Railway Earthworks: *Slips, Slides and Flows*

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What are we going to talk about?

Introduction to LNE&EM Geotech team & Railway Earthworks

Case histories: Slips (Gonerby, Dorrington) Slides (Woodwalton, Apperley Lane) Flows (Sutton Bonington, Clarborough)

Complex failures: Unstone, Hatfield, Farnley Haugh
Who we are:

LNE&EM Route

Geotechnical Asset Management team
What is a railway earthwork?

**Embankment**
Constructed by tipping fill from nearby cuttings / borrow pits onto natural ground

**Soil / Rock Cutting**
Constructed by excavating through natural ground
What is a railway earthwork?
What is a railway earthwork?
What can go wrong with earthworks?

Embankment Failure
Settlement of underlying natural ground

Settlement through embankment 'sinking' into underlying material.
What can go wrong with earthworks?

Embankment Failure

Settlement of underlying natural ground
Settlement of embankment fill over time

Settlement through compaction/consolidation of embankment material.
What can go wrong with earthworks?

Embankment Failure

Settlement of underlying natural ground
Settlement of embankment fill over time
Shrink / Swell of clay embankments
What can go wrong with earthworks?

Embankment Failure

Settlement of underlying natural ground
Settlement of embankment fill over time
Shrink / Swell of clay embankments
Settlement due to burrowing animals
What can go wrong with earthworks?

**Embankment Failure**

Settlement of underlying natural ground
Settlement of embankment fill over time
Shrink / Swell of clay embankments
Settlement due to burrowing animals
Translational failure
What can go wrong with earthworks?

Embankment Failure

- Settlement of underlying natural ground
- Settlement of embankment fill over time
- Shrink / Swell of clay embankments
- Settlement due to burrowing animals
- Translational failure
- Rotational failure
What can go wrong with earthworks?

Embankment Failure

Settlement of underlying natural ground
Settlement of embankment fill over time
Shrink / Swell of clay embankments
Settlement due to burrowing animals
Translational failure
Rotational failure
Earthflow
What can go wrong with earthworks?

Embankment Failure

Settlement of underlying natural ground
Settlement of embankment fill over time
Shrink / Swell of clay embankments
Settlement due to burrowing animals
Translational failure
Rotational failure
Earthflow
Washout
What can go wrong with earthworks?

Embankment Failure

Settlement of underlying natural ground
Settlement of embankment fill over time
Shrink / Swell of clay embankments
Settlement due to burrowing animals
Translational failure
Rotational failure
Earthflow
Washout
Scour
What can go wrong with earthworks?

Cutting Failure
Translational failure
What can go wrong with earthworks?

Cutting Failure
  Translational failure
  Rotational failure
What can go wrong with earthworks?

Cutting Failure
- Translational failure
- Rotational failure
- Washout
What can go wrong with earthworks?

Cutting Failure
- Translational failure
- Rotational failure
- Washout
- Earthflow
What can go wrong with earthworks?

Cutting Failure
- Translational failure
- Rotational failure
- Washout
- Earthflow
- Rock fall
What can go wrong with earthworks?

Cutting Failure
- Translational failure
- Rotational failure
- Washout
- Earthflow
- Rock fall
- Burrowing
Slips, Slides or Flows...?

Embankment Failure
- Settlement of underlying natural ground
- Settlement of embankment fill over time
- Shrink / Swell of clay embankments
- Settlement due to burrowing animals
  - Translational failure
  - Rotational failure
  - Earthflow
  - Washout
  - Scour

Cutting Failure
- Translational failure
- Rotational failure
- Washout
- Earthflow
- Rock fall
- Burrowing
Slips: Gonerby Moor Cutting
Gonerby Moor Cutting

- Nodular Charmouth Mudstone
- Jericho Gryphaea Bed (Shelly Carb Mudstone)
- Charmouth Mudstone
Gonerby Moor Cutting

Material in Cess

Steep well vegetated cutting slope

Track issues
Gonerby Moor Cutting
Gonerby Moor Cutting – Further Work
Gonerby Moor Cutting – Further Work
Gonerby Moor Cutting – Further Work
Gonerby Moor Cutting – Investigation
Gonerby Moor Cutting – Monitoring
Gonerby Moor Cutting – Monitoring

Negative V movement means bank is moving towards the track.
“Slips” – Dorrington Embankment
Slips (Rotational Failure) Dorrington Emb.
Slips (Rotational Failure) Dorrington Emb.

- Clay and silt, tidal flat deposits
- Till, Middle Pleistocene
- Mudstone, Peterborough member
- Sandstone and siltstone, Kellaways sand member
- Till, Middle Pleistocene
- Mudstone, Peterborough member
- Sandstone and siltstone, Kellaways sand member
Slips (Rotational Failure) Dorrington Emb.
**Slips (Rotational Failure) Dorrington Emb.**

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<td>CLAY (UNDIFFERENTIATED) and SILT (UNDIFFERENTIATED)</td>
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Slips (Rotational Failure) Dorrington Emb.

Minor track fault & loss of ballast (November 2013)
Slips (Rotational Failure) Dorrington Emb.

