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Basally Reinforced Platforms for Piled Embankments – Two Case Studies:

A421 M1 Junction 13 to Bedford Improvements, UK

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Piled Embankments - A Solution

What is the problem?

- Weak, compressible soils (i.e. alluvium, peat, normally consolidated clays and made ground)
- Leading to high settlements,
- Which may have a knock-on effect of long construction times (i.e. surcharge periods, staged construction) or unacceptable post construction settlements and differential settlements.

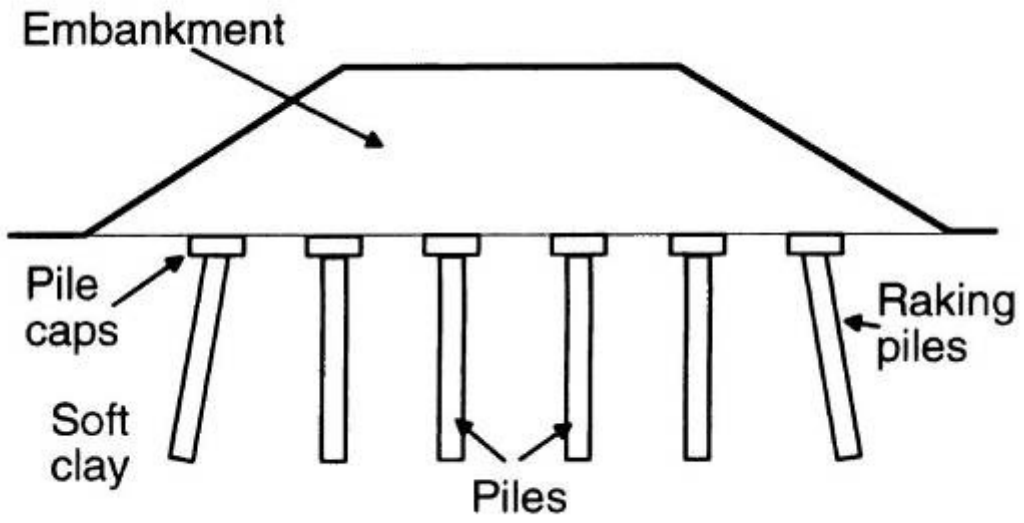
Available Solutions

- Excavate and replace
- Staged construction; with and without the use of surcharge and vertical drains.
- Lightweight Fill
- Ground improvement;

  Vibro stone columns, vibro concrete columns, soil mixing, dynamic compaction
- Piled reinforced concrete raft
- Piled embankment

Piled Embankments Without Reinforcement

Relies solely on arching in embankment fill, can lead to punching failure where the piles punch through into the embankment fill. Consideration required to ensure the edge piles can take the lateral loads imposed by lateral thrust in the embankment, i.e. stronger piles or raking piles.

