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No. RW/34014/3/87-NH Std. *Dated the 28/29th December, 1987*

To,

All Chief Engineers of States and Union Territories dealing with roads

Subject : Reinforced soil structures for highways — Note on.

With a view to introducing the subject of reinforced soil structures to highway engineers, this Ministry had earlier circulated a brief note under its letter No. RW/NHVI-67(9)/85 dated 12.12.85. As a follow-up to the same, a more detailed note has now been prepared on the subject which is enclosed herewith. The note touches on different aspects of the subject like its application, materials, procedures for design and construction etc. Since the technique holds promise of effecting savings in the use of some of the traditional materials for construction and thereby in cost, it is hoped that this will be found to be useful to the highway engineers.

A NOTE ON REINFORCED SOIL STRUCTURES FOR HIGHWAY WORKS

Reinforced soil is a composite building material formed by reinforcing the soil with strips of geofabrics or nets to withstand the tensile forces generated in the reinforced soil structure. As shown in Fig. 2A, 6A and 7 its main components are soil/backfill material, reinforcement and facing. The facing prevents the erosion of fill material whereas lateral deformation of entire soil mass is prevented by the reinforcement through the friction which developes between soil and reinforcement. The principle can be understood by simple hypothetical model as shown in Fig. 1. The action of vertical stress on an element in soil mass is to deform the element and mobilise an equalising horizontal stress in the surrounding soil (Fig. 1A). The magnitude of this horizontal stress is directly related to lateral expansion of element. When the same element is reinforced (Fig. 1B) the interaction between soil and reinforcement creates a tensile restraining force in the reinforcement. The reinforcement takes majority of the horizontal confining stress and creates a stable mass of soil.

2. Application in Road and Bridge Works

Reinforced soil can be used in bridge abutment. Some such applications are shown in Fig. 2A, 2B & 2C. Reinforced earth structure in these applications can be reinforced soil walls or a sloping embankment with or without any additional pile support.

In embankment reinforcement can be placed to steepen side slope Fig. 3A, make the slope stable or to provide vertical embankment slope. In hill roads, and cut portion it can be used in substitution of retaining wall (Fig. 3B). Reinforced soil structure can be provided in the foundation of embankment where subsoil is weak to make the embankment stable (Fig. 3C).

Other applications can be used of geogrid in the embankment foundation, anchoring the wall, providing stepped highway structures (Fig. 3B) and providing gabion support (Fig. 3D).

(The above illustrations do not cover all the areas of applications — the list can be very long.)

3. Materials

There are three basic materials required in construction of reinforced soil structure. They are (i) soil or fill material (ii) reinforcement or anchor system and (iii) a facing if necessary. In addition, other materials are required to cover associated elements such as foundations, drainage and connecting elements, etc.

3.1 Soil/Fill

Usually well graded cohesion less fill is used in re-inforced soil or alternatively a good cohesive frictional fill can be used. Although purely cohesive soil have been used with success, their use is not common. The advantages of cohesionless fills are that they are stable, free draining and relatively non corrossive to reinforcing elements. Mine waste and pulverised fuel ash can be used.

