GROUND IMPROVEMENT TECHNIQUES

MODULE 1

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What is Ground Improvement??

- Ground Improvement or Ground treatment is defined as “controlled alteration of the state, nature or mass behavior of ground materials to achieve an intended satisfactory response to existing or projected environmental and engineering actions”

Formation & Development of Ground

- The materials that constitute earth's crust is broadly classified into two categories as rock and soil.
- Rock is a material strongly bonded of minerals where as soil is an assemblage of solid particles formed by disintegration of rocks.
- Soil spreads beneath rivers and seas and on land along with all organic and inorganic materials overlying the bedrock.

Formation & Development of Ground

- After formation of soil, changes in ground due to different natural causes and man’s activities other than that produced by structures.
- Man-made lands called reclaimed lands are formed in low lying areas and on water by land fillings

Need for Ground Improvement

When a project encounters difficult foundation conditions, the possible alternative solutions are:

- To avoid the particular site
- To design the planned structure accordingly.
- Use a soft foundation supported by piles, design a very stiff structure which is not damaged by settlement.
- Remove and replace unsuitable soils
- Attempt to modify the existing ground

Leaning tower of Pisa

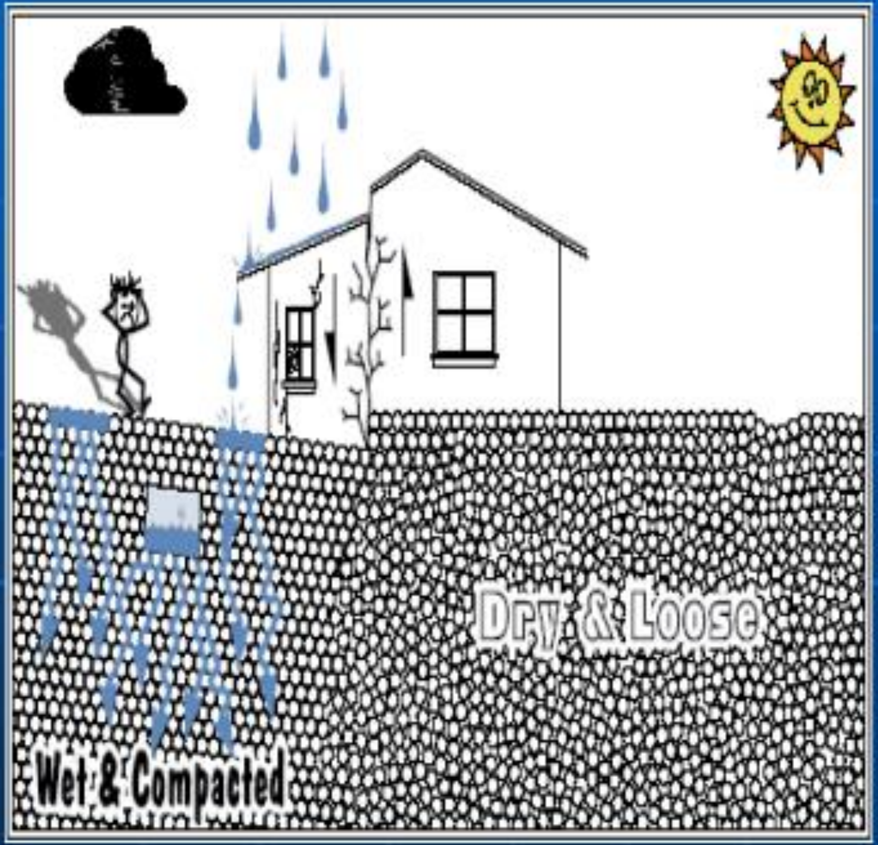
Kandla Port Building after 2001 earthquake