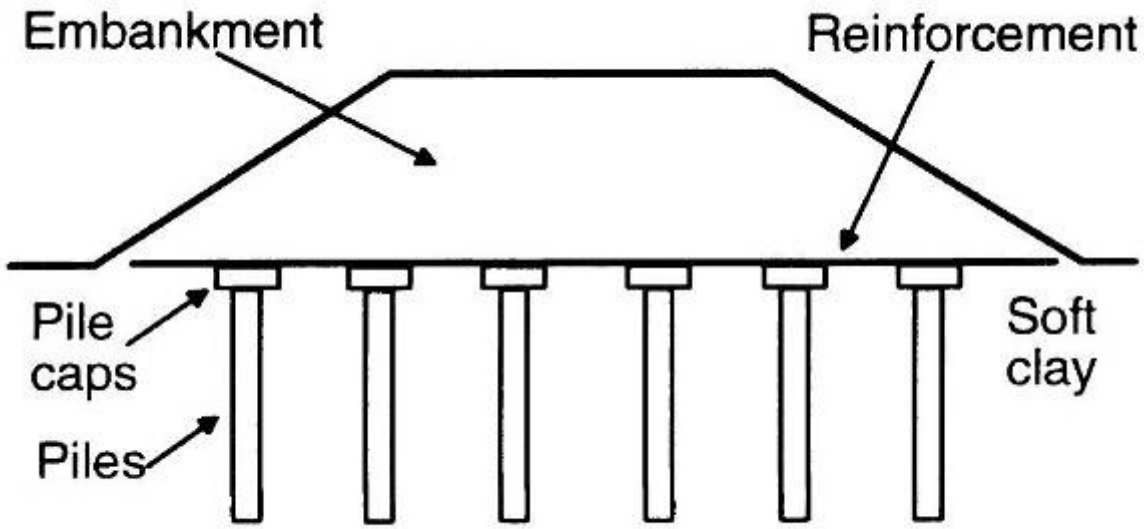


a) Conventional piled embankment

(Fig 66a from BS8006)

Piled Embankments With Reinforcement

Relies on soil arching in the embankment and membrane action within the reinforcement. The reinforcement takes the lateral embankment thrust loads so raking piles not required.



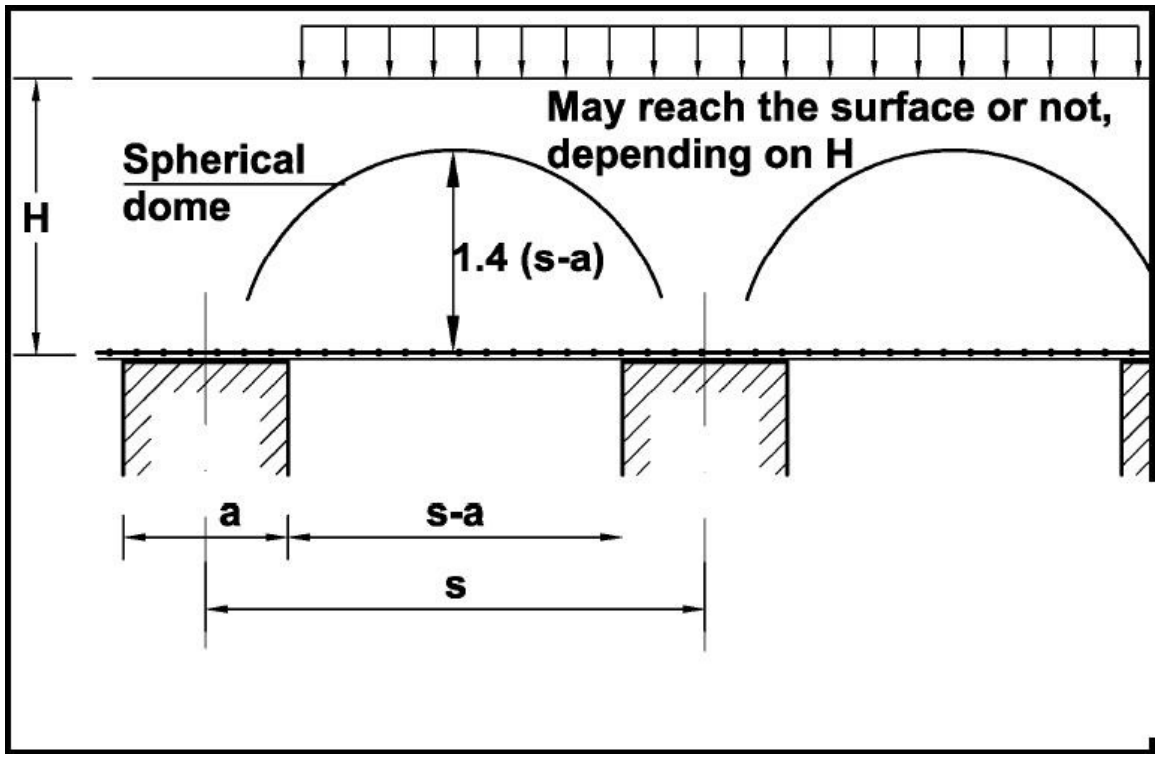
b) Piled embankment with basal reinforcement

(Fig 66b from BS8006)

General Mechanism of Piled Embankments with Reinforcement

- Arching Mechanism

  (as BS8006 1997)



