IGS SLIDE LECTURE : VERTICAL RETAINING WALLS

Reinforced Soil : Vertical Retaining Walls : Lecture Notes

Text *Slide*

Basic Principles of Reinforced Soil [0]

Soil is strong in compression (when confined) but weak in tension. Resistance to tensile strain in the soil can be provided by reinforcement. The interaction between the reinforcement and the soil is by friction or interlock (in case of grids). [1]

When soil and the reinforcement are effectively connected, the strain in the soil is the same as the strain in the reinforcement, providing a classic example of strain compatibility. [2]

Strain compatibilty is a fundamental concept; when applied to reinforced soil it implies that the stiffness of the reinforcement influences the strain in the reinforced soil and also that the properties of the soil and the stress state of the soil influence the behaviour, Jones (1996). [3]

Why Construct Vertical Reinforced Soil Walls? [4]

Reinforced soil provides technical and economic benefits. [5]

From a technical aspect reinforced soil walls produce solutions which are not possible in other modes/materials and also produce more economical solutions to conventional structures, both with regard to materials and labour. [6]

Reinforced soil is particularly beneficial for structures constructed on poor/weak foundations which would require piled foundations or some other method to improve the bearing capacity of the soil. Reinforced soil structures are fully compatible with modern design philosophies, for example reinforced soil abutments are regularly used in the design of integral bridges. [7]

Reinforced soil walls have been shown to be particularly suitable for construction in seismic regions, notably the Kobe earthquake in Japan and the 1996 earthquake in California.

Type of Structure

Reinforced soil walls are defined as vertical structures if they are steeper than 80°. They are used for all forms of structures including:

- Conventional retaining walls [8]
- Retaining structures in difficult terrain (on steep slopes) or to construct terraces [9]
- Bridge abutments [10]
- Industrial structures including temporary works [11]
- Enhancing/improving existing infrastructure (i.e. widening railway embankments without the need for additional land) [12]

Main Elements of Reinforced Soil Walls [13]

Reinforced soil retaining walls consist of three main elements:

soil, reinforcement and facing

The nature of the soil used influences the behaviour of the wall

A wide range of fill can be used although fine grained purely cohesive material is not usually used in vertical structures. Good cohesionless soil with a high shearing resistance (ϕ) will produce a very stable structure. [14]

Geosynthetic reinforcement is available in a range of forms including strips, grids and sheets. Most geosynthetic reinforcements are proprietary products which have been subjected to extensive testing. A number have been awarded certificates by [15]
international/national testing agencies (i.e. [16]
Agrément Board in UK, BAM in Germany) [17]

A facing is required with vertical reinforced soil retaining walls. The facing can take a number of forms, ranging from elemental, modular or full height. Facings are a key
element in the appearance of the structure and [18]
aesthetic considerations are an important [19]
feature of modern reinforced soil walls. [20]

Design of Reinforced Soil Walls [21]

Conventional design is to provide stability against the:

- Ultimate Limit State (typically rupture of the reinforcement)
- Serviceability Limit State (typically excessive distortion) [22]

The failure mechanisms of reinforced soil walls can be identified as "limit modes". There are six common limit modes: tilt failure, bearing, rupture, pullout, slip/wedge failure, rotation. All are failures at the Ultimate Limit State except rotation which is a serviceability criteria. [23]

Other limit modes may be identified depending upon circumstances (i.e. seismic conditions)

A number of analytical models have been produced, based upon limit equilibrium methods or empirical relationships. A number of Design Codes have been produced: BS 8006, French, Australian, Hong Kong, Japanese, US (Italian? Swiss? German?). Plus a range of proprietary analytical procedures used with separate systems (reference at end of lecture). [24]

Some analytical procedures are simplistic, others are sophisticated limit state Codes of Practice. The level of analytical sophistication used depends upon the intended use of the structure. A reinforced soil bridge abutment used on a major motorway/interstate highway of strategic importance will require greater analytical care than a temporary structure.