Effect of Swelling

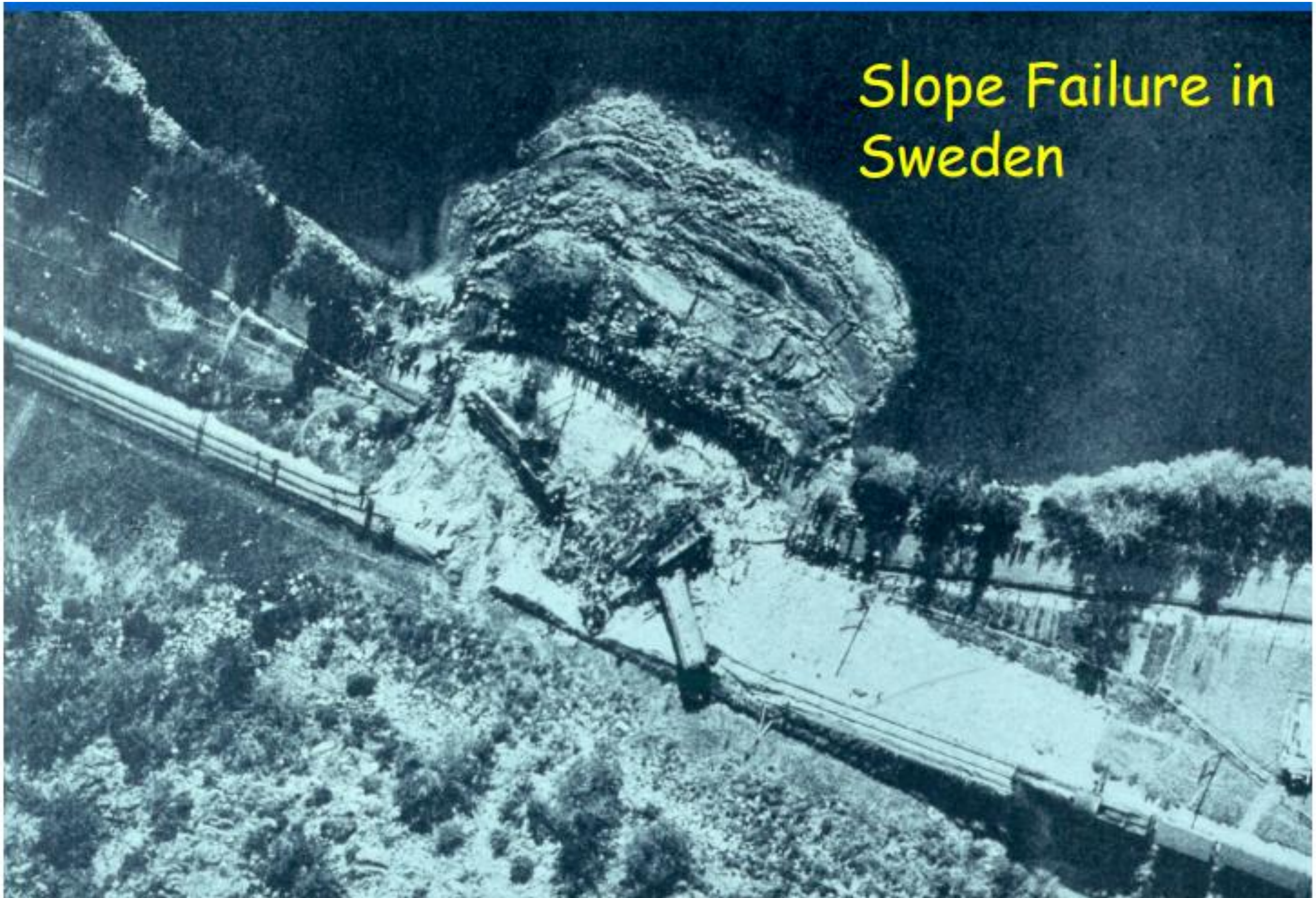
Effect of shrinkage

Swelling and shrinking soils exist in many areas in India, Large tracts of Maharashtra, Andhra, Deccan plateau, Chennai

Collapsible soils



Collapse occurs due to saturation, loss of cementation bonds, specific clay structure and areas in some areas in Rajasthan and in some counties abroad this is prevalent.


Slope Failure in
Sweden

Effects of liquefaction

Classification of Ground Improvement Techniques

There are four types of ground improvement techniques:

a) Mechanical modification
b) Hydraulic modification (Sand drains)
c) Physical & Chemical modification (Grouting)
d) Those using inclusion & confinement techniques (Reinforcement)

Mechanical modification

- Soil density is increased by the application of mechanical force, including compaction of surface layers by static vibrator such as compact roller and plate vibrators

Hydraulic modification

- Free pour water is forced out of the soil via drains or wells.
- In course grained soil this is achieved by lowering the ground water level through pumping from boreholes or trenches.
- In fine grained soils this is achieved by the long term application of external loads (preloading) or electrical forces.