Minor track fault & loss of ballast (November 2013)
Dorrington Embankment

Cess rail dropping, loss of ballast

Back scar

Assumed slip surface

Toe bulge and leaning fence
Dorrington Embankment

Excavation to install gabions and stone
Dorrington Embankment

Excavation to install gabions and stone
Dorrington Embankment

Excavation to install gabions and stone
Dorrington Embankment

Further track fault

Gabions pushed forwards
Dorrington Embankment

Gabions pushed forwards

Placed stone
Dorrington Embankment

SP02 67.0330 Down
Dorrington Embankment Slip
7 Jan 2013

Outline Design

Free Draining (6-8 inch) or Similar

Layer of Terram

Original Profile

3m

6-8 inch
Dorrington Embankment
Dorrington Embankment
Dorrington Embankment
Dorrington Embankment
Dorrington Embankment
Dorrington Embankment

SPD2 67m+0400yds
Slides: Woodwalton Cutting

[Image: A railway cutting with railway tracks and a grassy slope.]
Woodwalton Cutting

[Map showing Oxford Clay, Glacial Till (Diamicton), and Aqueduct]
Woodwalton Cutting
Woodwalton Cutting
Woodwalton Cutting
Woodwalton Cutting
“Slides” – Apperley Lane
Apperley Lane – translational failure
Apperley Lane – translational failure
Apperley Lane – translational failure
Apperley Lane – translational failure
Photomontage following regrading works on Monday night. Note the location of the seepage which was observed during the excavation works approximately 3 metres to 4 metres below patio level (location to be confirmed by photographs taken during these works).
Apperley Lane – investigation

Slip plane exposed during emergency remedial works approximately 3 metres to 4 metres below slope crest, note smoothened and slickensided surface between the dark grey weak and friable siltstone and the softened and distorted clay / weathered rock.
Boundary between the dark grey weak and friable siltstone and the softened and distorted clay / weathered rock exposed during emergency remedial works approximately 3 metres to 4 metres below slope crest.
Apperley Lane – Ground model
Apperley Lane – Ground model

Water flowing towards slope from perforated pipes

Groundwater levels are estimated

Seepage noted during excavation works

Surface layer of clay (weathered rock)

Siltstone bedrock, exposed below 0.5 metre to 1 metre thickness of clay (weathered rock) on slope surface

[Diagram of Apperley Lane ground model with annotations]
Apperley Lane – temporary support

- Ground profile prior to failure (dashed line)
- Temporary retaining structure (concrete and scaffold arrangement)
- New slope profile
- Scaffold platform
Apperley Lane – temporary support
Apperley Lane – Final repair

Sketch plan of proposed works at Apperley Lane (Phase 2)

- Area of gabion mattresses and ground nails (Phase 1)
- Retaining wall below slope
- Proposed kingpost retaining wall (Phase 2)
- Original line of wall
- Cut off drain (Phase 2)
- Approximate extent of slipped areas
- No. 1 West View
- Garage
- Garden
- Patio
Apperley Lane – Final repair
Flows: Sutton Bonington, nr Keyworth
Flows: Sutton Bonington, nr Keyworth

Gunthorpe Formation
L. Triassic Gypsiferous Mudstone

Soakaway

Sports Hall

Sand and Gravel Deposits
Sutton Bonington, nr Keyworth
Sutton Bonington, nr Keyworth
Sutton Bonington, nr Keyworth
Flows: Sutton Bonington, nr Keyworth
Clarborough derailment (washout)
Clarborough derailment (washout)
Clarborough derailment (washout)
Clarborough derailment (washout)

Sketch showing the drainage conditions immediately following the incident on the afternoon of 27 April 2012.

- **Debris on track**
- **Surface water flowing down slope face**
- **Damp ditch (becoming drier downstream and almost fully dry at the west end of the cutting in the woods)**
- **Ponding water**
- **Ditch flowing with water**
- **Dry ditch**
- **Surface water flows**
- **Stream**
- **Stream in culvert beneath path**
- **Surface water flows**

Significant quantities of water could be heard going into the small culvert here in the hours immediately following the failure, this had slowed to a trickle by 8pm.
Clarborough derailment (washout)
Clarborough derailment (washout)

View from crest from point of failure, note fast flowing water over slope surface and the grass covered unstable masses on the slope face. Note also the part of the tree stump on the Up Line (circled).
Clarborough derailment (washout)
Clarborough derailment (washout)

View of failure on 28/04/2012.

Work to clear loose material on slope face during night of 28 and 29/04/2012.
Clarborough derailment (washout)

View of failure on 28/04/2012.

View of failure on 29/04/2012 following works to clear loose material on face. This work found that there was an significant area of potentially unstable very soft saturated material near slope crest highlighted in orange.
Clarborough derailment (washout)

Simple monitoring system put in on 29/04/2012 comprising pegs with string line and white paint at top edge of soft saturated mass.
Clarborough derailment (washout)

Work carried out on 10/05/2012 to remove soft saturated mass near slope crest.
Clarborough derailment (washout)

View from crest of opposite slope of re-profiled upper slope following work to remove soft saturated mass near slope crest.
Unstone Landslip

Photograph taken on 23 January 2014

Recently placed material, date of placement unknown

Water ponding in upper slope

Main body of the landslip in yellow. 5 metre high backscar just in front of dashed line, toe bulge by solid line.

Toe bulge from lower slip shown in red
Hatfield Colliery
Farnley Haugh
Thank you.