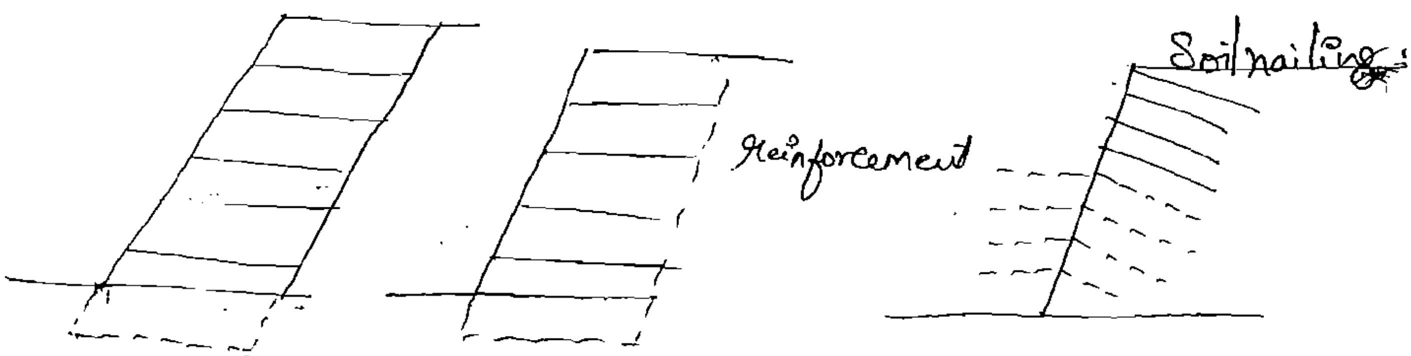
UNIT-4

ced Earth:

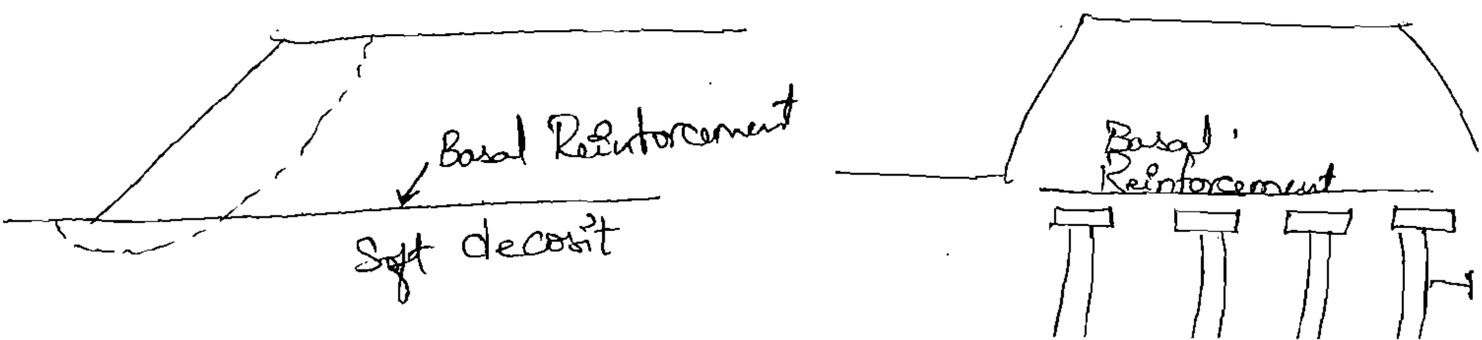
The concept of combining of two materi of different strengths characteristics to form a composi material of greater strength is quite familiar in civil engineering practices and in use for ages. The reinforced concrete constructions are examples for such composite materials. It combines the high tensile strength of steel with the high compressive but relatively low tensile strength of concrete. Likewise soils which have little if any tensile strengths can also be strengthened by the inclusion of materials with high tensile strength. This mobilisation of tensile strength is obtained by surface interaction b/w the soil and the reinforcement through friction and adhesion. The reinforced soil is obtained by placing extensible or inextensible materials such as metallic strips or ploymeric reinforcement within the soil to obtain the requiste properties

Soil reinforcement through metallic strips, grids or meshes and polymeric strips sheets is now a well developed and widely accepted technique of earth improvement. Anchoring and soil nailing is also adopted to improve the soil properties.

The use of reinforced earth technique is primarily due to its versatility, cost effectiveness and ease of construction. The reinforced earth technique is particularly usefull in urban location where availability of land is min and construction is req. to take place with min. disturbance traffic.



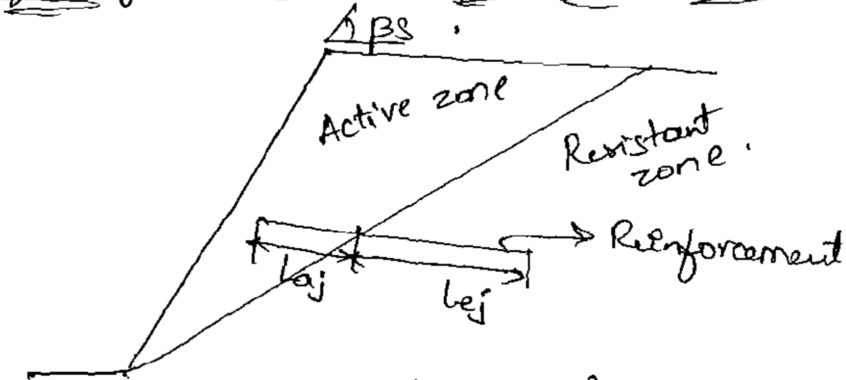
Reinforced Slopes.



Concept of Soil Reinforcement:

Reinforced Soil refers to a soil which is Strengthened by a material able to resist tensile stresses and which intracts with the soil through friction/adhesio

Soil reinforcing Mechanisms is wall and Slopes:



mechanism in wall and Slopes,.

- 'β_s' is the Slope of dry ~~chocohesion~~ less soil with a face Inclined at β_s .
- Where β_s is greater than the internal angle of Shearing resistance .
- Without the benfits of Soil reinforcement the Slope ~~may~~ be would collapse, however by the incorporation of Suitable Soil reinforcement the Slope may be render. Stable,
- Investigation of the basic reinforcing mechanism revels that the Soil in the Slope Comprises two distinct zones viz. active zone and the

resistant zone. without reinforcement the active zone is unstable and tends to move outwards and downwards with respect to the resistant zone. If soil reinforcement is installed across the active & resistant zones it can serve to stabilize the active zone. fig shows a single layer of reinforcement with a length of 'Laj' embeded in Active zone and length 'Lej' embedded in the resistant zone. The embedded length of 'Lej' should be sufficient enough to mobilise enough bond strength b/w the soil & reinforcement to resist the disturbing force caused by active zone. The tensile strength of the reinforcement is not constant but it decreases towards the free end of 'Lej' and it is zero at the end.

flexible reinforcement is incorporated in fill during construction. Consequently the layers of reinforcement are horizontal. felixable reinforcem is also inserted into cut sections during construction (in the form of soil nails) at inclinations close to the horizontal. This inclination is convenient since it coincides with the general inclinations of the tensile strength developed in the soil in the active zone.