Physical & chemical modification

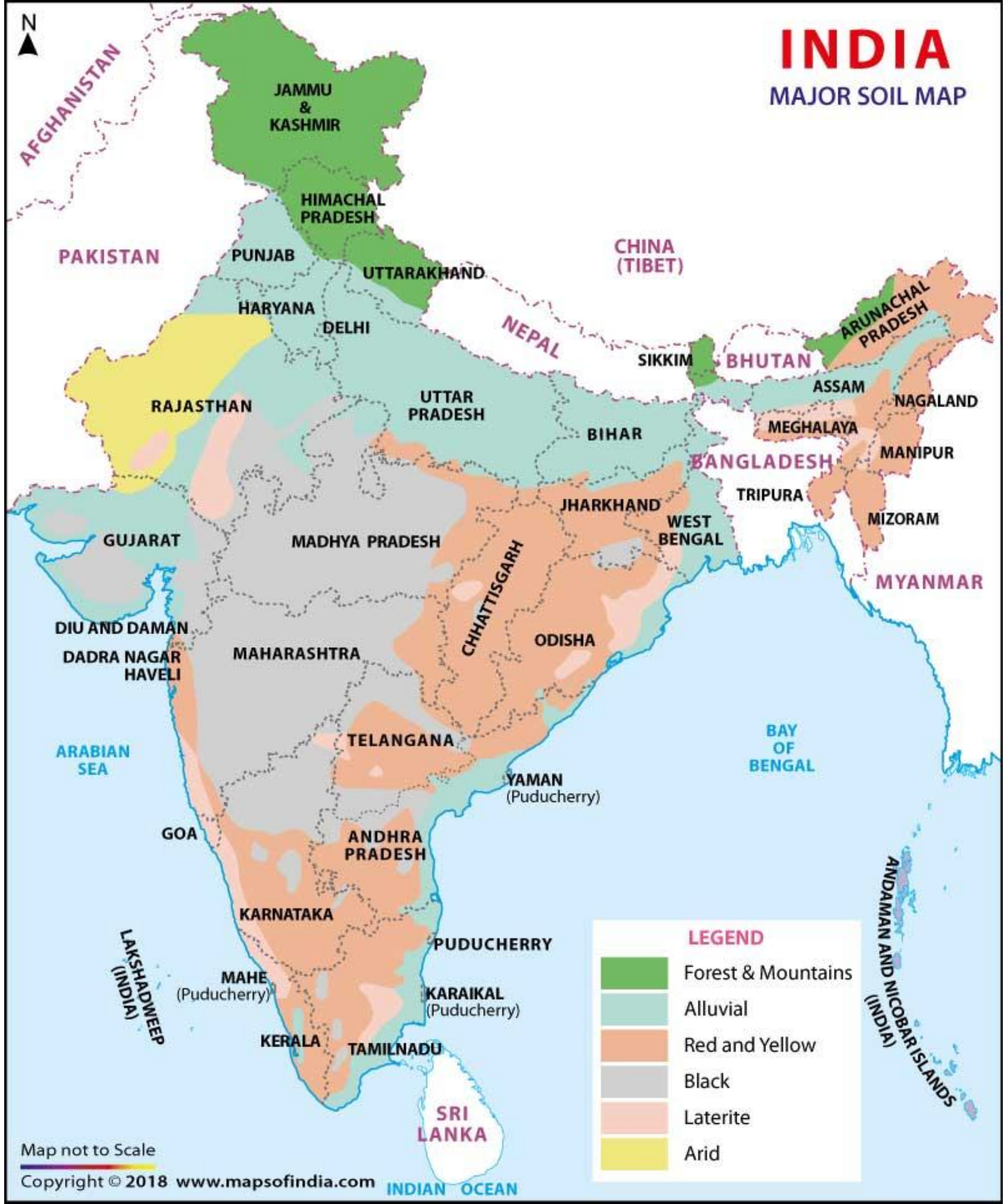
- Stabilization is done by physically mixing some adhesives with surface layers or columns of soil
- The adhesive materials may include natural soils, industrial by products or even waste.
- The process of injecting adhesives via boreholes under pressure into voids within the ground or between the ground and a structure is called grouting.
- Soil stabilization by heating & freezing the ground is considered thermal methods of modification

