DISPERSE SOILS

Thanks to Dr Phil Paige-Green
Dispersive (and Erodible) Soils
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DISPERSEIVE SOILS

EASTERN FREESTATE
Research problems

- Problems with dispersive soils are difficult to predict without full-scale structures
- Learn most from failures
- Testing is not 100% reliable yet – research is continuing
This Dam is Gone!!!

Introduction

- Erosion can be a serious problem for agriculturists and conservationists
- Often neglected by geotechnical community (except earth dam engineers)
- Costly implications
- Dispersiveness only really identified in mid 1960s (Australia)
- Important to differentiate between dispersion and erosion in geotechnical applications
Introduction

- Use of dispersive materials (in for example dams) are significantly more problematic than purely erodible soils
- Piping failures in dispersive soils
- Erosion and siltation in erodible materials
- Dispersion can occur in relatively flat terrain
- Erosion usually doesn’t (you need velocity of flow!)

Typical dispersive soil problems

- Failure usually associated with rapid filling of dam
- After construction or drought
- Piping failure
Soil dispersion

- Refers only to those soils in which clay minerals deflocculate and go into suspension in still water.
- Result of repulsive forces between clays (electrical surface charges) exceeding attractive (van der Waals) forces.
- Colloid components repel each other, go into suspension.
- Clay particles can be washed out by slow movement of water to cause internal erosion, pipes and tunnels.
Dispersive soils

• Dispersiveness depends on:
  
  – Soil mineralogy
  – Clay chemistry
  – Soil water chemistry (dissolved salts in soil)
  – Eroding water chemistry

Na⁺ ions cling around negatively charged clay particles resulting in positive surface charges on clay particles. When the clay particles are in suspension in water they repel each other due to the positive surface charges, causing dispersion. The problem can be improved by getting rid of the excess Na⁺ in the soil.

Dispersive soils

• Require high exchangeable sodium percentage (ESP) in clay component.
• i.e., high ratio of Na⁺ on clay surface relative to other polyvalent cations (Ca⁺⁺, Mg⁺⁺, Al³⁺)
• Smectite, vermiculite and illite minerals (colloidal clays) in the soil.
• Rare in kaolinitic soils.
• Low dissolved salts in eroding water.
Distribution of dispersive soils

• Less common than non-dispersive clays.
• Generally more common in arid areas (not always).
• Mostly in Weinert’s N = 2 to 10 zone

Distribution of dispersive soils

• In South Africa usually occurs where:
  – rainfall less than 850 mm
  – weathering of mudrocks
• Some disagreement
  – Range of materials
  – Sometimes in wetter areas
• Usually rocks low in calcium and magnesium and high in sodium
• Sodium derived from natural weathering, deposition under marine/saline conditions or leaching in of sodium
Distribution of dispersive soils

- Weathering of granites (low Ca)
- Mudstones and siltstones of Beaufort Group and Molteno Formation (Stormberg Group)
  - Particularly low lying areas
- More common in arid areas
  - Dispersiveness can increase with time
- Kaolinite at surface/smectite below
  - Be careful!

Identification

- Field and other indicators
  - Eroded, gullied and channelled slopes with tunnels and internal cavities.
  - Turbidity in local waters.
  - Poor crop production and stunted growth.
  - Stunted and multi-stemmed trees (particularly colophospermum mopane)
  - Absence of these does not necessarily mean that the material is not dispersive
Identification (cont)

• Field and other indicators of potential dispersiveness
  – Calcretes above a clay horizon.
  – Various chemistry changes lead to change in pore water SAR and increase in ESP (exchangeable sodium percentage).
  – Clay soils with a “greasy” feel when wet.

Laboratory identification of dispersive soil

• Difficult to reliably identify dispersiveness using a single laboratory tests. We therefore do a number of tests and accept the outcome given by the majority of the tests.
• Various tests for dispersiveness:
  – ESP based tests (exchangeable cations on clays)
  – Double hydrometer test
  – Crumb test
  – Pinhole test
Laboratory identification of dispersive soil

- **Crumb test (Emerson)**
  - USBR Method 5400
  - 2 versions in use
  - Natural & remoulded (15 mm cube)
  - Put small lump in distilled water and describe suspension (1 to 4) that forms.
  - Not totally reliable, but good initial indicator

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Laboratory identification of dispersive soil

- **Double hydrometer (Dispersion) test**
  - Originally used in 1937
  - USBR 5405
  - Based on self dispersion (ie no chemical or mechanical dispersion)
  - Compare with conventionally dispersed hydrometer test
  - Ratio of -5μm fraction in water and using conventional test
  - **Wide variations!! (Not reliable.)**
  - Critical value 35% (Sherard)
  - Walker > 30%
  - Maharaj > 50%
Laboratory identification of dispersive soil

• Chemical tests

– Before 1945 agricultural and soil scientists noted that soil with an Exchangeable Sodium Percentage (ESP) > 15 was dispersive.