Soil reinforcement Interaction:

For soil reinforcement interaction to be effective reinforcement is required absorbs strains which would be otherwise cause failure. In this context can ultimate state of collapse in terms of interaction with the soil and reinforcement this state can be bought by rapture of reinforcement or failure of bond between soil and reinforcement. In serviceability limit state is occurred when deformation occurs beyond serviciable limit or strain within the reinforcement exceed prescribed limit.

If the soil is cohesion less the bond resistance will be friction and will depend upon.

Surface roughness and Soil. If Soil is cohesive the bond Stress will be adhesive.

In Case of grid reinforcement the bond Stress will be governed by the Shear Strength of the Soil and roughness of the reinforcement.

Having absorbed load it is necessary for the reinforcement to Sustain this load during the design life without rupture or without Suffering time dependent deformation Which migh give rise to Serviceability limit. To maximise the tensile load capacity the flexiable reinforcem are Installed horizontally to Coincide with the principle tensile Strain. The axial forces adsorbed by the reinforcement are Statically determined.

<u>Soil properties req to be taken into Considerat</u>

The Soil property required to be taken Into Consideration are effective Shear Strength parameter 'c' and 'φ' which are obtained by taking into consideration pore pressure within the soil. However shear strength of fill or soil incorporating multiple layer of reinforcement.

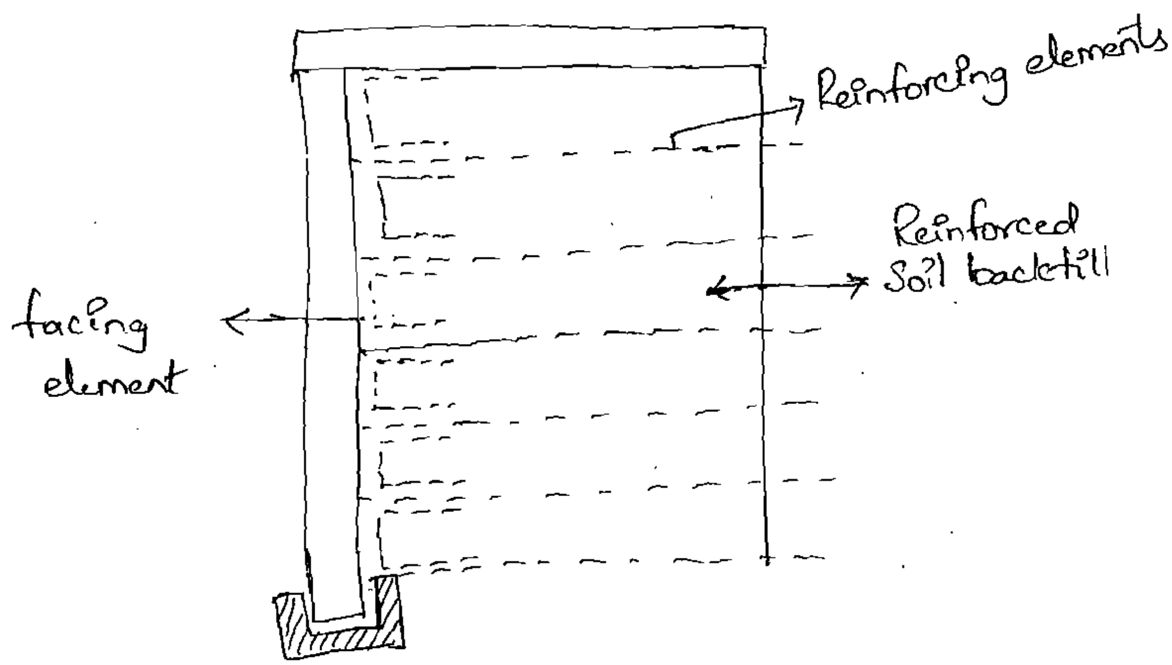
In wall and slope load imposed on the soils reinforcement will increase if positive pore water pressure are allowed to develop. The development of adverse pore pressure in reinforcement fill wall can be prevented by providing appropriate drainage. In case the development of pore water pressure is unavoidable in water front construction increased reinforcement is required to be considered

In addition to physical interaction of soil & reinforcement electrochemical interaction is also required to be considered for design life to assess the durability.

Components of Reinforced Earth Structure:

it Consists of 3 main Components

1. Reinforcing element
2. Soil back fill
3. facing element.



Reinforcing element:

different types of reinforcing materials are in use Such as Steel, Concrete, glass fibre, wood, rubber, aluminium and thermoplastics. Reinforcement may take the form of Strips, grids, anchors and Sheet material, chain pl rope, vegetation & Combinations of these or other mat forms.

Types of reinforcing materials:

→ Strips
→ planks
→ geo grids & grids.
→ Sheet reinforcement
→ Nailing.
→ Anchors
→ Composite reinforcement

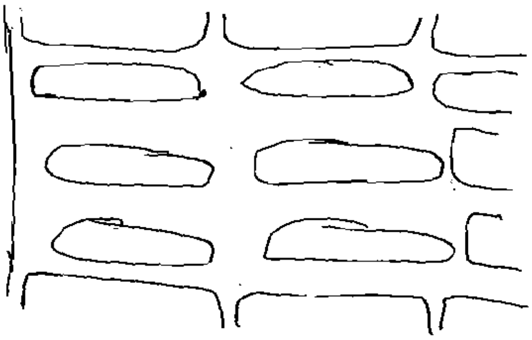
<u>Strips</u>: These are flexiable linear element normally having their breadth 'b' and thickness 't'. (B > t). dimensions v with application and structure, but are usually within the range t = 3-5mm and B = 5-100mm. The most Common Strips are metals. The form of Stainless, galvanized or Coated Steel Strips being either plain or having Several protrusions Such as ribs or gloves to increase the friction between the reinforcement and the soil back fill. Strips Can also be formed from aluminium, copper polymer and glass fibres reinforced plastic (GRP). Reed & Bamboo reinforcements are normally Categorized as Strips as are chains.

<u>Planks</u>: Similar to Strips except that their form of Construction makes them Stiff. planks can be formed from timber, reinforced Concrete or prestressed

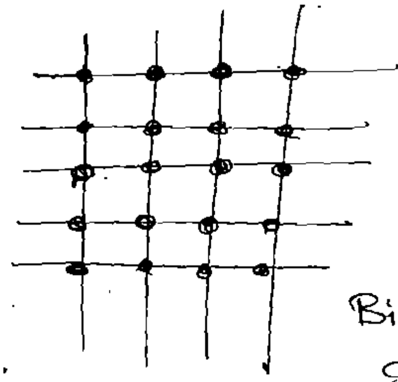
Concrete. The dimensions of Concrete planks vary, however reinforcements with thickness 't' = 100mm & 'B' = 200-300 are used. They ~~are~~ have to be handled with care as they can be susceptible to cracking.