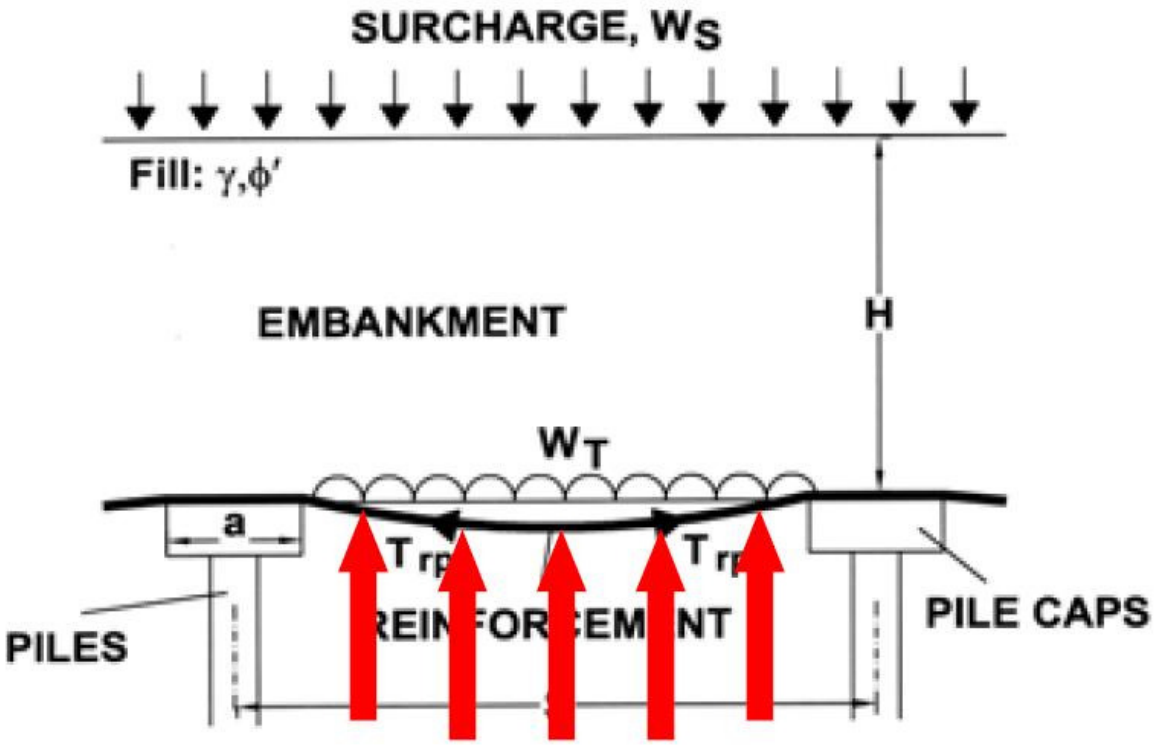
General Mechanism of Piled Embankments with Reinforcement

- Membrane action mechanism

Photograph courtesy of Huesker Ltd

General Mechanism of Piled Embankments with Reinforcement

- Counter pressure – subsoil support acting to resist the formation of hammocks in the reinforcement