– ESP = (Exch Na/CEC) x 100

– Also Sodium Absorption Ratio (SAR) where free salts are present (in pore water solution) (> 10 for dispersive)

– SAR = Na/√((Ca+Mg)/2)

– NB clay chemistry vs pore water chemistry
– Cation exchange from clays
– Dissolved salts in pore water (saturation extract)

Laboratory identification of dispersive soil

• Chemical tests (cont)

– Threshold value of total cation concentration (TCC) in pore water for any given ESP above which soil remains flocculated (non-dispersed)
– Figure shows 2 different soils
– Dispersion could increase with time as leaching of pore water salts
Laboratory identification of dispersive soil

- Chemical tests (cont)
  - US method uses % sodium (Na%) and Total Dissolved Salts in saturation extract (TDS – total dissolved solids)
  - Na% = Na/TDS
  - TDS = Na + K + Ca + Mg (meq/l of sat extract)
  - Revised pinhole test is, however, more reliable

Identification of dispersive soil

- Elges 1985
  - Based on work by Harmse (1980) - a combination of pH, conductivity, Sodium Adsorption Ratio (SAR), ESP and Exchangeable Magnesium Percentage (EMgP) are employed
  - Generally implemented in southern Africa (YOU MUST BE ABLE TO APPLY THIS)
Laboratory identification of dispersive soil

• Pinhole test
  – USBR Method 5410
  – Accepted reference test
  – Pass water through a 1 mm diameter hole in a 25 mm long and 35 mm diameter compacted sample under various “heads”
  – Monitor outflow turbidity
Identification of dispersive soil

- Since 1985
- Gerber and Harmse (1987)
  - Based on Double hydrometer?

![Graph showing the identification of dispersive soil based on cation exchange capacity.]

Identification of dispersive soil

- Important points
  - In crumb tests, composition of water important
  - Debate as to whether materials for pinhole and crumb test must stay at natural water content (drying affects results?)
  - Use slightly alkaline solution for crumb test (0.001 N NaOH)
  - Type (and preparation/age/etc) of dispersant appears to affect results
  - Interpretation of chemical results important (%age of soil or fines or clay?)
  - Remember
    - Li > Na > K > Rb
Dispersion versus erosion

• Three aspects:
  – *Deflocculation of clay particles in almost still, pure water* (*dispersion*)
  – *Removal of material under flow movement of water* (*erosion*)

Erodible materials

*Erosion is a result of the tractive forces of water flowing over the material exceeding the ability of the material to resist erosion. This erosion resistance is essentially the shear resistance.*
Erodible materials

- Erosion is thus a **function of speed of flow of water and resistance to erode**

Treatment

- Different treatment techniques are required for each type of material
- Needs to be identified first
- **Dispersive soils**
  - Replace sodium with calcium
  - Add lime or gypsum or CaCO₃
- **Erodible soils**
  - No problem if protected
  - Problems on slopes
    - Revegetation
    - Water flow retarding structures
    - Water control
Treatment (solving) of the dispersive problem

- Avoid its use
- Limit permeability ($10^{-5}$ to $10^{-7}$ cm/s)
- Add lime, gypsum or aluminium sulphate
  - Addition of calcium to erodible and slaking materials will not replace sodium
- May stabilize the materials and increase Cohesion
- When used in construction, ensure that materials are compacted
  - In thin layers
  - As high a density as practicable (min 98% Stand Proctor MDD)
  - Scarified between layers to avoid smooth interfaces
  - At 2 – 3% above OMC
- Control surface and subsurface water movement
  - Sand filters can be used to control leaks
    - $D_{15} = 0.5$ for soils with $d_{85} > 0.03$ mm
    - $D_{15} = 0.2$ for soils with $d_{85} < 0.03$ mm

END