Grids & geogrids:

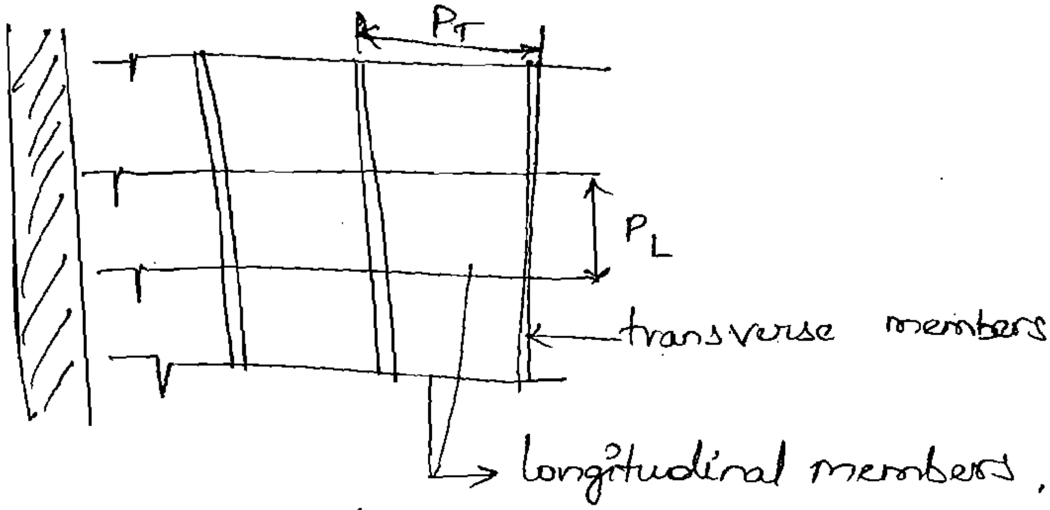
Reinforcing elements formed from ~~horizontal~~ transverse & longitudinal members, in which ~~horizontal~~ transverse members run parallel to the face or free edge of the structure and behaves as abutments or anchors. The main purpose is to retain the transverse member in position. Since the transverse members act as an abutment or anchor they need to be stiff relative to their length. The longitudinal members may be flexible having a high ~~mould~~ modulus of elasticity not susceptible to creep. The pitch of the longitudinal members, P_L is determined by their load carrying capacity & the stiffness of the transverse elements. The pitch of the transverse elements, P_T depen upon the internal stability of the structure under consideration. A surplus of longitudinal & ~~Verti~~ transverse elements is of no consequence provided the soil or fill can interlock with the grid.



mono oriented geogrid.



Bi oriented geogrid.



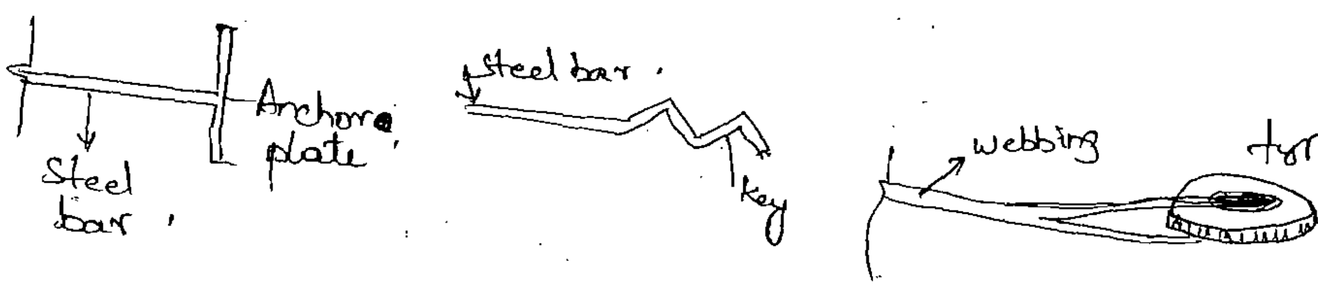
Grids are formed from steel in the form of plain (or) galvanized weldmesh, or from expanded metal.

Grids formed from polymers are known as 'geogrids'.

Sheet Reinforcement: may be formed from metal such as galvanized sheet, fabric (textile) (or) expanded metal not meeting the criteria for a grid.

Nailing: Earths are/may be protected by geosynthetics with earth nailing.

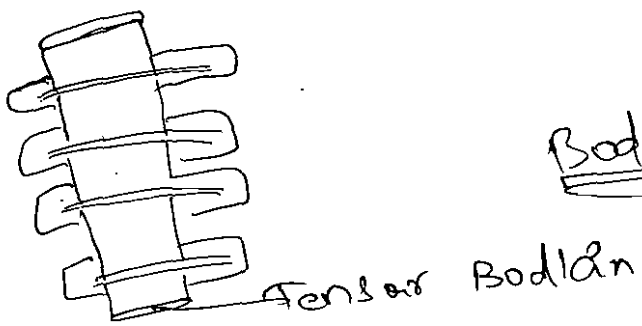
Anchors: flexible linear elements having one (or) more distortions which act as abutments or anchors in the fill or soil. They may be formed from steel, rope, plastic (or) combination of materials such as webbing & tyres, steel & tyres, or steel & concrete.



Composite reinforcement:

Reinforcement can be in the form of combination of materials & material forms such as sheets & strips, grid & strips & anchors, depending upon the requirements.

In reinforcement with polymers, polymeric joints are required. polymeric reinforcement joints are subdivided into prefabricated joints made during execution of the works. A number of different jointing systems are in use. joints in geotextiles should normally be sewn where load transference is needed. for polymeric meshes or grid a bodkin may be employed. A Bodkin joint is an effective method of joining some polymeric grid reinforcement.



Bodkin joint.

Care should be taken to ensure that

1. Bodkins have sufficient c/s area and strength to avoid excessive deformations.
2. Bodkins are not so large as to distort the parent material causing stress concentrations.
3. joints are pre-tensioned prior to loading, to reduce joint displacement as the components lock together.

Soil Backfill: The fill material for reinforced earth Structures Shall be preferably Cohesionless and it Should have an angle of on Interface friction b/w the compacted fill & the reinforcing element of not less than 30, measured in accordance with IS 13326 part (1). The Soil Should not react Chemically or electrically with the reinforcing element in an adverse manner.

A wide variety of fill types can be used with the grids including Crushed rock, gravel Industrial slag, pulverised fuel ash & clay, but fill particles greater than 125mm Should be avoided.

facing element:

facings may be 'hard' or 'Soft' and are Selected to retain fill material, prevent local Slumping and erosion of Steeply Sloping faces, and to Suit environmental requirments.