1-Amendment to circular dated 12.12.1985

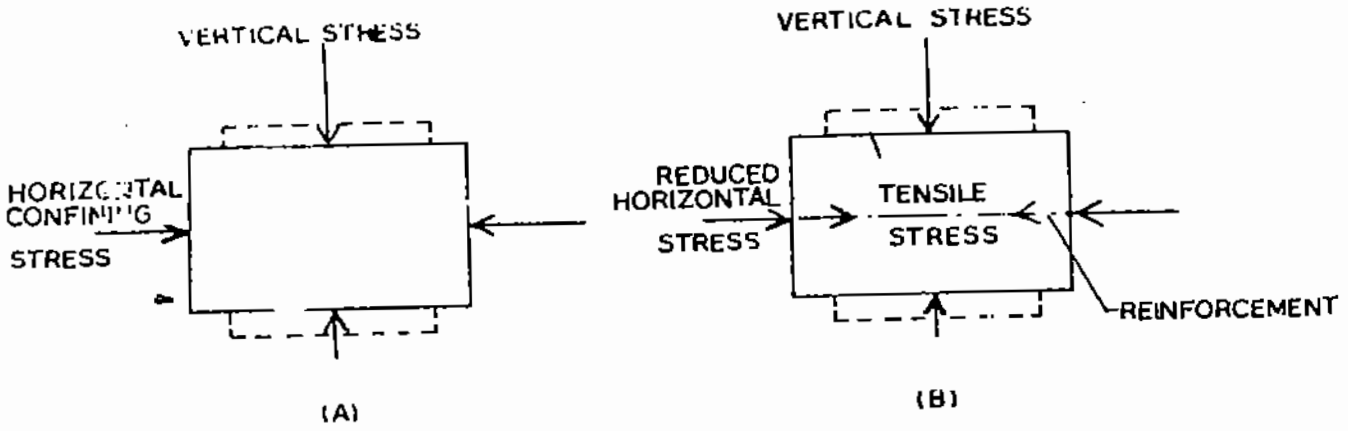


FIGURE 1- ELEMENT OF SOIL WITH AND WITHOJT REINFORCEMENT.