Picture Source: BS 8006: 1995

Case study: Brogborough Embankment

A421 M1 Junction 13 to Bedford Improvements, Bedfordshire, UK

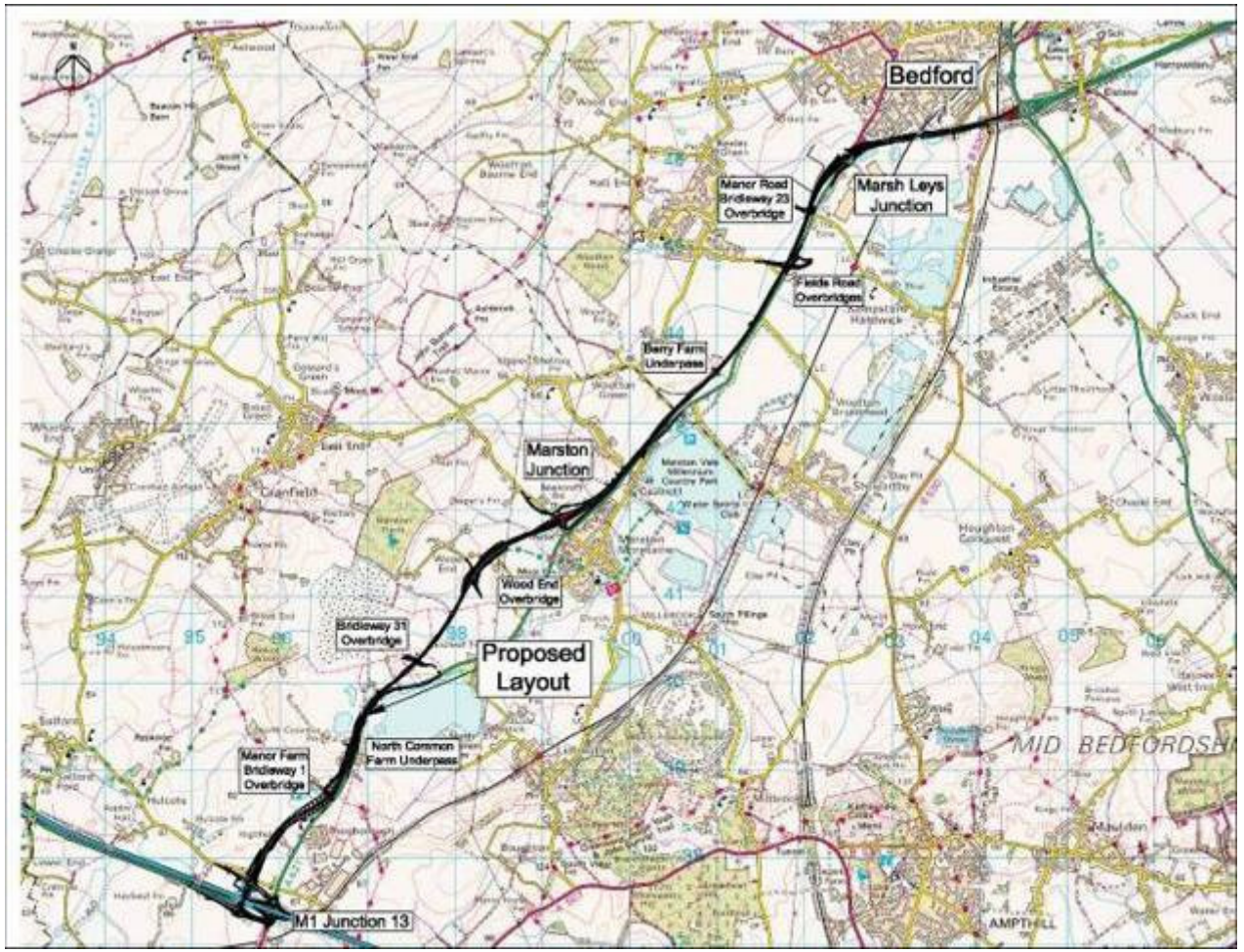
Photograph courtesy of BBCEL

Brogborough Embankment

Stakeholders:

- Client: Highways Agency
- Contractor: Balfour Beatty Civil Engineering
- Engineer: Scott Wilson Ltd
- Reinforcement Supplier: Huesker Ltd
- Piling Contractor: Stent Foundations
- Earthworks Contractor: John Jones Excavation

A421 M1 Junction 13 to Bedford Improvements Scheme.