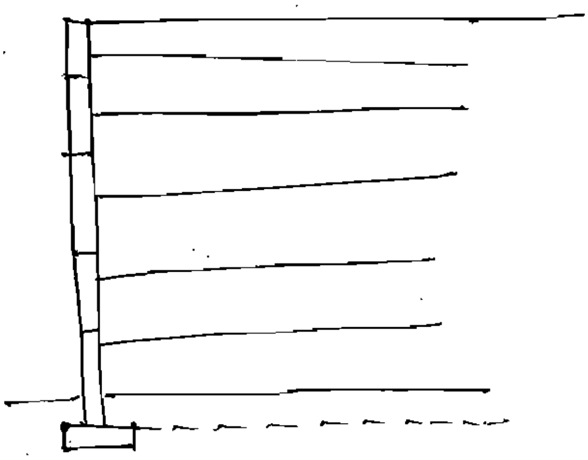
The facing Shall comprise of one of following:

(i) reinforced Concrete Slabs.

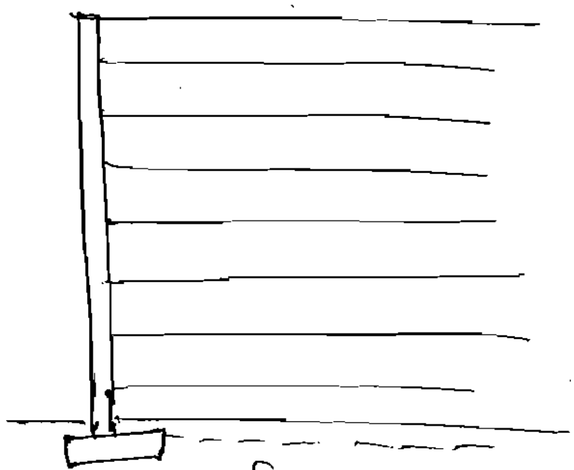
(ii) plain Cement Concrete form fill hollow block (precast).

(iii) Masonry Construction, rubble facia.

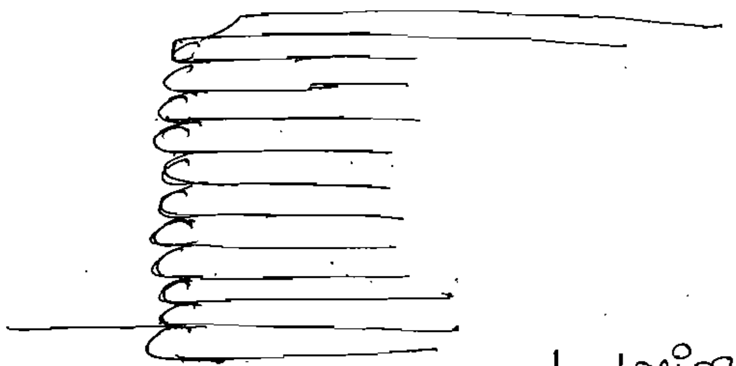
(iv) other proprietary and patented proven System.



Discrete panels



full length panels.



wrap around facing.

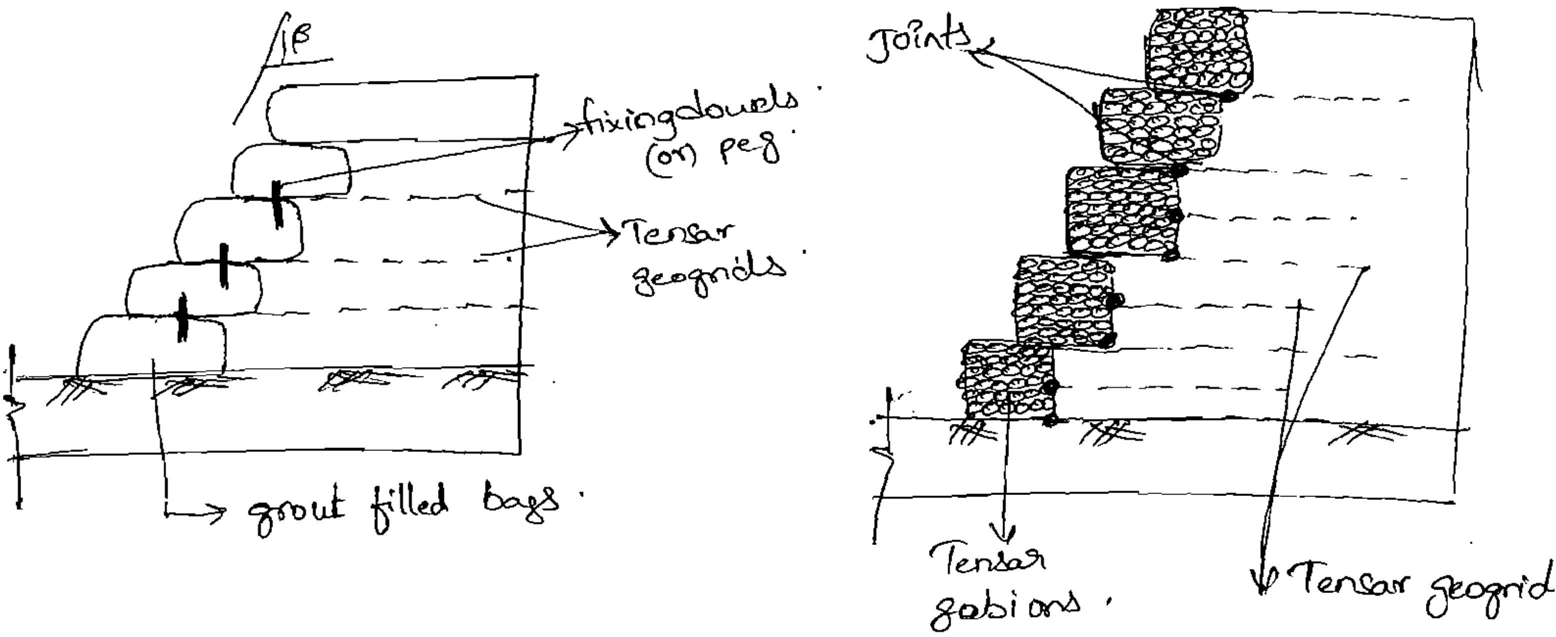
Hard facings

facing may Consists of Concrete, Steel Sheet

Steel grids or mashes, timber, proprietary materia

~~Standard~~ or Combination of these. they Should Conform to the appropriate material Standard and Should be Sized by normal design procedures using the appropriate Standard.

