended, strengthened/rebuilt to suit the B.G. formation and to confirm to standards adopted for B.G. Proper planning is done to extend these bridges as the work has to be done with minimum dislocation to traffic.

5. *Track Linking :*

(i) *Unloading of Track Materials :*.

(ii) *Arrangements of men and Materials*.

(iii) *Traffic Blocks :* Traffic is suspended on the railway line for a period of about 30 to 90 days depending upon the length of track so that the work of gauge conversion can be carried at one stretch. During the traffic block, traffic is diverted on alternate routes or transshipped and carried by road vehicles.

(iv) *Linking the new track :* During the traffic block, the existing rails are removed and new rails placed in the final position for B.G. track. The new sleepers are placed in proper position and the rails spiked to the sleepers as per B.G. requirements.

The track is properly leveled and aligned and traffic is allowed to pass on the new line at restricted speed after obtaining the sanction of commissioner of railway safety.

(v) *Ballasting & Packing :* Adequate quantity of ballast is then put in the track and the track properly packed.

CHAPTER 4
ELEMENTS OF FORMATION ENGINEERING

4.1 Introduction

Formation Engineering or Soil Mechanics is that branch of science which studies the structure, engineering properties and the reaction of behavior of soils under loading and the changing weather conditions.

4.2 Soil

Soil is the naturally occurring loose or soft deposit forming part of the earth's crust, produced as a result of weathering or disintegration or decomposition of rock formations, or decay of vegetation, intermingled together. The top layer of the ground that supports vegetation is called 'soil' or 'top soil' and the undisturbed strata lying immediately below the natural top soil is termed sub-soil.

4.2.1 Constituents of Soils

Soils contain three components viz, air, water and solids.

4.2.2 Types of Soils

There are six main types of soil viz. Gravels, sands, silts, clays, fine grained organic soils and peat. .

4.2.3 Characteristics of Soils

Characteristics of a soil are useful in predicting the performance of the soil under load, which depends upon the grain size, shape, surface texture and chemical composition. The properties having most influence on the physical characteristics is that of particle-size distribution, and therefore, it is essential to determine the extent of each type present.

There is wide variation in the characteristics of different soils and the performance of each individual soil is affected by its moisture content and density. In general, the properties of soils composed largely of coarse materials are primarily controlled by the characteristics of the parties, but for soils composed largely of clays and colloids the properties are primarily controlled by the moisture content. Behavior of soils containing 30 per cent or more clay depends solely on the characteristics of the clay.

4.3 Classification and Identification of Soils

Various systems of classifying soils for civil engineering purposes have been devised and the use of different systems has led to much confusion. The coarse-grained soils are usually classified mainly on the basis of their particle-size distribution and the fine-grained soils on the basis of their plasticity characteristics.

4.3.1 Particle-size Analysis or Mechanical Analysis of Soils

Particle-size Analysis or Mechanical analysis of Soils is the process of separation of a soil into several fractions of different grain size.

Soils are divided into various size groups as, 'gravels', 'sands', 'silts', and 'clays' on the basis of the particle size analysis which is carried out by combining sieving and sedimentation methods. Particle sizes for gravels and sands are determined by "Sieve analysis".

4.4 Definition of terms involved in soil analysis are :

(i) *Capillarity :* It is the ability of the soil to transmit moisture in all directions regardless of any gravitational force.

(ii) *Permeability :* Permeability may be defined as the property of soil which permits the flow of water through its interconnecting voids. The knowledge of permeability is essential for the following Civil Engineering problems.

- (i) Seepage through dams and levees
- (ii) Draining water-logged land
- (iii) Rate of settlement of structures
- (iv) To safeguard the hydraulic structures against piping.

(iii) *Elasticity :* A soil is said to be elastic when it suffers a reduction in volume (or change in the shape & bulk) while the load is applied, recovers its initial volume immediately when the load is removed.

(iv) *Resiliency :* It is regarded as extreme limit to which it can repeatedly be strained without fracture or permanent change of shape.

(v) *Compressibility :* Gravels, sands and silts are incompressible i.e., if a moist mass of these materials is subjected to compression, moisture and or air may be expelled, resulting in a reduction in volume which is not immediately recovered when the compression load is withdrawn. The decrease in volume per lunette increase of pressure is defined as the "compressibility" of the soil, and a measure of the rate at which consolidation proceeds is given by the "Coefficient of consolidations" of the soil.