Modifications by inclusion & confinement techniques

- Reinforcement by fibres, strips, bars meshes and fabrics imparts tensile strength to a constructed soil mass.
- In-situ reinforcement is achieved by nails and anchors.
- Stable earth retaining structure can also be formed by confining soil with concrete, steel or fabric elements

Soil distribution in India

- Alluvial soils
- Black (or Regur soil)
- Red and Yellow soils
- Laterite soils
- Arid and desert soils
- Saline and alkaline soils
- Peaty and marshy soils
- Forest and mountain soils



Characteristics of Indian Soils

- Most soils are old and mature. Soils of the peninsular plateau are much older than the soils of the great northern plain.
- Indian soils are largely deficient in nitrogen, mineral salts, humus and other organic materials.
- Plains and valleys have thick layers of soils while hilly and plateau areas depict thin soil cover.
- Some soils like alluvial and black soils are fertile while some other soils such as laterite, desert and alkaline soils lack in fertility and do not yield good harvest.
- Indian soils have been used for cultivation for hundreds of years and have lost much of their fertility.

Problems Of Indian Soils

- Soil erosion (Himalayan region, Chambal Ravines etc.), deficiency in fertility (Red, lateritic and other soils), desertification (around Thar desert, rain-shadow regions like parts of Karnataka, Telangana etc.), waterlogging (Punjab-Haryana plain) salinity and alkalinity (excessively irrigated regions of Punjab, Haryana, Karnataka etc.), wasteland, over exploitation of soils due to increase in population and rise in living standards and encroachment of agricultural land due to urban and transport development.

Alluvial Soils

- Alluvial soils are formed mainly due to silt deposited by Indo-Gangetic-Brahmaputra rivers. In coastal regions some alluvial deposits are formed due to wave action.
- Rocks of the Himalayas form the parent material. Thus the parent material of these soils is of transported origin.
- They are the largest soil group covering about 15 lakh sq km or about 46 per cent of the total area.
- They support more than 40% of the India's population by providing the most productive agricultural lands

Alluvial Soils- Characteristics of Alluvial Soils

- They are immature and have weak profiles due to their recent origin.
- Most of the soil is Sandy and clayey soils are not uncommon.
- Pebbly and gravelly soils are rare. Kankar (calcareous concretions) beds are present in some regions along the river terraces.
- The soil is porous because of its loamy (equal proportion of sand and clay) nature.
- Porosity and texture provide good drainage and other conditions favorable for agriculture.
- These soils are constantly replenished by the recurrent floods.

Distribution of Alluvial Soils in India

- They occur all along the Indo-Gangetic-Brahmaputra plains except in few places where the top layer is covered by desert sand.
- They also occur in deltas of the Mahanadi, the Godavari, the Krishna and the Cauvery, where they are called deltaic alluvium (coastal alluvium)
- Some alluvial soils are found in the Narmada, Tapi valleys and Northern parts of Gujarat.

Black Soils

- The parent material for most of the black soil are the volcanic rocks that were formed in the Deccan Plateau (Deccan and the Rajmahal trap).
- In Tamil Nadu, gneisses and schists form the parent material. The former are sufficiently deep while the later are generally shallow.
- These are the region of high temperature and low rainfall. It is, therefore, a soil group typical to the dry and hot regions of the Peninsula.

Characteristics of Black Soils

- A typical black soil is highly argillaceous [Geology (of rocks or sediment) consisting of or containing clay] with a large clay factor, 62 per cent or more.
- In general, black soils of uplands are of low fertility while those in the valleys are very fertile.
- The black soil is highly retentive of moisture. It swells greatly on accumulating moisture. Strenuous effort is required to work on such soil in rainy season as it gets very sticky.
- In summer, the moisture evaporates, the soil shrinks and is seamed with broad and deep cracks. The lower layers can still retain moisture. The cracks permits oxygenation of the soil to sufficient depths and the soil has extraordinary fertility.

Distribution of Black Soils

- Spread over 46 lakh sq km (16.6 per cent of the total area) across Maharashtra, Madhya Pradesh, parts of Karnataka, Telangana, Andhra Pradesh, Gujarat and Tamil Nadu.