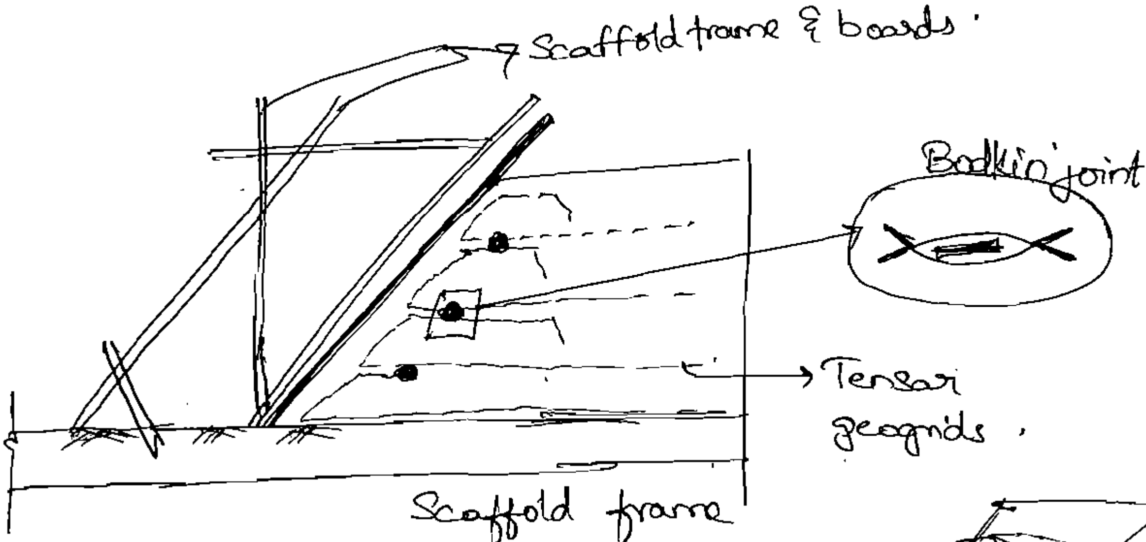
Interlocking Concrete blocks, grout filled bags or gabions can provide a Substantial facing.



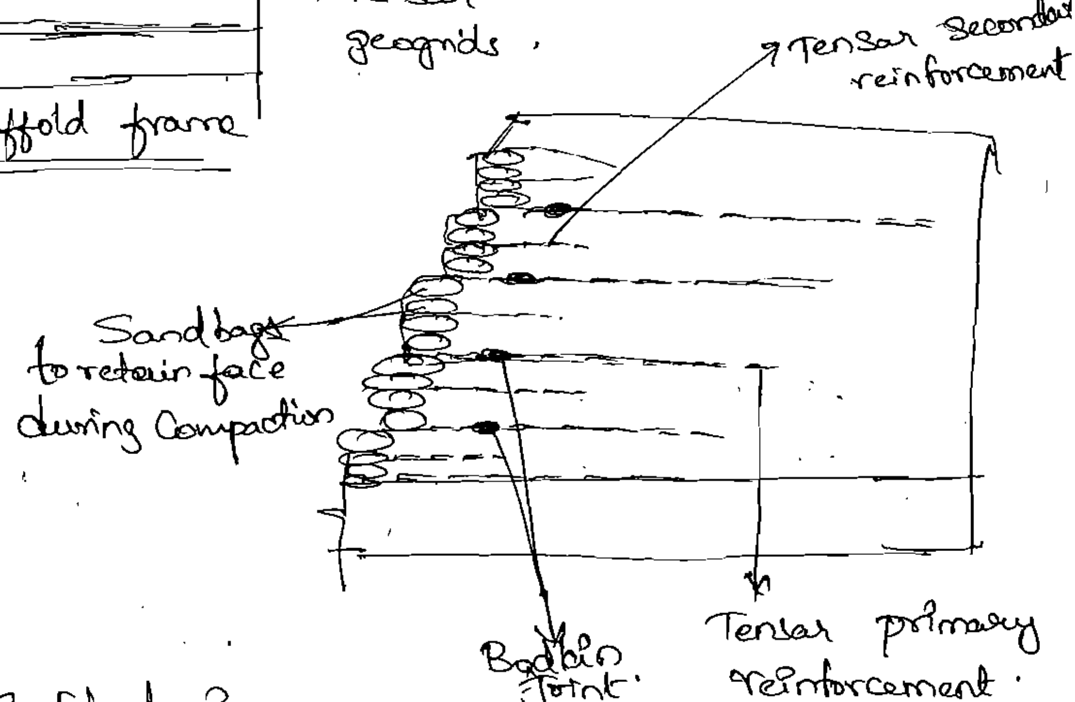
<u>Hard facing</u>

<u>Soft facings</u>

generally, external temporary formwork is erected to Support the face during the Construction of Steep Slopes (>45°). It Can take the form of a lightweight System of Scaffold tubes and boards or Consists of Some form of 'climbing' Shutter. The grids are turned up the face of the framework and returned into the embankment directly below the next reinforcement layer. the two grids are Connected using a high density polyethylene bodkin.



Scaffold frame



Soft facing

Sand bags.

Turf & topsoil can be placed on the fill sides of the grid reinforcement as it is turned up the face of the slope to create a natural & aesthetic appearance.

Where the vertical spacing of the main reinforcement is greater than 500mm, biaxial grid reinforcement is used as intermediate secondary reinforcement to provide local stability at the face of the slope.

* fasteners are used to make a connection b/w the reinforcement and the facing and take the form of dowels, rods, hexagonal headed screws & nuts & bolts and may consist one of the following materials.

- plain steel
- Coated steel.
- galvanized steel
- Stainless steel
- polymers.

Design principles

general:

By its nature reinforced soil is a combination of structural & geotechnical engineering. The evolution of limit state design in structural engineering has led to the definition of a number of partial load factor which are applied to loads in design combinations & material factors which are applied to the structural components. In geotechnical engineering the application of partial factors to the various geotechnical parameter has not been found practical in general design & overall factors of safety are still used.

for the purposes of reinforced soil design, a limit state is deemed to be reached when one of the following occurs:

(a) Collapse (or) major damage.

(b) deformations in excess of acceptable limits.

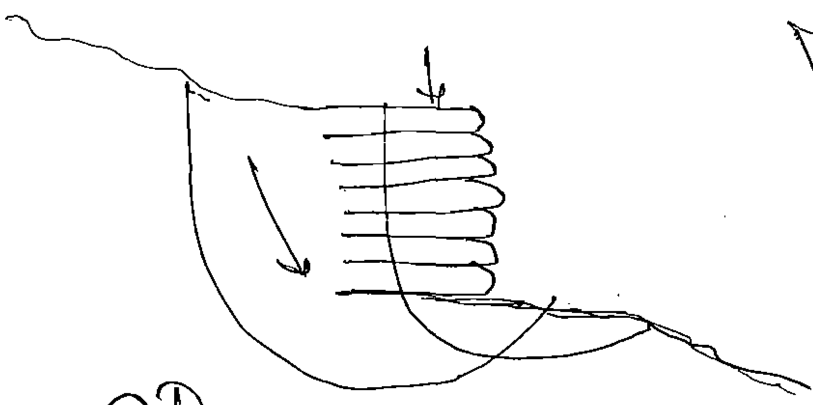
(c) other forms of distress (or) minor damage, which would render the structure unsightly require unforeseen maintenance.

The condition defined in (a) is the ultimate limit state. (b) & (c) are serviceability limit states.