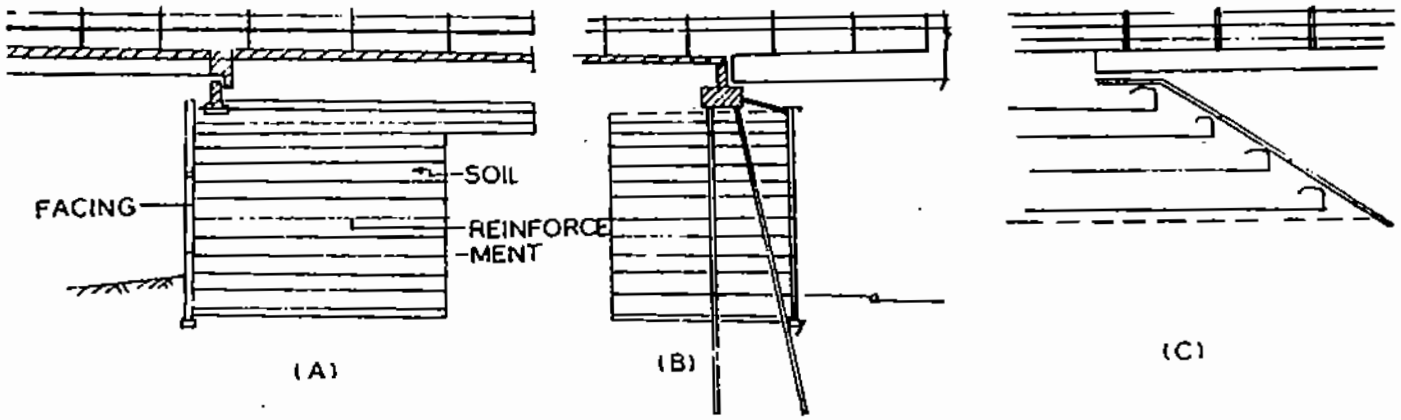


FIGURE 2- BRIDGE ABUTMENTS (A) WITHOUT PILE SUPPORT (B) WITH PILE