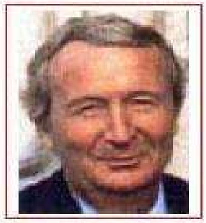
UNIT-5

EARTH REINFORCEMENT

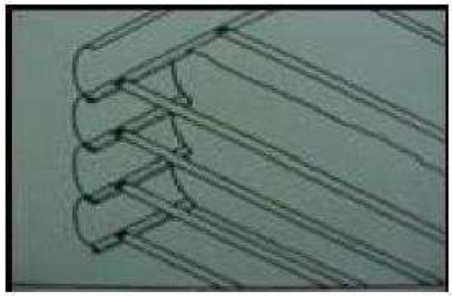
Concept of reinforcement - Types of reinforcement material - Applications of reinforced earth – use of Geotextiles for filtration, drainage and separation in road and other works Soil nails are more or less rigid bars driven into soil or pushed into boreholes which are filled with grout.Together with the insitu soil, they are intended to form a coherent.

Reinforced earth has been in use by man since ancient times with the fundamentals of the techniques being mentioned in the Bible The earliest remaining examples of soil reinforcement are the Agar-Quf Ziggurat and the Great wall of China The Romans, Gauls, Dutch and British have been documented using reinforced

Henri Vidal (re)invents Reinforced Earth in 1963



Henri Vidal
French Engineer & Architect



An early form of Reinforced Earth using steel strip reinforcement and steel membrane facing

The concept of reinforced soil was accidentally thought about by Mr. Vidal while playing with his children on a beach

1963 : Patent filed for Reinforced Earth

REINFORCED SOIL

- Soil + reinforcement = reinforced soil
- Reinforcement:

  Ancient: Tree branches, grass reeds, straw, roots of vegetation, bamboo, tree trunks

  Modern: Steel, polymeric, natural materials
- Soil is strong in compression & reinforcement is strong in tension
- Combined product has much better engineering properties than the individual constituents
- Reinforced soil concept is similar to that of reinforced concrete

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Applications of reinforced earth for ground improvement. Theory of Reinforcement

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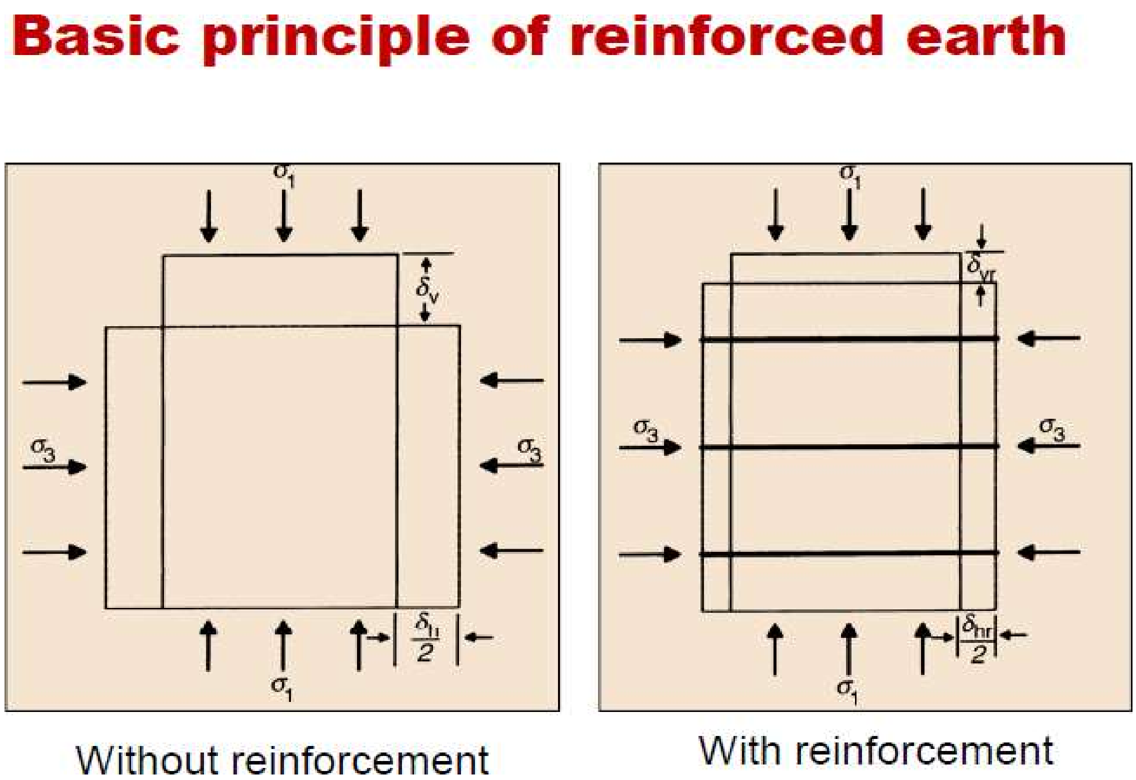
Principle of Reinforced Earth