Clay Pits: Historic Aerial Photography

Aerial photo from 1962

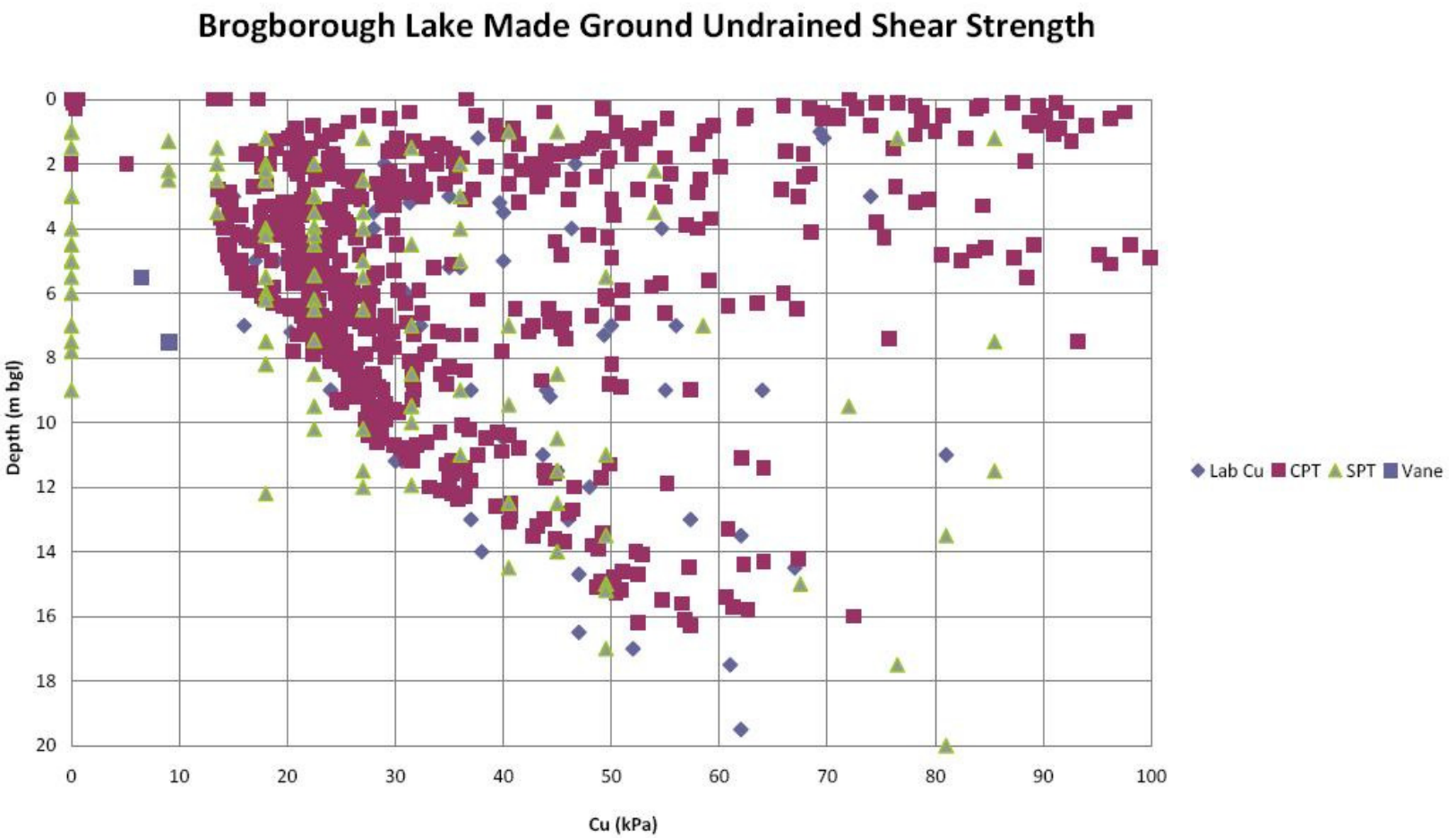
Brogborough Lake Clay Pit

Brogborough Clay Pits – Ground Conditions

Made ground consisting of soft clay to depths up to 20m:

- Desiccated crust
- Soft clay, increasing in stiffness below around 8m depth
- Oxford Clay Formation

Brogborough Lake - Undrained Shear Strength



Geometry

- Embankment heights above the reinforcement between 1.5m and 7m
- Clay fill embankment
- 1v in 3h side slopes
- (1v in 1h reinforced side slopes adjacent to the landfill to prevent the embankment encroaching onto the landfill).
- 275mm square precast driven piles with cast insitu 900mm diameter pile cap
- Piles at 1.75m, 2.0m and 2.5m centres