(vi) *Density :* The density or true weight of a soil is equal to the specific gravity of the solid materials x 1000 (weight or density of water per cu. m.) A soil consists of solids, pores or voids and the moisture. The overall weight or the mass (including solid, particles and the effect of voids whether filled with air or water) per unit volume, i.e. total weight of soil- divided by total volume of soil, is termed Bulk Density. Bulk density varies with the type of the soil, moisture content and its compaction.

(vii) *Compression of soil :* The phenomenon of the gradual reduction in volume of soil due to expulsion of water from its voids is called compression.

(viii) *Shear strength :* The shear strength of soil may be defined as the property of the soil which enables it to maintain equilibrium on a sloping surface. It plays an important role while designing earth dams, canals, etc

(ix) *Voids ratio :* Voids ratio is the ratio between the volume of voids or pores in the soil and the volume of the solid particles.

(x) *Porosity :* Porosity is the ratio of the volume voids in a given soil mass to the total volume of the soil mass (solids plus voids).

4.5 Effects of Moisture on the Performance of Soils

4.5.1 The properties of a soil mixture

The properties of a soil mixture are influenced more by variations in moisture content than by any other cause. Saturated soils are improved in strength by drainage and dry soils lose strength by saturation. A water-logged ground is undesirable because of its low bearing capacity.

4.5.2 *The Moisture content of a soil* is defined as the ratio of the weight of waster pressure in the soil to the dry weight of the solid soil particles and is expressed as a percentage of the solid particles.

4.5.3 *Optimum Moisture Content :* (OMC) It is the moisture content at which a specified amount of compaction will produce the maximum dry density in a soil.

4.5.4 *General Properties of soil Materials :* The main properties affecting the mechanical stability of granular materials are internal friction and cohesion both of which depend on the moisture.

4.6 Soil Consistency

The property of the material which is evident by its resistance to flow is called consistency.

Consistency limits :

By changing the moisture content, the consistency of cohesive soils can be altered from a solid state to a semi-solid, plastic or liquid state. The water contents at which the soil passes from one state to another are known as consistency limits or Atterberg's limits.

Atterberg's limits are very useful for Civil Engineering purposes, He defined the consistency limits as under

(i) liquid limit : The minimum moisture content at which the soil remains in liquid state, possessing very little shear strength against flowing is called liquid limit.

Liquid limits can also be defined as the minimum water content at which a part of soil cut by a groove of standard dimensions, will close for a distance of about 12 mm at the bottom of the groove under an impact of 25 blows in standard liquid limit apparatus.

(ii) Plastic limit (P.L) is defined as the minimum water content at which the soil can be rolled into a thread approximately 3 mm in diameter without breaking.

(iii) **Shrinkage limit (S.L.)** is defined as the water content below which further reduction in water content by evaporation does not cause a reduction in volume of the soil mass.

(iv) **Plasticity index (P.I) :** The numerical difference between liquid limit and plastic limit is called the plasticity Index.

P .I = L.L.-P.L.

4.7 Black Cotton Soils

These are heavy clay soils, varying clay to loam, with clay contents of 40 to 50 per cent, formed by the decomposition of rocks by long continued weathering.

4.8 Load Bearing Capacity of Soils

The bearing capacity of a soil depends upon the physical characteristics of the soil particles, (i.e. size, shape, cohesive properties, frictional resistance and the power to retain moisture, etc.),

CHAPTER 5

EARTH WORK IN CONSTRUCTION PROJECTS

5.1 Initial Measurements for earth work

Before commencement of earth work, initial Cross-Sections are required to be taken in cuttings at an interval of 20 metres and for banks at intervals of 50 metres. However, they may have to be taken at close intervals in cases where the land has heavy undulations.

Calculation of Earth Work : On completion of the work profile of the executed work.

Deductions : While calculating the quantity of earth work for payment, deductions are made from the gross quantity, of Bridge structures, opening and other gaps. For embankments, the gross quantity is reduced by the shrinkage allowance which is usually specified as follows :

(a) Where embankment has been compacted by heavy mechanical machinery -5% of gross quantity.

(b) Where earth work is executed without heavy Mechanical machinery -10 % of gross quantity.

In cases, where an embankment is executed both by means of earth work from cutting as well as borrow pits, fresh Cross Sections are to be taken at the level where one category of earthwork is completed before commencement of the other category.

5.2 Standard Profile (Fig .5.2)

Standard profiles to be adopted for broad gauge line cuttings and embankments are shown below fig. 4.2

5.3 Construction Machinery

The following types of machinery is normally used for execution of earth work :

(i) *Hydraulic Excavator :*.