It is analogous to reinforced concrete but direct comparison is not completely valid The mode of action of reinforcement in soil is to carry tensile loads or anisotropic reduction of normal strain rate Introduction of reinforcement into soil results in interaction between the two the interaction between the soil and reinforcement can be in the form of either adhesion or friction Failure can occur only if the adhesion or frictional force is overcome or the reinforcement itself ruptures

The reinforcement disrupts the uniform pattern of strain that would have developed if it did not exist



REINFORCED EMBANKMENTS ON SOFT FOUNDATIONS

The design and construction of embankments on soft foundation soils is a very challenging geotechnical problem. As noted by Leroueil and Rowe (2001), successful projects require a thorough subsurface investigation, properties determination, and settlement and stability analyses. If the settlements are too large or instability is likely, then some type of foundation soil improvement is warranted. Traditional soil improvement methods include preloading/surcharging with drains; lightweight fill; excavation and replacement; deep soil mixing, embankment piles, etc., as discussed by Holtz (1989) and Holtz et al. (2001a). Today, geosynthetic reinforcement must also be considered as a feasible treatment alternative. In some situations, the most economical final design may be some combination of a traditional foundation treatment alternative together with geosynthetic reinforcement. Figure 2a shows the basic concept for using geosynthetic reinforcement. Note that the reinforcement will not reduce the magnitude of long-term consolidation or secondary settlement of the embankment.

REINFORCED STEEP SLOPES

The first use of geosynthetics for the stabilization of steep slopes was for the reinstatement of failed slopes. Cost savings resulted because the slide debris could be reused in the repaired slope (together with geosynthetic reinforcement), rather than importing select materials to reconstruct the slope. Even if foundation conditions are satisfactory, costs of fill and right-of-way plus other considerations may require a steeper slope than is stable in compacted embankment soils without reinforcement. As shown in Fig.3, multiple layers of geogrids or geotextiles may be placed in a fill slope during construction or reconstruction to reinforce the soil and provide increased slope stability. Most steep slope reinforcement projects are for the construction of new embankments, alternatives to retaining walls, widening of existing embankments, and repair of failed slopes.
Another use of geosynthetics in slopes is for compaction aids (Fig. 3). In this application, narrow geosynthetic strips, 1 to 2 m wide, are placed at the edge of the fill slope to provide increased lateral confinement at the slope face, and therefore increased compacted density over that normally achieved. Even modest amounts of reinforcement in compacted slopes have been found to prevent sloughing and reduce slope erosion. In some cases, thick nonwoven geotextiles with in-plane drainage capabilities allow for rapid pore pressure dissipation in compacted cohesive fill soils.

GROUND ANCHORS

An **earth anchor** is a device designed to support structures, most commonly used in geotechnical and construction applications. Also known as a **ground anchor**, **percussion driven earth anchor** or **mechanical anchor**, it may be impact driven into the ground or run in spirally, depending on its design and intended force-resistance characteristics.

Earth anchors are used in both temporary or permanent applications, including supporting retaining walls, guyed masts, and circus tents.

Typical applications

Earth anchors are typically used in civil engineering and construction projects, and have a variety of applications, including:

- Retaining walls, as part of erosion control systems.[1]
- Structural support of temporary buildings and structures,[2] such as circus tents and outdoor stages.
- Tethering marine structures, such as floating docks and pipelines.
- Supporting guyed masts, such as radio transmission towers.
- Anchoring utility poles and similar structures.
- Drainage systems, for loadlocking and restraining capability to happen simultaneously
- Landscape, anchoring trees, often semi-mature transplants. .
- General security, as in anchoring small aircraft.
- Sporting activities, such as slacklining or abseiling.

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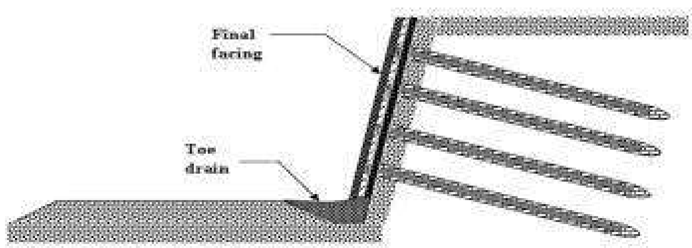
A rock bolt is a long anchor bolt, for stabilizing rock excavations, which may be used in tunnels or rock cuts. It transfers load from the unstable exterior, to the confined (and much stronger) interior of the rock mass. Rock bolts were first used in mining starting in the 1890s, with systematic use documented at the St Joseph Lead Mine in the US in the 1920s. Rock bolts were applied to civil tunneling support in the US and in Australia, starting in the late 40s. Rock bolts were used and further developed, starting in 1947, by Australian engineers who began experimenting with four metre long expanding anchor rock bolts while working on the Snowy Mountains Scheme.