Design Aspects and its Realization in Practice

BS 8006 – limit strain / deformation

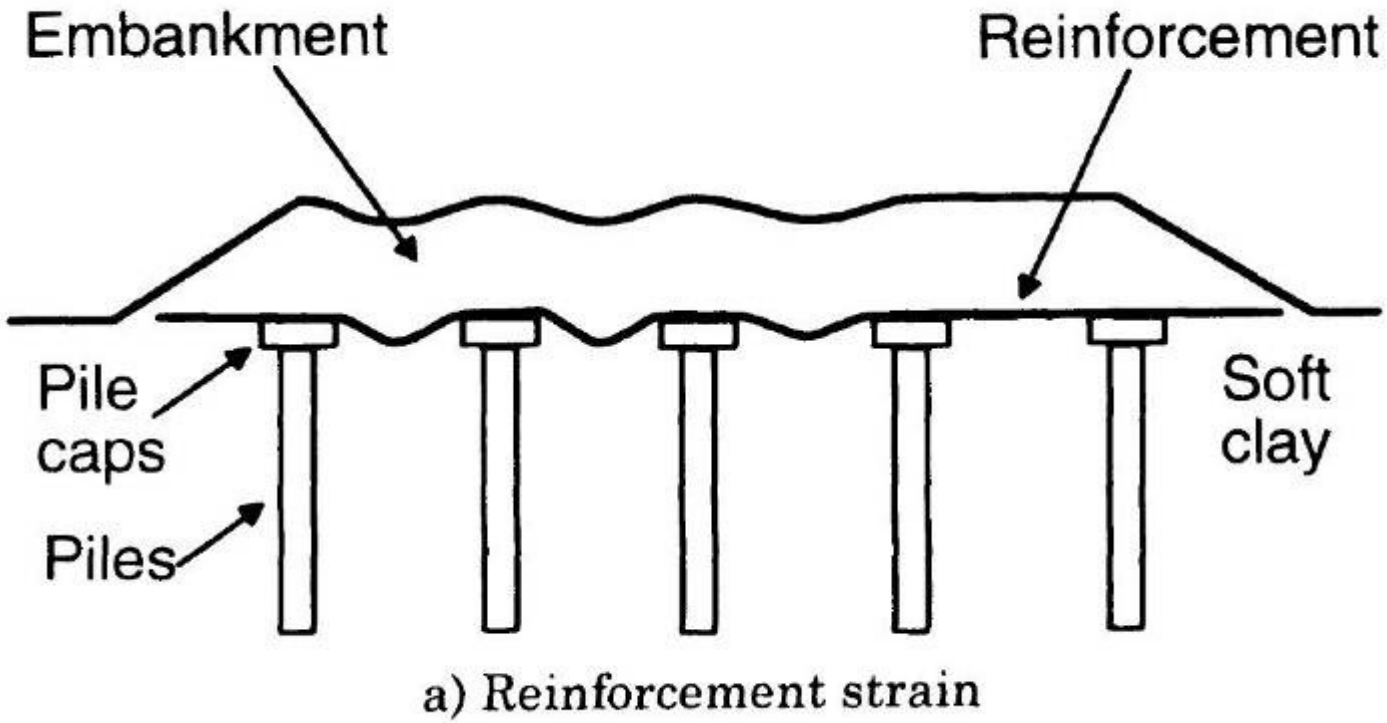


Fig 68a from BS8006

Low Embankment Heights: Maximum Design Strain 3%

- Multiple layers of high strength polyethylene reinforcement (strain at peak strength c. 10% - 12%)
- Single layer (in each direction) of high strength low strain Poly-Vinyl Alcohol (PVA) reinforcement (strain at peak strength c. 6%)
- Huesker Fortrac R-MP reinforcement used

Reducing Long-Term Reinforcement Strain

Strain the reinforcement during construction in order to reduce post construction movements:

- Lay the reinforcement flat and even
- Adequate anchoring of reinforcement
- Allow reinforcement to form hammocks during construction – minimise counter pressure: use compressible fill.

Compressible Fill Between Pile Caps

Fill between pile caps needs to be:

- Sufficiently stiff to allow the reinforcement to be placed flat and without sagging
- Compressible enough to allow rapid deflection under load.