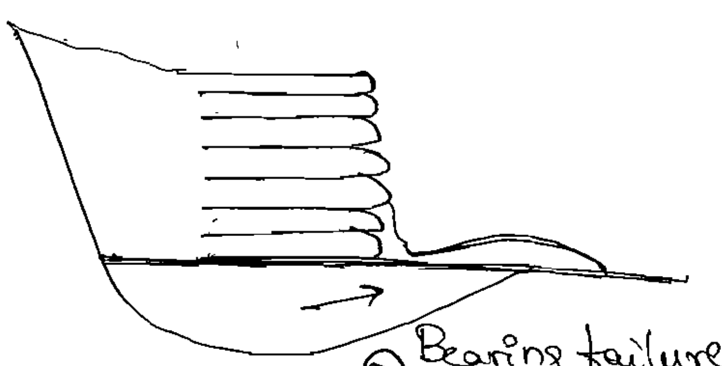
Stability checks:-

Types of Failures

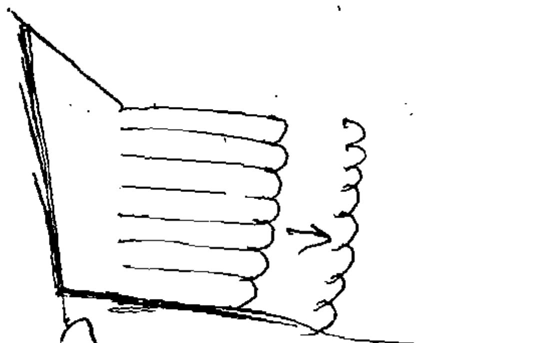
If the major failure plane considered lies outside the reinforced earth mass, the failure is termed external and is analyzed following conventional soil engineering practice. Internal failure can occur by rupture of the reinforcement; slippage b/w the reinforcement and the surrounding soil; rupture, excessive deformation, or buckling of face elements; or failure of connections.



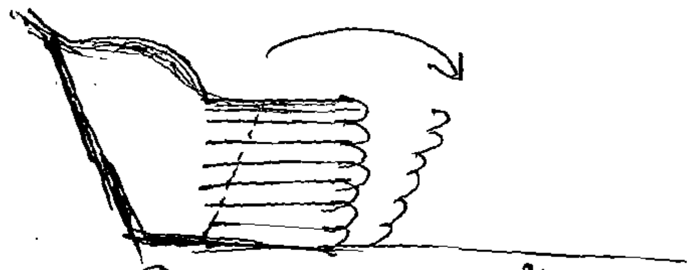
(1) Deep-seated failure



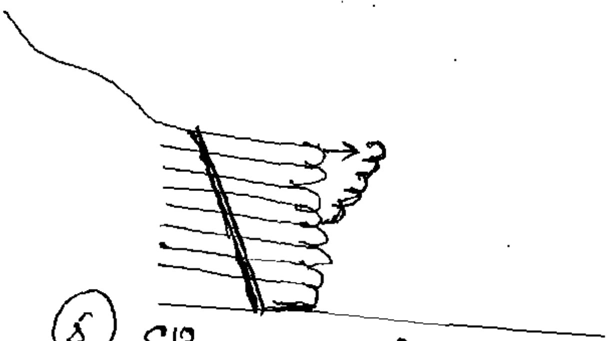
(2) Bearing failure



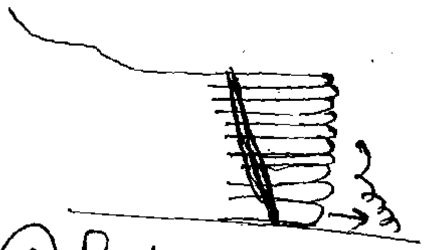
③ Sliding failure.



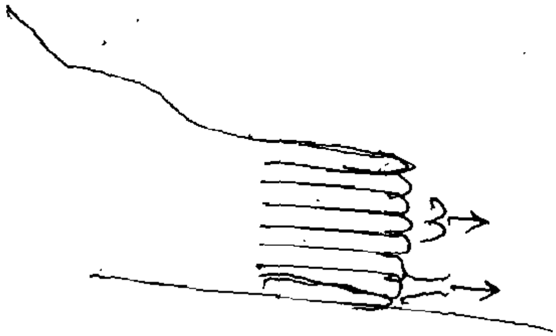
④ Overturning failure.



⑤ Slippage of Reinforcement



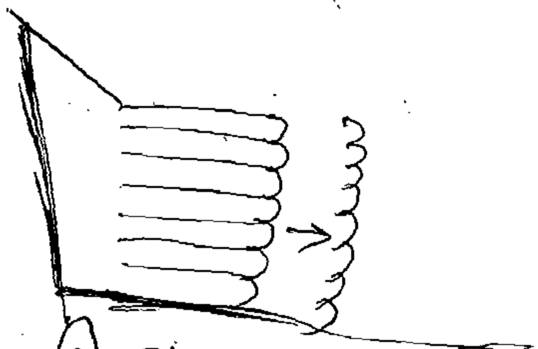
⑥ Rupture of the Reinforcem[ent]



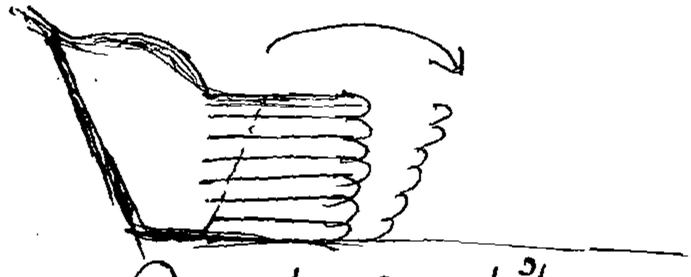
⑦ Rupture, excessive deformation, (or) buckling of face elements or failure of Connections.

① __Deep - Seated failure:__ For the case of poor backfill material (behind the reinforced earth) and soft foundation Strata, a deep - Seated Circular failure Surface Could form. For this Case, Conventional Slope Stability analysis, eg, using the met[hod] of Slices, yields a safety factor according to the definiti[on]

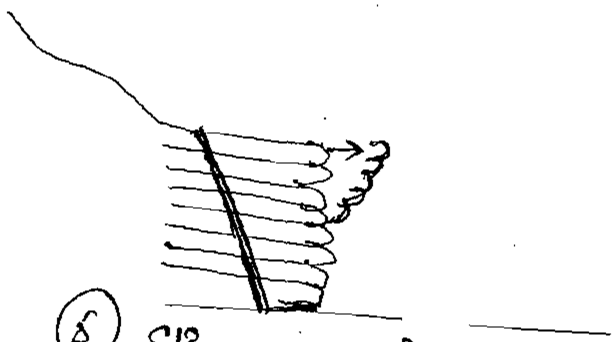
$$F = \frac{\text{resisting moment}}{\text{driving moment}} = \frac{\text{moment of shear strength along fail[ure] arc}}{\text{moment of wt. of failure ...}}$$



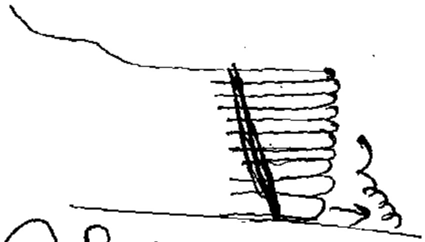
③ Sliding failure.