SUPPORT (C) SLOPING

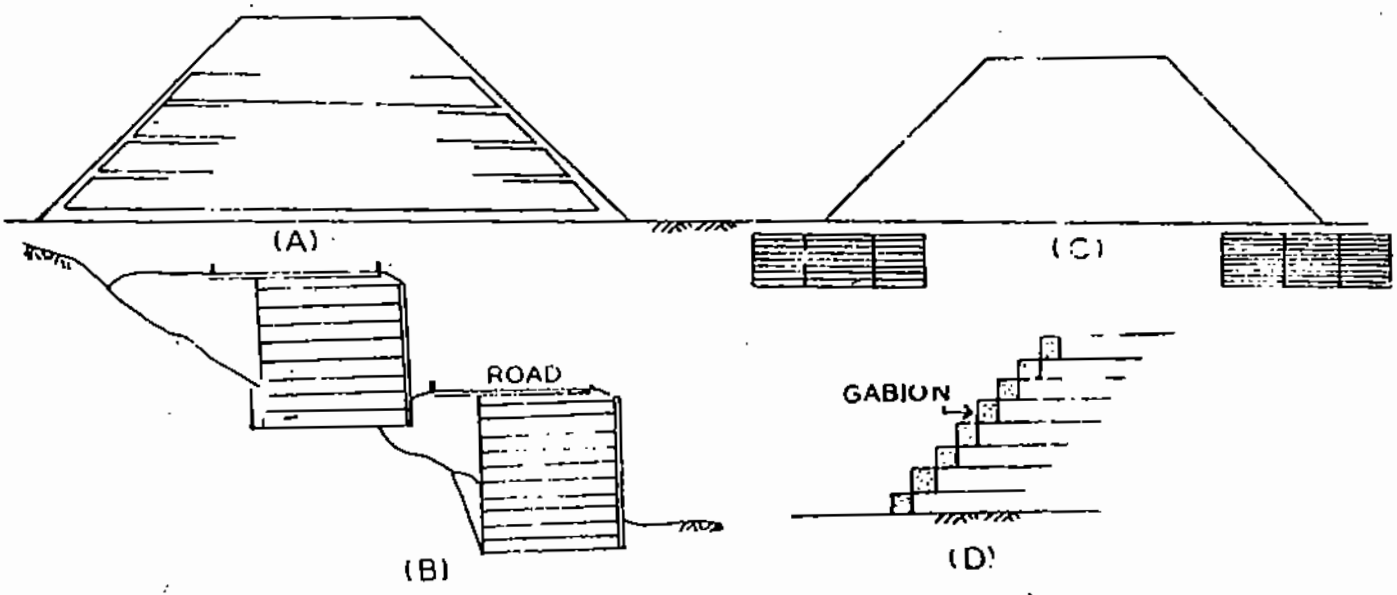
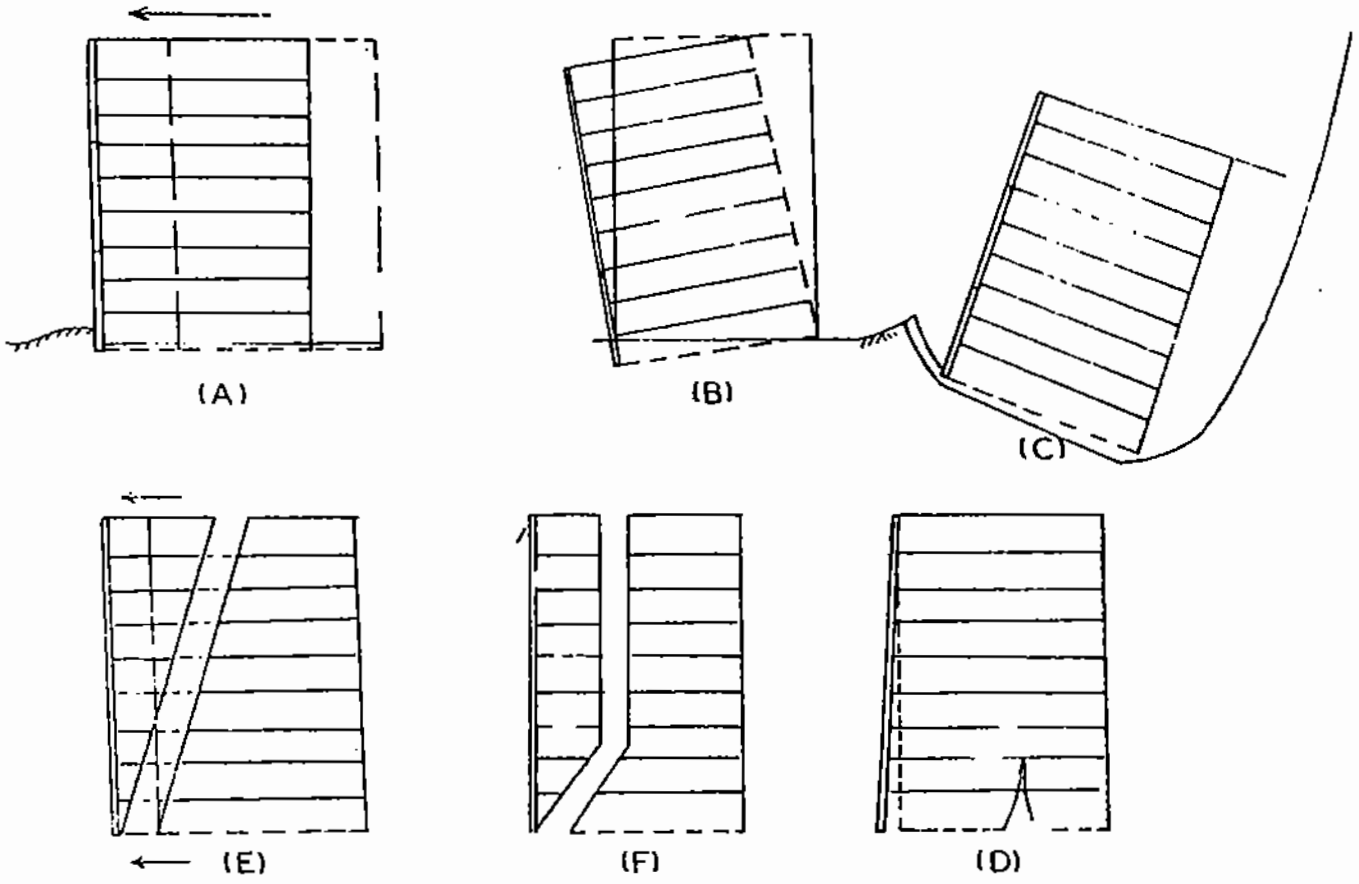