Construction Techniques [25]

A basic property of reinforced soil is that some strain must occur before the soil and reinforcement can interact (i.e. the structure has to move). All reinforced soil structures move (strain) during construction, and the construction techniques used reflect this flexibility.

There are three established construction techniques:

- wraparound (concertina)
- elemental (telescopic)
- full height (sliding) [26]

Each of these techniques can accommodate the internal vertical strains which occur as the reinforced soil wall is constructed. As the structure grows in height it get heavier and the lower levels of the structure are compressed. If this compression is not accommodated additional stresses will be introduced in the reinforcement or reinforcement facing connections.

The construction for reinforced soil walls is a sequential operation: [27]

Construction is always at ground level [28]

Construction is in lifts; the fill is usually placed in 300 mm layers and compacted

Compaction of the fill is essential to the proper performance of the structure and without adequate compaction of the fill the reinforcement may be required to take additional load and strains will be enhanced.

Reinforcement is laid on compacted fill and loose fill placed on top of the reinforcement. This protects the reinforcement (i.e. no construction plant should run over the reinforcement).

Depending on the type of facing being used, the facing may need support during the compaction phase. Walls built with full height
facings are frequently propped during the [29]
construction of the wall. Propping forces are [30]
small, Jones (1996). [31]

Facings can be applied to the wall after construction; this is a notable feature of one form of retaining wall constructed in Japan. [32]

Bibliography

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French Standard (1992) "Soil reinforcement and backfilled structures with inextensible and flexible reinforcing straps or sheets", NFP94-220 (English translation).

Geotechnical Control Office (1989) "Model specification for reinforced fill structures", GeoSpec 2, Government Publications Centre, Hong Kong, p.140.

Jones, C J F P (1996) "Earth reinforcement and soil structures", Thomas Telford/ASCE Press, p.379.

Ministere des Transports (1979) "Les Ouvrages en Terre Armée: Recommendations et Regles de l'Art", Direction des Routes et de la Ciculation Radar, Paris, France.

Roads & Traffic Authority, New South Wales, Australia - Construction of Reinforced Soil Walls, R58.

IGS SLIDE LECTURE

Reinforced Soil : Vertical Retaining Walls : Slides

[0] Title slide : IGS Lecture Series
Reinforced Soil : Vertical Retaining Walls

[1] [2] [3] BBC "Tomorrow's World" slides illustrating the benefit of reinforcement placed in a block of soil
(reinforcement geogrid, coloured yellow)

[4] "Benefits of Reinforced Soil Vertical Walls"
- technical
- economic

[5] [6] Historical slides showing the costs of reinforced soil structures v. conventional structures
Reduced labour costs required for reinforced soil structures

[7] Slide illustrating the change in design philosophy with reinforced soil
- conventional abutment supported on piles
- reinforced soil abutment with no piles required

[8] Slide of a retaining wall

[9] Slide of terracing

[10] Slide of a bridge abutment (integral bridge)

[11] Slide of industrial structure or temporary works

[12] Slide illustrating the concept of embankment widening (Japanese?)

[13] Title slide : Main Elements of Reinforced Soil Walls
- soil
- reinforcement
- facing

[14] Grading curves showing the range of material often used as fill in reinforced soil walls

[15] [16] [17] Slides showing strip, grid and sheet reinforcement

[18] [19] [20] Slides showing different forms of facing:
elemental, full height, modular

[21] Title slide : Design of Reinforced Soil Walls

[22] Design to produce stability against:
- Ultimate Limit State
- Serviceability Limit State

[23] Slide showing main six limit modes

[24] Slide listing main national design Codes of Practice

[25]	Title slide : Construction of Vertical Reinforced Soil Walls
[26]	Established construction techniques
[27] [28] [29]	Sequence of slides illustrating the construction of a wall, placing the fill, compaction, fixing reinforcement
[30]	Support of a wraparound facing
[31]	Propping of a full height panel
[32]	Japanese construction sequence, a wraparound structure with a full height rigid facing applied when construction movement has ceased
[33] [34] [35] [36] [37]	Selection of slides showing finished structures