Red Soils

- Red soils along with its minor groups form the largest soil group of India.
- The main parent rocks are crystalline and metamorphic rocks like acid granites, gneisses and quartzites.

Characteristics of Red Soils

The texture of these soils can vary from sand to clay, the majority being loams.

On the uplands, the red soils are poor, gravelly, and porous. But in the lower areas they are rich, deep dark and fertile.

Distribution of Red Soils

- These soils mostly occur in the regions of low rainfall.
- They occupy about 3.5 lakh sq km (10.6 per cent) of the total area of the country.
- These soils are spread on almost the whole of Tamil Nadu.
- Other regions with red soil include parts of Karnataka, south-east of Maharashtra, Telangana, Andhra Pradesh, Madhya Pradesh, Chhattisgarh, Odisha, Chota Nagpur plateau; parts of south Bihar, West Bengal, Uttar Pradesh; Aravalis and the eastern half of Rajasthan (Mewar or Marwar Plateau), parts of North-Eastern states.

Laterite – Lateritic Soils

- Laterite soils are mostly the end products of weathering.
- They are formed under conditions of high temperature and heavy rainfall with alternate wet and dry periods.
- Heavy rainfall promotes leaching (nutrients gets washed away by water) of soil whereby lime and silica are leached away and a soil rich in oxides of iron and aluminium compounds is left behind.
- ‘Laterite’ means brick in Latin. They harden greatly on loosing moisture.
- Laterite soils are red in colour due to little clay and more gravel of red sand-stones.

Distribution of Laterite – Lateritic Soils

- Laterite soils cover an area of 2.48 lakh sq km.
- Continuous stretch of laterite soil is found on the summits of Western Ghats at 1000 to 1500 m above mean sea level, Eastern Ghats, the Rajmahal Hills, Vindhyan, Satpuras and Malwa Plateau.
- They also occur at lower levels and in valleys in several other parts of the country.
- They are well developed in south Maharashtra, parts of Karnataka etc. and are widely scattered in other regions.

Forest – Mountain Soils

- These soils occupy about 2.85 lakh sq km or 8.67% of the total land area of India.
- They are mainly heterogeneous soils found on the hill slopes covered by forests.
- The formation of these soils is mainly governed by the characteristic deposition of organic matter derived from forests and their character changes with parent rocks, ground-configuration and climate.
- Consequently, they differ greatly even if they occur in close proximity to one another.

Mountain Soil

Distribution of Forest – Mountain Soils

- In the Himalayan region, such soils are mainly found in valleys, less steep and north facing slopes. The south facing slopes are very steep and exposed to denudation and hence do not support soil formation.
- Forest soils occur in Western and Eastern Ghats also.

Arid – Desert Soils

- The desert soils consist of Aeolian sand (90 to 95 per cent) and clay (5 to 10 per cent).
- They cover a total area of 1.42 lakh sq km (4.32%).
- The presence of sand inhibits soil growth. Desertification of neighbouring soils is common due to intrusion of desert sand under the influence of wind [Aeolian sand].

Distribution of Arid – Desert Soils

- Occur in arid and semi-arid regions of Rajasthan, Punjab and Haryana. The sand here is blown from the Indus basin and the coast by the prevailing south-west monsoon winds.
- Sandy soils without clay factor are also common in coastal regions of Odisha, Tamil Nadu and Kerala.

Saline – Alkaline Soils

- In Saline and Alkaline Soils, the top soil is impregnated (soak or saturate with a substance) with saline and alkaline efflorescences (become covered with salt particles).
- Undecomposed rock fragments, on weathering, give rise to sodium, magnesium and calcium salts and sulphurous acid.
- Some of the salts are transported in solution by the rivers.

Saline – Alkaline Soils

- In regions with low water table, the salts percolate into sub soil and in regions with good drainage, the salts are wasted away by flowing water.
- But in places where the drainage system is poor, the water with high salt concentration becomes stagnant and deposits all the salts in the top soil once the water evaporates.
- In regions with high sub-soil water table, injurious salts are transferred from below by the capillary action as a result of evaporation in dry season.