As shown in the figure, rock bolts are almost always installed in a pattern, the design of which depends on the rock quality designation and the type of excavation.[2] Rock bolts are an essential component of the New Austrian Tunneling method. As with anchor bolts, there are many types of proprietary rock bolt designs, with either a mechanical or epoxy means of establishing the set. There are also fiberglass bolts which can be cut through again by subsequent excavation. Many papers have been written on methods of rock bolt desi. Rock bolts work by 'knitting' the rock mass together sufficiently before it can move enough to loosen and fail by unravelling (piece by piece). As in the photo, rock bolts may be used to support wire mesh, but this is usually a small part of their function. Unlike common anchor bolts, rock bolts can become 'seized' throughout their length by small shears in the rock mass, so they are not fully dependent on their pull-out strength. This has become an item of controversy in the Big Dig project, which used the much lighter pull-out tests for rock bolts, rather than the proper tests for concrete anchor bolts. Rock bolts can also be used to prevent rockfall.

Soil Nailing

Soil nailing is a process of retaining soil by the incorporation of a large number of reinforcements, in the form of „nails", in the soil which are free at the farther end, the other end being anchored to a thin grouted concrete wall (Fig.25.15,also see Fig.25.16). It is a variant of the reinforced earth construction with the main difference that, whereas in reinforced earth the reinforcing strips are laid and the backfill soil compacted above in layers (Sec.25.5), in soil nailing, short lengths of stiff iron rods are driven into the soil, securing them at the facing wall. In either case the mechanics of retention is based on the friction developing at the interface between the reinforcement and the soil. In order to protect the nail, and to enhance interface friction, the nail surfaces can be pressure-grouted with cement grout. Since no bulb is formed at the end, it is not a system based on point anchorage as in ground anchors, but on continuous friction anchorage as in reinforced earth. For this a large number of nails are driven at closer spacing as in reinforced earth rather than a few anchor rods at wider spacing as in ground anchors. Soil nailing can be temporary or permanent. Figs. 25.17 and 25.18 show two examples of permanent nailing. The former illustrates a scheme for retaining the soil face vertically adjacent to a multilevel car parking structure, and the latter, for cutting a steep and deep slope keeping the buildings above stable and intact. Soil nailing is an effective alternative where existing structures are so close that ground anchors cannot be laid under them due to objection from the property owners. Further, nailing can be carried out with simpler and lighter equipments which can be manoeuvred without much difficulty within limited spaces where space restrictions exist. Also, its flexibility enables its adoption to varying ground conditions. Soil nailing was originally introduced in France in the 1970s. It can be described as an in-situ reinforcing of soil using an array of nails installed as passive inclusions in a grid. The construction begins with the excavation of a shallow cut (Fig.25.19) on the face of which wire mesh is laid followed by applying shotcrete to the face. When the latter is set, soil nails are drilled through the shotcrete and grouted, followed by 9 anchoring them to the wall. The sequence is repeated until the final depth is reached. The nail being rigid, unlike the reinforcing strip in reinforced earth, can resist some bending and shear in addition to axial tension. An innovative step is the use of screw nails which are installed by rotation (like screw piles), giving rise to enhanced friction at the soil-nail interface. (This is akin to increased bond in the case of deformed reinforcement bars.)



VARIOUS TYPES OF SOIL NAILING:-

Various types of soil nailing methods that are employed in the field are listed below:

- **Grouted Nail:** After excavation, first holes are drilled in the wall/slope face and then the nails are placed in the predrilled holes. Finally, the drill hole is then filled with cement grout.
- **Driven Nail:** In this type, nails are mechanically driven to the wall during excavation. Installation of this type of soil nailing is very fast; however, it does not provide a good corrosion protection. This is generally used as temporary nailing.
- **Self-Drilling Soil Nail:** Hollow bars are driven and grout is injected through the hollow bar simultaneously during the drilling. This method is faster than the grouted nailing and it exhibits more corrosion protection than driven nail.
- **Jet-Grouted Soil Nail:** Jet grouting is used to erode the ground and for creating the hole to install the steel bars. The grout provides corrosion protection for the nail.

Advantages of Soil nailing cannot replace all other methods of soil retention technically or economically. Notwithstanding the same, it has the following advantages.

1) It is not dependent on heavy equipment,

2) It is economical where the geometry of the wall is complex and where space space restrictions exist,

3) Since nails are of low strength steel, the need for corrosion protection stands reduced,

4) Construction can be carried out with little disturbance to the environment in terms of noise and vibration.