(2) *Bulldozers & Rollers :*

(3) *Drilling Equipments :* Drilling Rig equipments are required for blasting rocky strata in cuttings.

Suitability of Type of Rollers

Type of Soil	Suitable type of roller
(i) Coarse grained soils such as gravel, sand and gravel sand Mixtures with very little	Rubber tyred roller, vibratory plate or smooth wheel roller.

	Fines.	
(ii)	Gravel or sand with appreciable amount of silt or clay.	Vibratory roller, rubber tyred rollers Sheep-foot roller.
(iii)	Silt and clay of low plasticity.	Vibratory roller, rubber tyred roller.
(iv)	Silt and clay of high plasticity.	Sheep-foot roller and vibratory roller.

5.4 Classification of Earthwork in Railway Projects :

(a) *Soft Soil :* Comprising any of the following :

Vegetable or organic soil, turf, sand, cinder, gravel, loam, clay, mud, peat, black cotton soil or loose moorum etc or previously dug earth or a mixture of these, as can be excavated by space or shovel.

(b) Soil Medium Hard is as in (c) but softer, requiring close application of picks only.

(c) *Hard soil or Soft rock :* Comprising any of the following :

(i) Stiff heavy clay, hard shale, or compact moorum etc. requiring crowbar and/or pick and shovel closely applied.

(ii) Generally any material which requires close 70 application of picks and crow bars or scarifies to loosen and not affording resistance to digging greater than any of the hard soil mentioned above.

(d) *Rock :* Comprising any of the following :

(i) Lime stone, sandstone, laterite, hard conglomerate or other soft or disintegrated rock etc. which can be quarried or split with crowbars or wedges; but not requiring blasting.

(ii) Rocks of above variety, but hard, requiring light blasting.

(iii) Any rock for the excavation of which the use of mechanical plant for boring holes & blasting is required on an extensive scale.

5.4.1. Embankments/Cutting in 'Other than Good Soils

The following steps should be taken for execution of earthwork in other than good soils :

(a) *Embankments :* The earth should be compacted by mechanical means in the usual manner. Thereafter, a blanket of suitable material should be provided over the bed. The thickness of the blanket layer should usually not be less than 30 cms, which may go upto 100 cms. in very weak soils. The blanketing material should be compacted in layers in the usual manner giving a cross slope of I in 40 from the center towards the cess.

(b) *Cutting :* In addition to an efficient drainage system, a blanket of suitable material not less than 30 cms. thick should be compacted in 2 layers (at or near (OMC) over the road bed.

General points :

(i) For embankments and cuttings in soils other than good soils, it may be necessary to provide flatter side slopes with or without sub-banks/berms.

(ii) In the case of embankments in highly clayey soils, special treatment may be necessary to ensure a stable formation. Such measures will have to be determined after thorough investigation and study of the soil properties.

(iii) Special investigation will also be necessary in regard to high fill construction on swampy ground or marshy lands.

(iv) The blanket should cover the entire width of the formation from shoulder to shoulder, except that in case of sand or similar erodible material, it should be confined within berms of width 60 to 75 cms.

5.5 Provision of Sub-Ballast

A layer of sub-ballast or blanket shall be provided as the top layer of the embankment in all new construction and also in the existing lines whether in bank or in cutting. The main purpose of the sub ballast layer is to have top most layer of sufficient strength so that the ballast does not puncture into the bank due to high pressure caused by heavier axle loads which are being introduced to carry heavier freight traffic.

Specification of Material to be used in Sub-ballast layer :

The material to be used in sub-ballast layer or blanket shall have the following characteristics :

(i) It must be sufficiently impervious to divert most of the water falling over it to sides so as to prevent softening of subgrade soil.

(ii) It must be reasonably pervious to permit escape of capillary or seepage water to prevent accumulation of water below it and development of pore pressure.

(iii) It must possess sufficient strength to withstand the imposed loads.

(iv) It should get easily compacted to a degree so as to have minimum plastic deformation in it. In compacted state it should disperse load in a better way.

(v) Finished surface of the blanket should give a stable platform for placing track ballast with out any rutting or other surface irregularities which may accumulate water.

(vi) The blanket material should be coarse, granular and made from hard rock.

(vii) The material should have small quantity of fines. If the fines are plastic, the percentage of fine particulars (up to 75 microns) should be between 2% to 5%. In case the fines are non-plastic, these should be between 8% to 12%.