Distribution of Saline – Alkaline Soils

- Saline and Alkaline Soils occupy 68,000 sq km of area.
- These soils are found in canal irrigated areas and in areas of high sub-soil water table.
- Parts of Andhra Pradesh, Telangana, Karnataka, Bihar, Uttar Pradesh, Haryana, Punjab (side effects of improper or excess irrigation), Rajasthan and Maharashtra have this kind of soils.
- The accumulation of these salts makes the soil infertile and renders it unfit for agriculture.
- In Gujarat, the areas around the Gulf of Khambhat are affected by the sea tides carrying salt-laden deposits. Vast areas comprising the estuaries of the Narmada, the Tapi, the Mahi and the Sabarmati have thus become infertile.
- Along the coastline, saline sea waters infiltrate into coastal regions during storm surges (when cyclones make landfall) and makes the soil unfit for cultivation. The low lying regions of coastal Andhra Pradesh and Tamil Nadu face this kind of soil degradation.

Peaty – Marshy Soils

- These are soils with large amount of organic matter and considerable amount of soluble salts.
- The most humid regions have this type of soil.
- They are black, heavy and highly acidic.

Distribution of Peaty – Marshy Soils

- Kottayam and Alappuzha districts of Kerala where it is called kari.
- Also occur in the coastal areas of Odisha and Tamil Nadu, Sunderbans of West Bengal, in Bihar and Almora district of Uttarakhand.

Reclaimed soils

- The term reclaimed soil comprises of all materials deposited on a site using various methods for different purpose.

SOLIMP - Minecreek. Before and after

Need for reclamation

- Industrial & commercial development of urban areas
- Development of navigation channels for ports & other water front structures.
- Disposal of garbage, industrial wastes etc

Problems in reclamation

- Reclamation near large bodies of water lead to unsavoury odours, greater turbidity & toxicity of shore waters and affect in great extent the ecology of marine life.

Generally reclamation followed by ground treatment is preferable and economical than designing deep foundations

Types of reclamation materials

- The materials which are used in practice for reclamation purposes fall into the following groups:

1. Hydraulic fills of dredged soil
2. Sanitary fill
3. Paper sludge
4. Flyash including slag and
5. Rubbish & debris

Hydraulic fills of dredged soil

- Generally used for large reclamations.
- The soil needed for this is usually obtained by developing it from the adjacent river, lake or ocean to place it at the desired location.
- A well graded soil is preferred for the process.
- Sand deposited by hydraulic methods will be relatively in loose condition and hence is to be densified.
- Silt and clay are difficult to compact after

placement and hence is left to consolidate

and stabilize naturally.

Hydraulic fills of dredged soil

- Problems

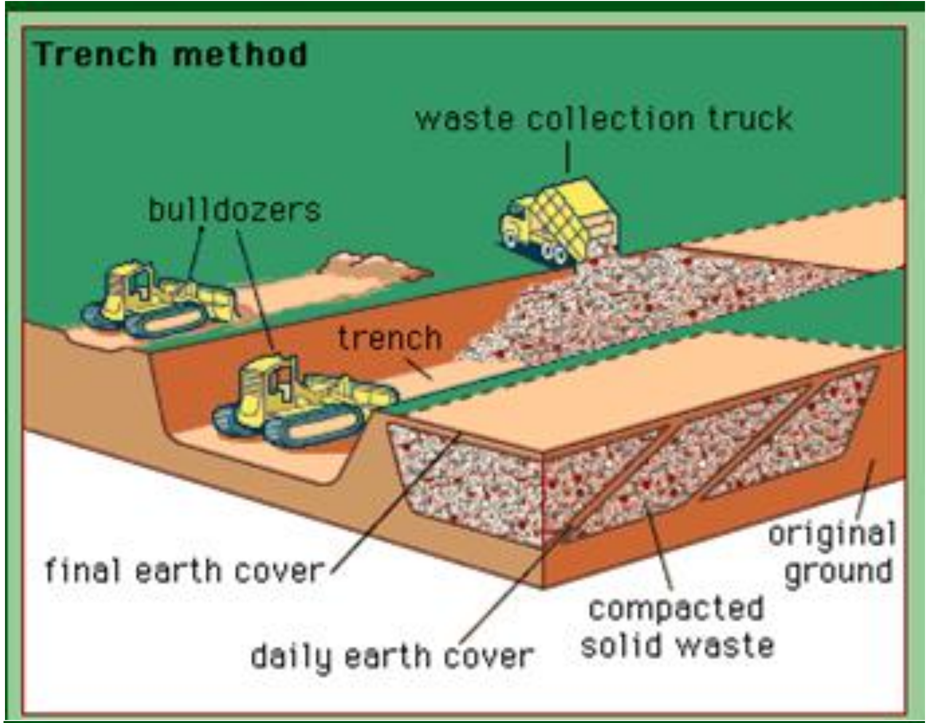
✓Low density, segregation & turbidity of the area.