FIGURE 3- USE OF REINFORCED SOIL STRUCTURES IN ROAD WORKS IN (A) IMPROVING EMBANKMENT STABILITY (B) STEPPED UP ROADS (C) FOUND-ATION IMPROVEMENT (D) GABION SUPPORT

FIG. 3.4 – FAILURE MECHANISM (1) EXTERNAL FAILURE (A) SLIDING (B) TILT / BEARING FAILURE (C) SLIP FAILURE (D) TEAR FAILURE (2) INTERNAL FAILURE (E) ADHESION FAILURE (F) TENSION FAILURE



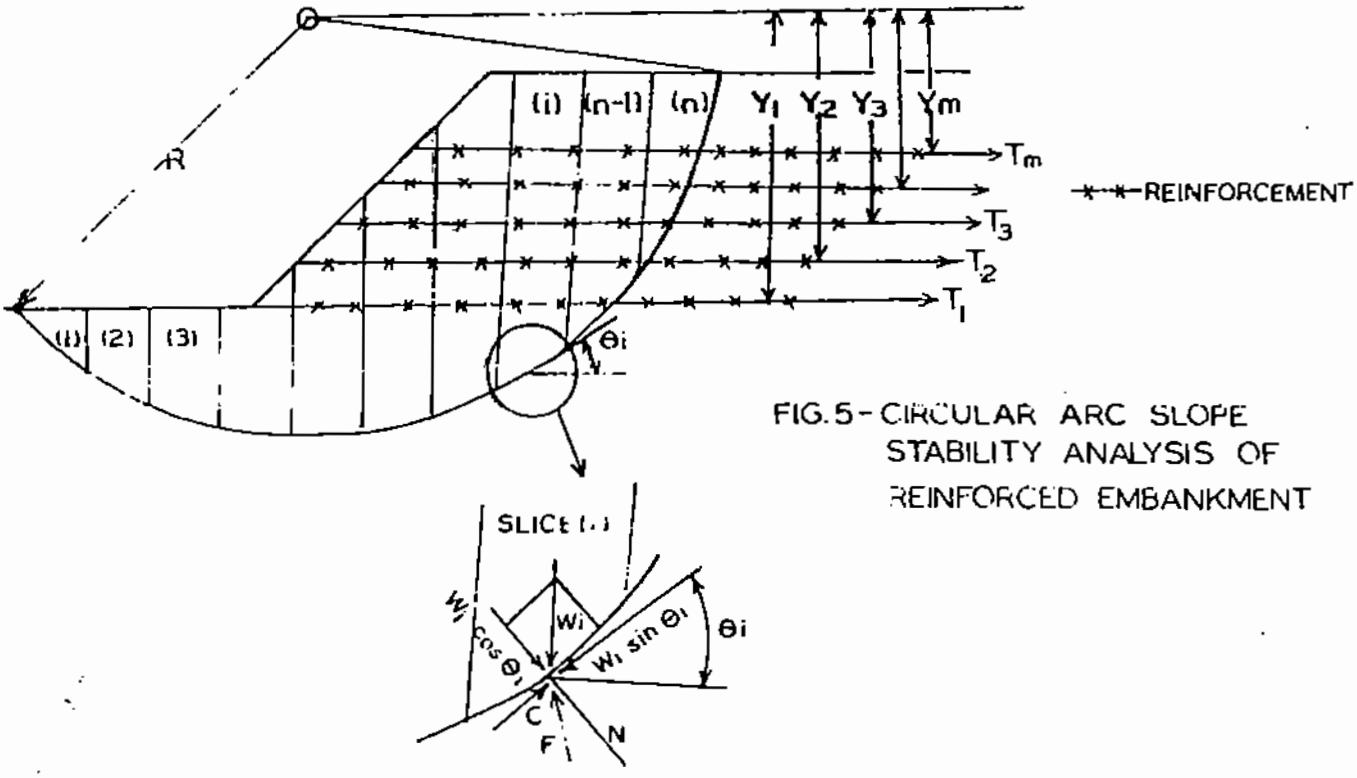


FIG. 5 – CIRCULAR ARC SLOPE STABILITY ANALYSIS OF REINFORCED EMBANKMENT

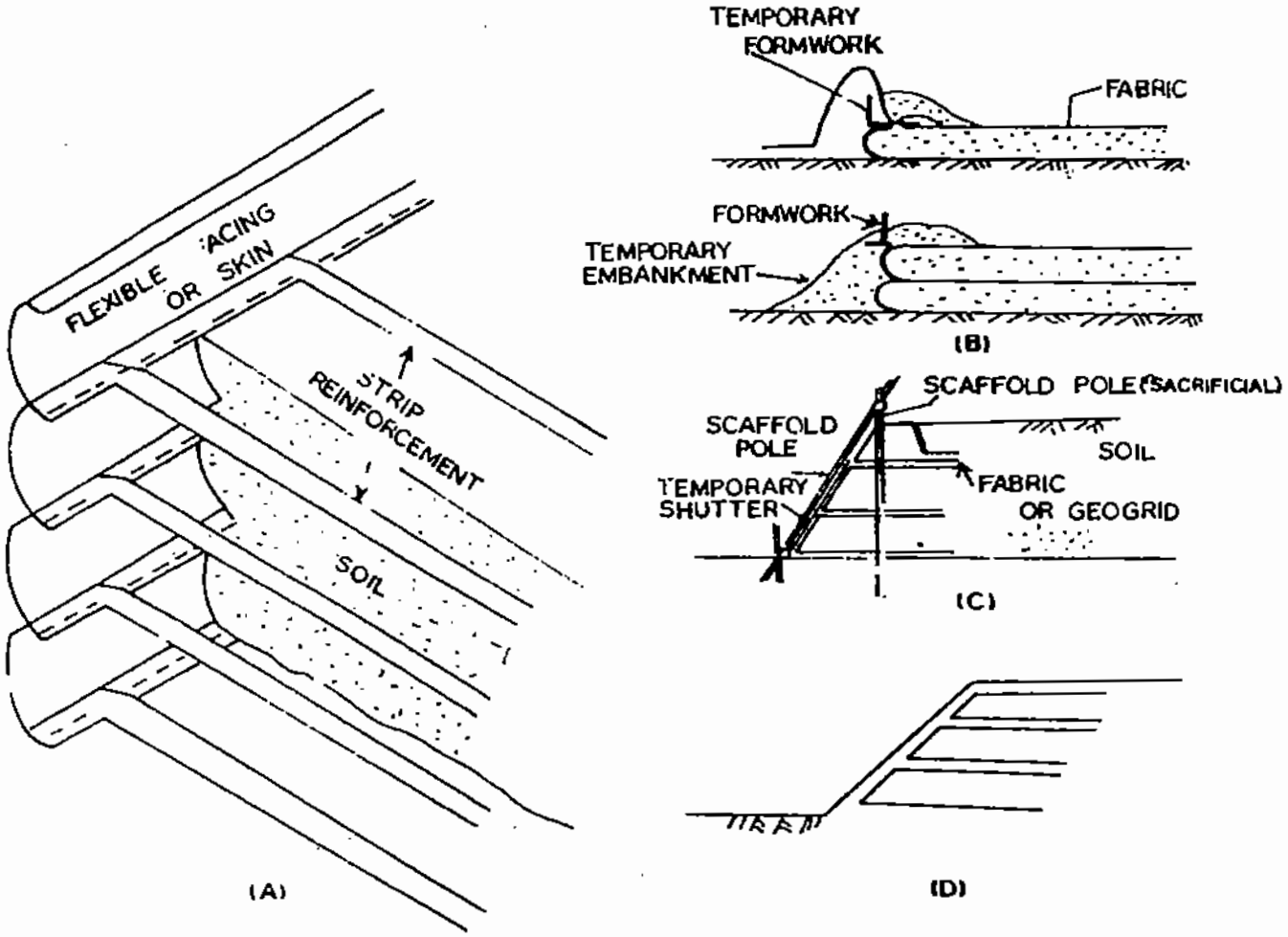


FIG.6 – CONCERTINA CONSTRUCTION METHOD – (A) WITH METTALIC FACE (B) FABRIC WALL (C) & (D) SLOPING.