In respect of facing, it must, however, be stated that mere shotcreting is not aesthetically pleasing; the same must either be supplemented or give way to more appealing facing methods. We shall close this section with an example of temporary soil nailing than can be used in construction sites to secure the faces of cuts.

Disadvantages of Soil nailing

- Soil nail walls may not be appropriate for applications where very strict deformation control is required for structures and utilities located behind the proposed wall, as the system requires some soil deformation to mobilize resistance. Deflections can be reduced by post tensioning but at an increased cost.
- Existing utilities may place restrictions on the location, inclination, and length of soil nails.
- Soil nail walls are not well suited where large amounts of groundwater seep into the excavation because of the requirement to maintain a temporary unsupported excavation face.
- Permanent soil nail walls require permanent, underground easements.
- Less suitable for coarse grained soil and soft clayey soil, which have short self-support time, and soils prone to creeping.
- Suitable only for excavation above groundwater.

Rock Bolting:

Intended to mobilize the inherent strength of a jointed and fragmented mass of rock by active or passive confinement.

Principles of rock mass modification by bolting

- Rock is like soil a natural material occurring in on infinite variety of forms. Its engineering properties show enormous unexpected variability
- While designing major tunnels, underground openings excavations, foundation abutments and slopes in rock the civil engineers are teamed up with a geologist for best possible understanding of the structure and quality of rock formation.
- The mechanical behavior of a rock mass differ because of joints, fractures and other discontinues.
- Insitu modification of rock is mainly aimed at changing rock mass properties rather there rock substance.
- Rock bolting is involved in tunneling and is the construction of large underground openings.

Rock bolts have two basic functions

- To pin or nail well-defined blocks or slabs of rock on to a more stable formation.
- To form a new structural entity cut of jointed rock by applying compressive stresses.

In both cases attempt is made to preserve or mobilize the inherent shear strength of rock along existing joints and potential fractures by a direct increase of the normal stresses in the failure planes or by controlling deformations so that no loosening of rock mass occurs.

TYPES OF ROCK BOLTS

Slot and wedge Anchor:

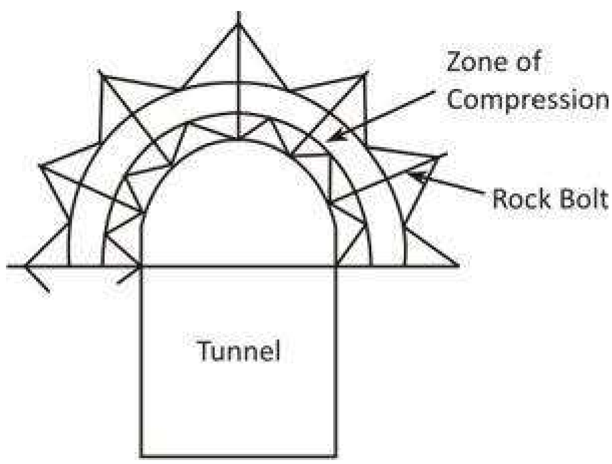
- The end of its shank is slotted with a wedge partially inserted. As the bolt is pushed against the back of the borehole the wedge is driven home and end of the shank expands and anchors the bolt in rock.
- The bolt is tensioned by tightening a nut against a plate placed on the rock face
- Anchor performs well in hard rock but is unreliable in poor quality rock.

Granted bolts

- Granted bolts are preferred for permanent reinforcement because they provide a better bond between the bolt and the rock.
- Granted bolts are less prone to corrosion if the face plate fails, the bolt force is still transferred to the rock by mems of grout bond
- Grout may be a non shrinking cement mix or a resin.

Rock bolt action around an excavation

- Rock bolts create compressive stresses per perpendicular to the free surface of the excavation.
- This creates a zone of strengthened rock which may resemble a structural element such as an arch or a beam which stands up without additional steel or timber support.



Formation of a strengthened
zone through rock bolt

- Rock bolts must be applied as soon as possible after excavation the rock must be restrained promptly because any loosening of the rock add more weight onto the support system.

Design Rules

- The ratio of bolt length to bolt spacing should be not less than 2, this is to ensure that overlap of zones of pressure between adjacent bolts is sufficient to create a zone of approximately uniform compression with a thickness equal to about 1/3 of the bolt length.

- The length of the bolt should not be less than 3 times the width of the joint blocks this is to ensure that the anchorage takes place in blocks not less than two layers behind the surface, although four blocks would be preferable.
- Aim at a bolt spacing and tension sufficient to create a compression of 70 kpa.
- In large excavations the rock bolts should be longer than in small excavations in the same condition.
- 25mm dia hollow core steel bolts were used, grouted with neat cemenst.