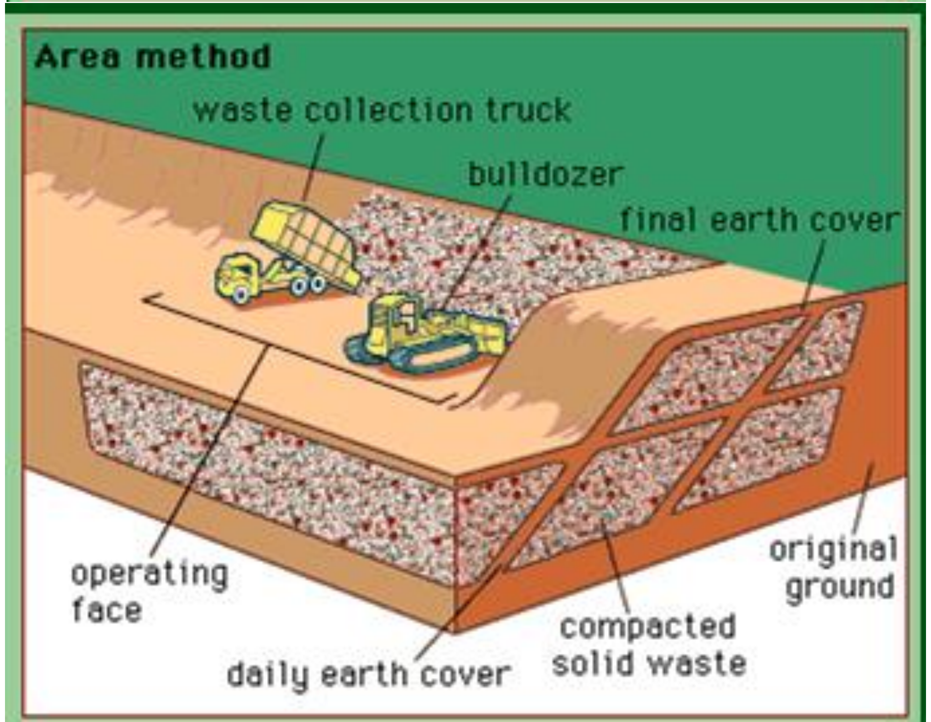
✓The extent of segregation in the fill and the amount of turbidity of the adjoining water depends on the type of dredger used

Quick dumping of well-graded material has been shown to produce good results in depths up to 15m

Sanitary fills

- Sites where waste is isolated from the environment until it is safe.
- It is considered safe when it has completely degraded biologically, chemically, and physically.
- Sanitary landfills use technology to contain the waste and prevent the leaching out of potentially hazardous substances.
- There are two main methods used in sanitary landfills, the trench method and the area method.





Problems in Sanitary fills

- It is considered a problem for chemical stability.
- In such fills, high moisture content due to rainfall, snow melt or otherwise reacts with the waste materials themselves to form a polluted liquid called leachate which often has dreadful characteristics.
- Leachate from such fills may give rise to pollution of drinking waters and bad odours
- Production of methane and other gases cause explosion and fire hazards
- Such fills experience large settlement due to move of materials to large voids, and also due to chemical and biological changes, consolidation

Paper sludge

- Paper mill sludge is also used as a material for landfilling.
- This sludge consists of kaolinite and organic cellulose fibres with ash content ranging from 32 to 59%.
- The density of the fill is low and the shear strength increases with degree of consolidation and attains good bearing capacity with time

Fly ash and Slag

- Flyash is a more stable material with a low percentage of solubility.
- Steel furnace slag also is used as reclamation material
- Incineration residues are also used as fill materials
- All these materials are low in weight and are highly alkaline

Flyash

Steel furnace slag

Rubbish & debris

- These fill materials represent a most heterogenous material ranging from stone, concrete pieces to paper, glass and grass.
- These are used as bottom portion of a fill and rolled.
- Top portion may be a structural or hydraulic fill.
- Such fill are highly compressible and a load test has to be conducted to evaluate its properties

GROUND IMPROVEMENT POTENTIAL

- The soil and rock conditions can be placed under 3 categories.