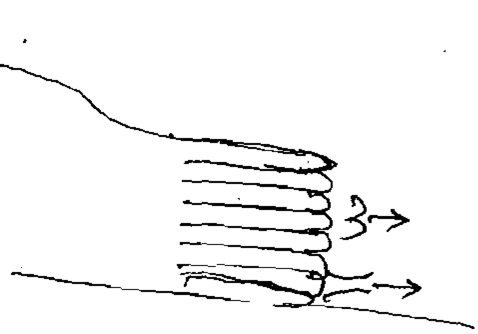
④ Overturning failure.



⑤ Slippage of Reinforcement



⑥ Rupture of the Reinforcem



⑦ Rupture, excessive deformation, (or) buckling of face elements or failure of Connections.

① Deep-Seated failure: For the case of poor backfill material (behind the reinforced earth) and soft foundation Strata, a deep-Seated Circular failure Surface Could form. For this Case, Conventional Slope Stability analysis, eg, using the meth of Slices, yields a safety factor according to the definitio

$$F = \frac{\text{resisting moment}}{\text{driving moment}} = \frac{\text{moment of Shear strength along fail arc}}{\text{moment of wt. of failure [illegible]}}$$

N_c, N_q & N_γ are Bearing Capacity factors.

Coefficients S – Shape

i – load inclination

d – depth factors

g & b are Slope of ground surface & the inclination of the base into account.

→ The eccentricity of the resultant load on the base, the presence of groundwater and any stratification of the subsoil will also have to be considered.

→ It is suggested that the standard analysis of shallo footings be followed.

<u>Sliding</u>: Sliding of the reinforced soil mass is another type of external failure which can be analyzed using conventional methods. The base of the reinfo block of soil is normally placed at some depth below the ground surface at the toe so that so passive resistance may also be relied upon.

<u>Overturning</u>: A type of failure analogous to the overturning of a conventional retaining wall.

It is assumed that an active failure wedge develops and full "wall friction" is mobilized along the back face of the reinforced earth mass. This failure mode implies that distortion of the Reinforced earth mass occurs, or in other words, internal failure by slippage of the reinforcement takes place simultaneously. In the Standard design of Reinforced earth walls it is considered sufficient to show an adequate safety factor against slippage of the reinforcement in order to exclude the possibility of this type of block failure taking place.

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Le-8 ~~82, 85 88~~, 89, 8
12-128 ~~92, 97,~~ A6, A8, B

11.0 References

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6.4 Fasteners and connections

Fasteners and connections are often necessary in reinforced soil structures, particularly where reinforcing elements are connected to some form of facing. Appropriate materials factors should be applied to the strength of the connection in the same way as for the reinforcing elements.

6.5 Design Information:

In order to develop the design of reinforced soil structure the following:
Information is required to be evaluated:

(A) Site investigation
(B) Environmental consideration
(C) Load combination
(D) Design record

(A) Site investigation:

In site investigation initial field study , ground investigation and its field study report should be considered in design and in some case (construction over soft soil) investigation during construction should be monitor

i) Initial field study

The availability and characteristics of the potential local fill materials should be accessed together with details of local drainage.

ii) Ground investigation

i) Area of investigation
- ground conditions
- behaviour of the foundation strata under the imposed loads
- information of settlement(total & differential)

ii) Ground water investigation

- Ground water conditions (pH and chemical content of ground water may affect the durability of reinforcing elements, fasteners & facing).
- Fluctuations in ground water regime may affect the overall structural behaviour.

iii) Field study report

Site investigation report should contain the relevant design parameters for the appropriate structure. The fill or ground material which is proposed to be used in structure should be tested for particle size distribution ,short and long term strength parameters and consolidation parameters where applicable should be included.

9.0 Test Properties For Design

As such a typical list of important properties of geosynthetics required for reinforcement function may thus include :-

1. Basic Physical Properties
   - Constituent material and method of manufacture
   - Mass per unit area
   - Thickness
   - Roll width, roll length
2. Mechanical Properties
   - Tensile strength
   - Tensile modulus
   - Seam strength
   - Interface friction
   - Fatigue resistance
   - Creep resistance
3. Hydraulic Properties
   - Compressibility
   - Opening size
   - Permittivity
   - Transmissivity
4. Constructability/survivability Properties
   - Strength and stiffness
   - Tear resistance
   - Puncture resistance
   - Penetration resistanee
   - Burst resistance
   - Cutting resistance
   - Inflammability
   - Absorption
5. Durability (Longevity)
   - Abrasion resistance
   - Ultra-violet stability
   - Temperature stability
   - Chemical stability
   - Biological stability
   - Wetting & drying stability

All these may not be important for every application. For design purpose ultimate tensile strength, partial factor of safety for environment and creep reduction factor are required.

7.0 Design of reinforced earth retaining walls

The aim of design is to achieve of an acceptable probability that designed structures will perform satisfactorily during their intended life. With an appropriate degree of safety, they should sustain all the loads and deformations of normal construction and use along with adequate durability and resistance to the effects of misuse and fire etc.

Design of reinforced earth structure investigate two main eriteria to develop the dimensions and layout of the reinforced earth structure. The external stability of a reinforced soil wall is easily investigated since it behaves as a rigid gravity structure and conforms to the simple laws of statics. The analysis of internal stability is essentially one of designing reinforcement against tension failure and ensuring that it has a sufficient anchorage length into the stable soil.

Design methods are based on both limit equilibrium and limit state approaches and most common methods of design are described as under:

7.1 Design of walls and abutments

Vertical walls and associated abutment structures can be constructed using horizontal grid reinforcement as shown in Fig. 15

