GEOSYNTHETIC REINFORCED SOIL: FROM THE EXPERIMENTAL TO THE FAMILIAR

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Abstract

The lecture begins with a historical review of reinforced soil technology, from the ancients, the developments by H. Vidal and K. Lee on Terre Armée and Reinforced Earth, the early uses of geosynthetics for soil reinforcement in France (Bidim), Sweden (Wager and Broms), and the USA (USFS, FHWA, J. R. Bell, T. A. Haliburton, B. R. Christopher and others). The advantages and basic behavior of geosynthetic reinforced soil (GRS) are presented along with an overview of current design procedures, and with reference to UW analytical research results. Practical suggestions are given for dealing with creep, pullout, and backfill drainage. Geosynthetic properties are then discussed, again with reference to UW research results. Although GRS is quite a mature development, a few technical and professional issues remain; primarily, too many failures of these structures occur. Reasons for these failures and some suggestions as to what the profession can do about them are presented. The lecture ends with several examples of successful applications of GRS and reinforced soil technology.

Outline:

i. Introduction
ii. Reinforced soil—a historical perspective
iii. Advantages and basic behavior of GRS
iv. Design
v. Properties
vi. Things we need still need to know and do—technical and professional issues
vii. Successful examples
viii. Final remarks

Detailed outline

1. Introduction

2. Reinforced soil—a historical perspective

- Examples from nature and the ancients
- How I got into soil reinforcing and geosynthetics while working in Sweden 1970-75.
- Early work by Vidal and the French—Terre Armée or Reinforced Earth; Lee at

UCLA

- USFS, FHWA and early workers with geosynthetic reinforcement (Bell, Haliburton, Christopher, and others)

3. Advantages and basic behavior of GRS

- Cost
- Flexibility
- Simple, rapid construction
- Attractive facing systems including “green” facings
- Steeper slopes
- Increased safety

Description of basic behavior

4. Design—GRS “walls” and steep slopes

- Background—historical and traditional approaches
- Question: What is the difference between a GRS “wall” and a very steep GRS steep slope?
- Design considerations:
  - External stability – conventional (BC, sliding, OT, overall slope stability)
  - Internal stability – several approaches, discussed in terms of fundamental soil behavior
  - Other issues -- reinforcement spacing, overall slope stability, internal drainage, seismic stability, constructability, etc.
- Discuss results of UW analytical research (Lee, Saidin)
- Design recommendations (Saidin)
  - Traditional design methods ≈ OK for GRS walls on soft foundations
  - Reinforced base layer → more uniform settlements
  - Traditional settlement analysis ≈ OK
  - Rate of construction important
  - Adequate provisions for drainage critical -- DRAINAGE! DRAINAGE! DRAINAGE!
- For LE analyses of “walls” and GRS steep slopes:
  - Use correct soil properties: $\gamma h + \phi' PS$ (not so easy)
  - For internal stability of steep GRS slopes, design as a well, a very steep slope
  - Use thin layers of weaker reinforcing -- ¢¢, and better face control
  - Pullout? Not a problem—based on research in Sweden (described earlier); geosynthetic will rupture before it pulls out. If a problem, e.g., surcharge loads near face, easily taken care of in design
  - Don’t forget: Drainage! Drainage! Drainage!

5. Properties

- Soil – FHWA and RECo recommendations
- Geosynthetic
  - Tensile strength
  - Soil-geosynthetic friction
  - Creep (?)
  - Durability
  - Installation damage
- Facing
- ASTM tests
- UW experimental research (Boyle), key findings:
  - For soil-geosynthetic interaction behavior, induced reinforcement tension must be measured directly otherwise you are just guessing the interaction parameters. And Boyle's UCD is the only test that does this.
  - Geosynthetics are much more efficient reinforcement than steel, because the strengths of both sand and geosynthetic are used more or less equally. With steel reinforced soil, the steel does most of the work and the sand just goes along for the ride. Not so with geosynthetics.
  - Creep of GRS "walls" is not really a problem at working stresses. When loading stops, GRS deforms as the geosynthetic relaxes. The GRS system is at equilibrium and no longer moves (unless additionally loaded).
  - Also shown by field measurements of real GRS walls [Rainier Ave. wall; Norway steep slope].

6. Things we need still need to know and do—technical and professional issues

- GRS is a mature technology, but there still are a few issues or concerns:
  - Technical
  - Professional
- Technical
  - A "poor man's" PS device that can also measure volume changes
  - A seismic design procedure better than M-O (PBBE?)
- Professional issues:

1. Too many failures! Most due to

  - Poor quality backfill
  - Poor drainage; saturated backfill
  - Construction problems
  - Inadequate global or external stability

- Unexpected surcharges

2. Disconnect between wall designer, geotech of record, and site civil; this relationship is complicated by wall designs supplied by materials suppliers and distributors

3. Other problems

- Lack of proper inspection
- No control of construction by designer
- Economic pressures
- "Value engineered" or "contractor supplied" designs, with no $$ for checking alternates by competent professionals
- Poor training for workers

Question: Is liability avoided by use of vendor-supplied designs?

- If not, then why give away billable design hours?
- Remember: Fixing problems always more expensive than proper inspection and control by the designer.

4. Jurisdictions that require a GRS "wall" design to be stamped by a registered structural engineer (who usually knows nothing about soil reinforcing and geosynthetics, and only a little about soils and drainage issues…and they are not responsible for construction inspection).

- The result? Too many failures! Costly, potentially tragic, and not acceptable!
- How to fix this current state of affairs? G-I? ASFE? IGS? ISSMGE? Us as individuals?
- Many of these issues are not unique to GRS, but they threaten a wonderful technology and a wonderful profession

7. Successful examples

8. Final remarks

If you would like a pdf file of my slides, write me at holtz@uw.edu and I'll send you a copy.