1. Hazardous
2. Poor
3. Favourable

- So as to identify the ground condition which will enable the engineer to decide a proper treatment approach and or design approach

1. HAZARDOUS GROUND CONDITIONS

It is a regional or local field condition such that regular design approach or an economical treatment is not feasible and construction in such location may result in ultimate disaster.

Such locations should be avoided

2. POOR

It is a regional or local field conditions which may require special design and/or special treatment

3. FAVOURABLE

It is a regional or local field conditions for which normal design and ground treatments are suitable

1. HAZARDOUS GROUND CONDITIONS

- Site located close to faults, particularly in seismically active region, may serve ground shock
- Loose to medium dense sand may easily susceptible to quick sand condition leading to liquefaction. when such sites are located in seismic region, due to liquefaction loss of ground support and lateral movement could occur
- Active mines or cavernous limestone
- Natural slopes in glacial lacustrine clays, clay shales, colluvium thick deposits of residual soils, stratified rock and deep cuts are susceptible to slope failure
- Flood plains and other relatively low ground may be quite often exposed to seasonal floods

Thus the above ground conditions may be categorized as hazardous and such locations should be avoided

2. POOR GROUND CONDITIONS

- Example: Loess, porous lightly cement clays, low density alluvium of arid climate valleys.
- Such soils should be fully saturated before construction. That is , precollapsible the soil below construction. thus the soil gets consolidated and then collapse.after settlement apply git toconvert to usable soil
- Expansive clays: including black cotton soil undergo large volume change with changes in moisture content.

Active zone: the depth upto which soil expands and shrinks . The depth of active zone should be determined . If it is very shallow we can use it for construction by using admixtures or other methods.

- Very soft to firm clays: deep foundations should be used to bypass the soft zone of soil

CONTD...

- Organic soil:

depth should be determined.

If it is shallow depth, remove the soil or apply GIT

Deep foundations also can be used. But make sure there is no presence of skinfriction

Ground water should check for all the types.

3. FAVOURABLE

- Cohesive granular soils such as sandy- clay mixture, are relatively strong and form good supporting medium for moderately to heavily loaded foundations.
- Cohesive granular soils such as medium dense to dense sands and sand gravel mixture provides excellent foundation condition for most loading conditions.
- Shallow rock without any discontinuities provides good foundation

ALTERNATIVE APPROACHES

- IF Unsuitable site conditions are encountered at the desired site od a proposed structure, one of the following four procedure may be adopted to ensure satisfactory performance of the structure.

1. Bypass the unsuitable soil by means of deep foundations extending to a suitable bearing material
2. Redesign the structure and its foundations for support by the poor soil
3. Remove that poor material and either treat it to improve and replace it or substitute it by a suitable material
4. Treat the soil in place or improve its properties.

factors considered in the selection of a best Ground improvement technique

- Soil type- soil, clay organic etc
- Area and depth of treatment required
- Type of structure and load distribution
- Soil properties- strength, compressibility, permeability etc
- Permissible total and differential settlements
- Material availability- stone sand water, admixture, stabilizers, etc
- Availability of skills and equipments
- Environmental considerations- waste disposal, erosion water pollution etc
- Local experience and preference
- economics

PREVIOUS YEAR QUESTIONS

1. What do you mean by liquefaction
2. Explain briefly about the major soil distributions in India?
3. What are the factors considered in the selection of a best Ground improvement technique?
4. What is reclaimed soil? Explain diff types of reclaimed materials?
5. What are the diff ground conditions which will enable an engineer to decide the proper treatment approach?
6. Give a brief explanation on the classification of ground modification techniques?
7. What are the diff soil conditions which are used to decide the proper treatment of soil?
8. Give notes on different type of ground improvement potential
9. Write short note on ground improvement potential