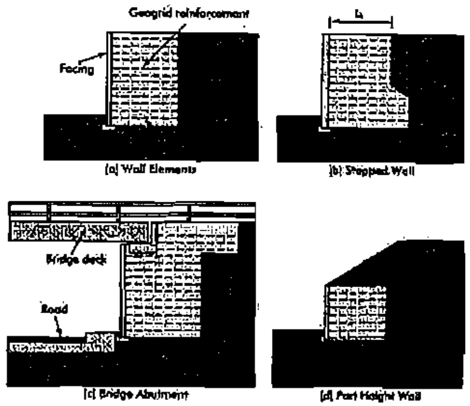


Fig 15 : Different strueture with grid reinforcement

(e) View of reinforced earth embankment

Fig . : 31

The flow diagram of the design procedure is shown in Fig 18

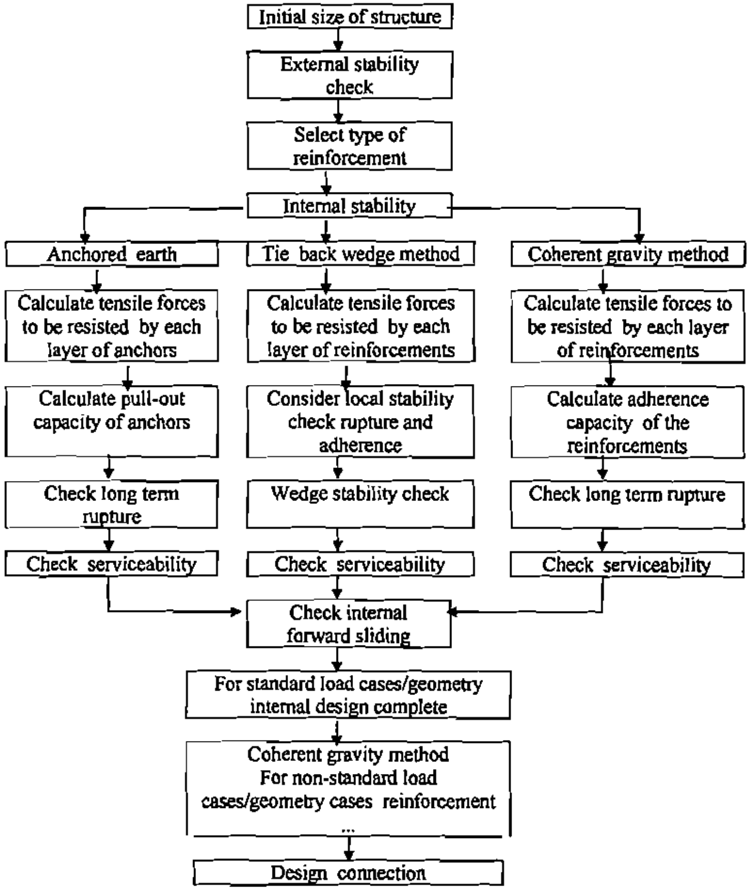


Fig 18 : Design Procedure for reinforced soil walls

Generally two design methods are identified for internal stability

i) Tie-back wedge method
ii) Coherent Gravity method

Design principle of Reinforced earth wall:

Service life: most cases the Selected design life of the reinforcing elements is equal to the Service life of the Structure.

for: temporary works – 1 to 2 yrs.
Short term – 5 to 10 yrs.
Industrial – 10 to 50 – Mining Structures.
longterm – 60 yrs – Marine & highway Struct
70 " – RE wall
120 " – Highway Retaining wall and highway Structure & bridges abutment.

FOS: The partial factor are required to be applied at appropriate stage in the design to obtain overall FOS to the reinforced Structure.

→ Partial factor for

design tensile strength

① metallic Reinforcement: $T_D = T_U / f_m$. $f_m = 1.5$ (for plain / galvanized steel)

② polymeric Reinforcement: $T_D = T_{CR} / f_m$
(or)
T_{CS} / f_m

③ Soil : $C_d = C_k / f_{ms}$ (This factor is applied to Soil parameters c & ϕ).

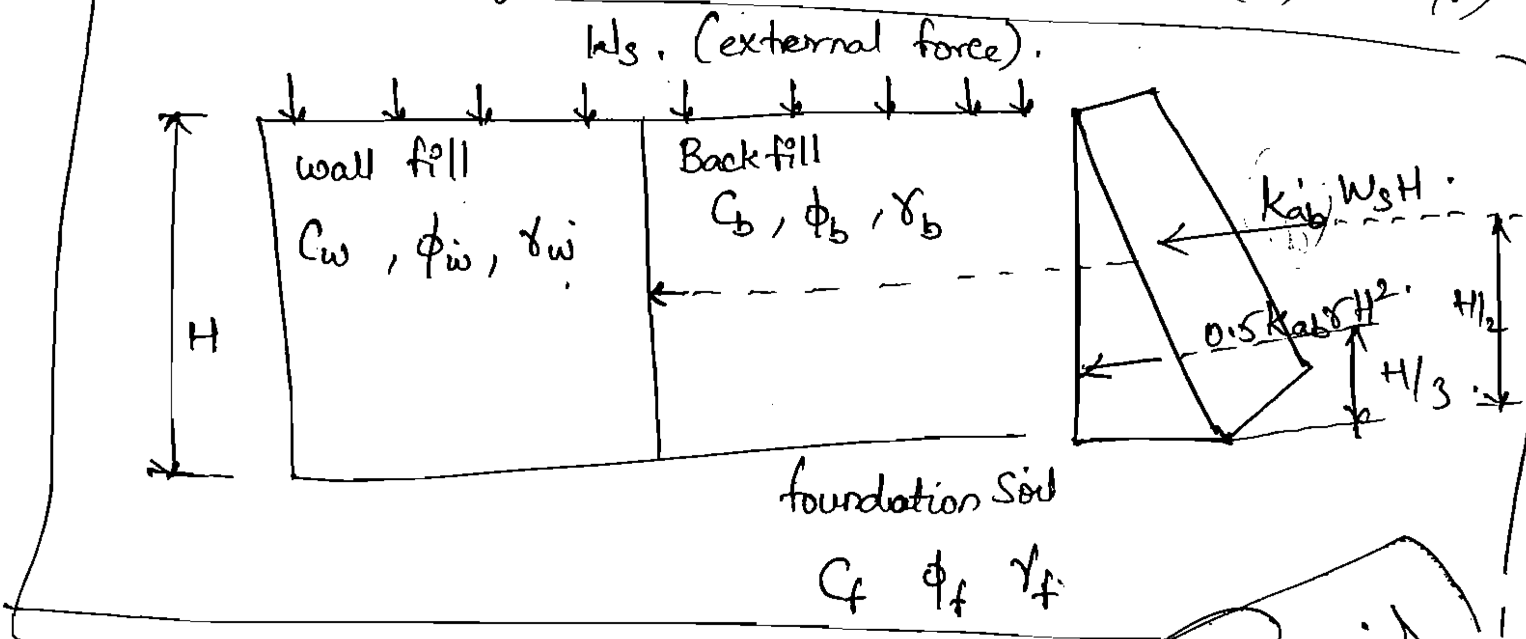
④ FO

<u>external sliding</u> : FOS for sliding $= \dfrac{\text{Resisting force}}{\text{Sliding force}}$

<u>target fos = 2.0 (generally).</u>

$$= \frac{2\mu(\gamma_w H + W_s)}{K_{ab}(\gamma_b H + 2W_s)\left(\frac{H}{L}\right)}$$

μ – Coefficient of friction on the base of the reinforced soil block ($\alpha \tan\phi_w$ (or) $\alpha \tan\phi_f$)



$$K_{ab} = \frac{1 - \sin\phi_b}{1 + \sin\phi_b} \text{ (Rankine)}$$

density $\gamma = \dfrac{\text{wt of soil}}{\text{Vol of soil}}$

<u>overturning failure</u> :

$$FOS = \frac{\text{Restoring moment}}{\text{overturning moment}} = \frac{3(\gamma_w H + W_s)}{K_{ab}(\gamma_b H + 3W_s)\left(\frac{H}{L}\right)^2}$$

Slip failure : FOS = 1.5

FOS against Slippage : $F_s = \frac{T_r}{T_d} = \frac{\text{max pulling force of strip}}{\text{Tension developed in Strip.}}$

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