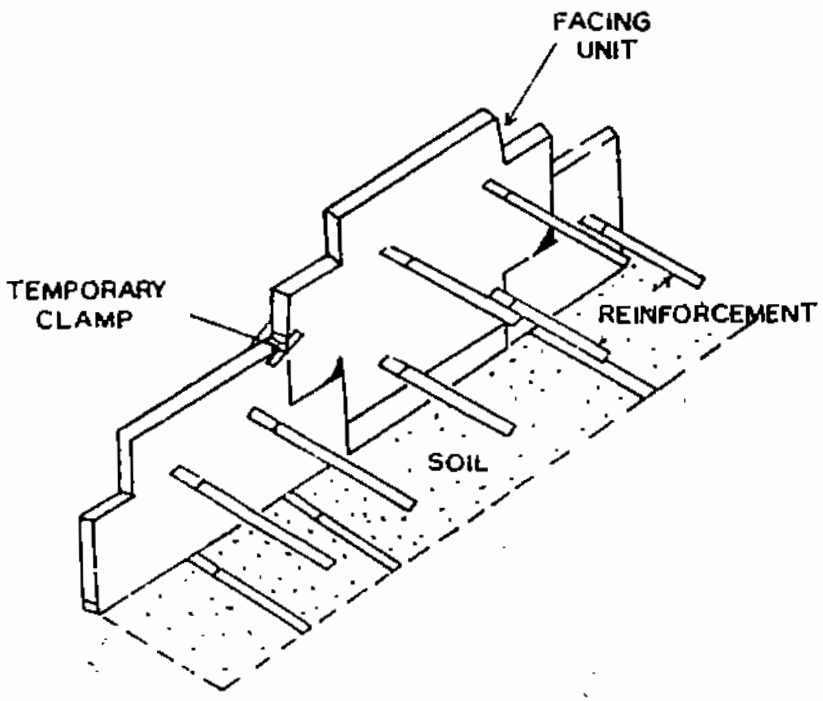


FIG.7– TELESCOPE METHOD OF CONSTRUCTION

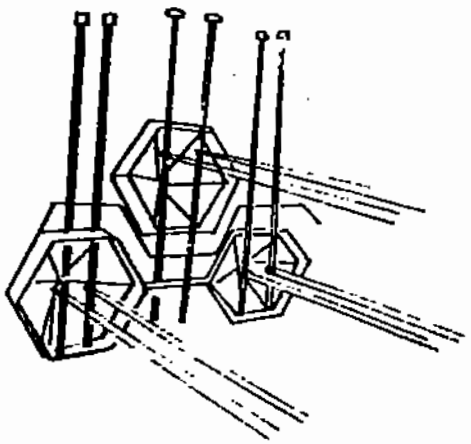


FIG.8 – SLIDING METHOD OF CONSTRUCTION

3.1.1 Cohesionless fill

UK Department of Transport, Technical memorandum (Bridges) BE 3/78 defines frictional fill as a material in which no more thn 10% of the material passes through 63 Lim BS sieve. Example of this material include crushed rock, river sand and gravel. Following material properties govern the selection of the cohesionless fill :

(i) Density
(ii) Grading
(iii) Uniformity coefficient 'C_u'
(iv) Angle of internal friction under effective stress.
(v) pH values
(vi) Resistivity
(vii) Coefficient of friction between fill and reinforcing element.

In addition for metallic reinforcement chloride ion content, total sulphate content and Radox potential also govern. The reinforced soil structure being gravity structures, density is directly used in design. The gradation is useful in selection of material. In UK uniformity coefficient of cohesionless soil is specified as Cu$\geq$ 5 similarly θ should be $\geq$ 25°. The pH, chloride ion, sulphate resistivity and Redoc potential are associated with the durability of reinforcing material. Coefficient of friction between fill and reinforcing material is directly used in the design.

3.1.2 Cohesive friction fill

The above referred memorandum BE 3/78 defines frictional fill as material with more than 10% passing 63μ BS sieve. In addition to the properties indicated in para 3.1.1 above, cohesion under effective stress condition C' adhesion between fill and reinforcing material under effective stress condition C_r, liquid limit LL, plasticity Index PI and consolidation properties are useful in calculation of settlement.

3.1.3 The disadvantages of cohesive fills in vertically faced structures are (i) the bond between cohesive soil and strip reinforcement is poor and subject to reduction if positive pore pressure develop, (ii) some clay minerals such as illite accelerate metal corrosion (iii) long term deformation may occur, (iv) comprehensive drainage arrangement may be required. However there are instances of use of cohesive fill. In reinforced embankment structures with fabric or geogrid as reinforcement, the cohesive soils can be used.

3.1.4 Waste materials

Mine waste materials have been used in reinforced soil. However, reinforcement formed from materials which have high corrosion and degregation resistance should be preferred. Proper drainage arrangement should be provided.