Reliance on the weak substrata to deform:

- Loads the substrata, inducing settlements (-ve SF on piles)
- Time for consolidation

Compost as Compressible Fill

- Peat has been used where locally available
- Absence of peat in Bedfordshire
- BBCEL proposed compost as an alternative
- Compost sourced from manufacturers of compost from garden waste
- Static load and compaction testing indicated compost had adequate compressibility

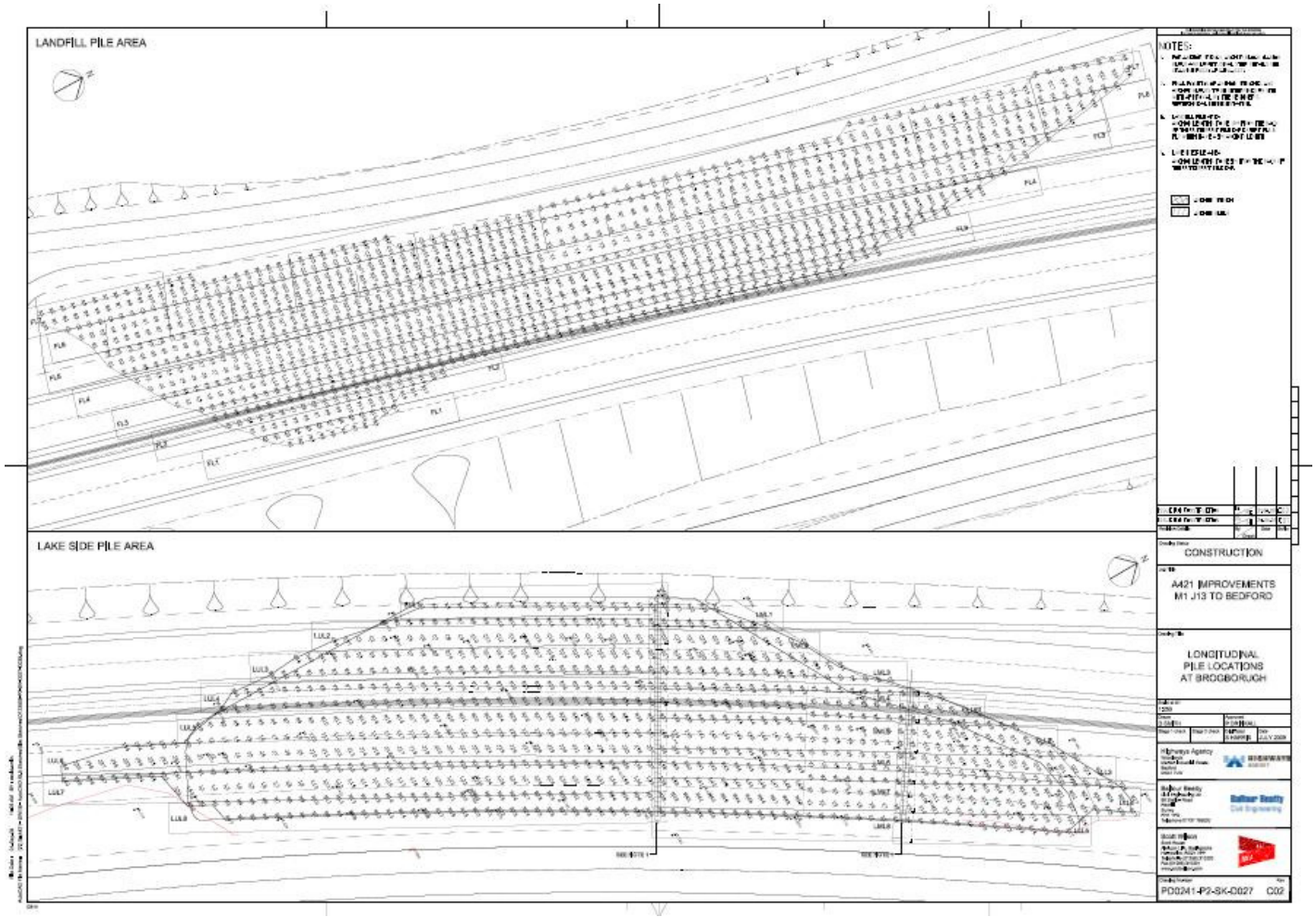
Compost Layer

Photograph courtesy of BBCEL

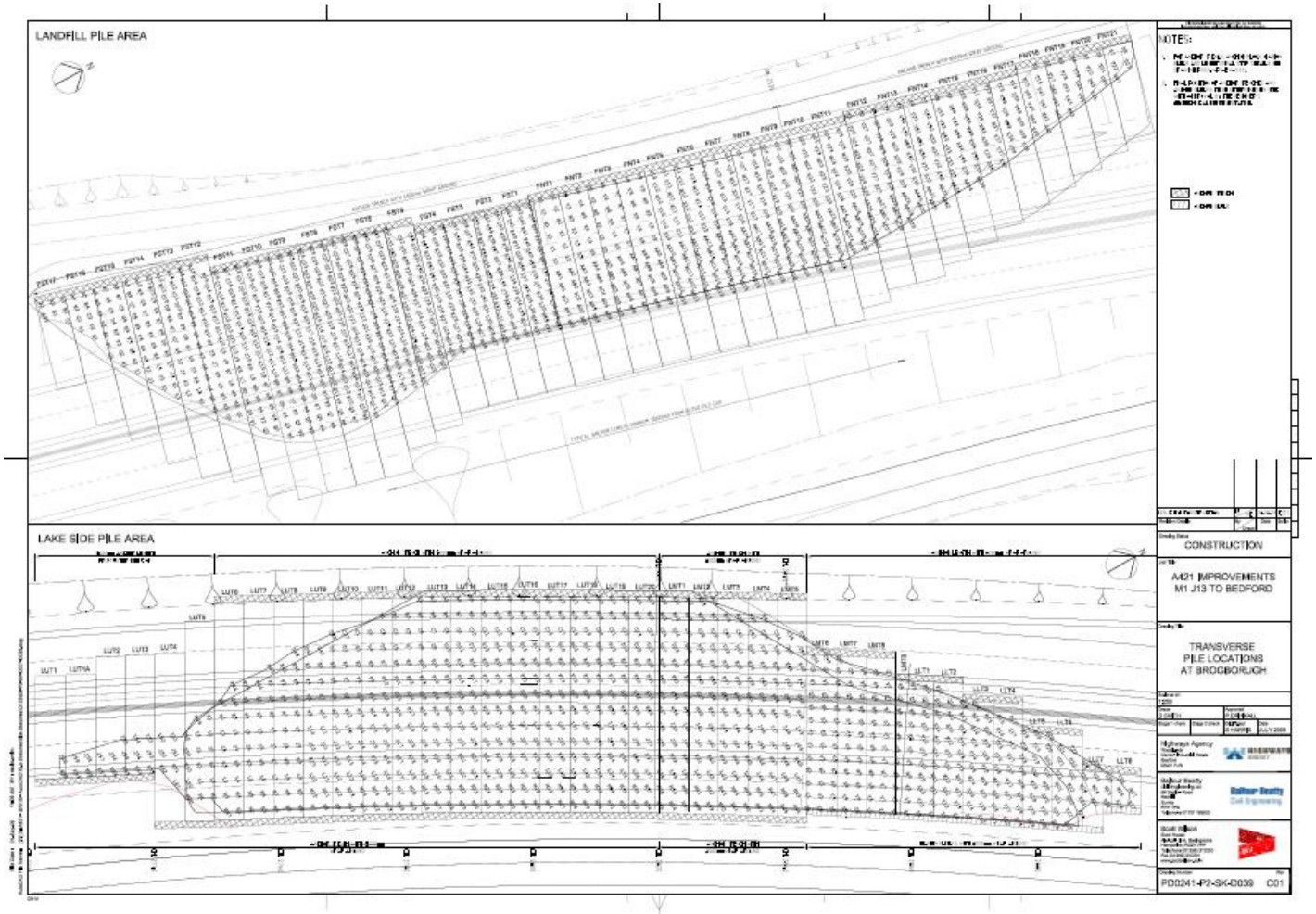
Construction

- Reinforcement ordered in bespoke lengths, each roll has its specific place in the construction
- 500mm of Class 6I/6J over the reinforcement
- Embankment made of Class 2 (site won Glacial Clay)
- Hi-visibility warning layer between the Class 6I/6J layer and the overlying Class 2 embankment

Reinforcement layout (1)



Reinforcement layout (2)



Construction - Driving Piles

Photograph courtesy of BBCEL

Construction - Casting Pile Caps

Photograph courtesy of BBCEL

Construction - Placing Compost Between Pile Caps

Photograph courtesy of BBCEL

Construction - Excavator Tracks on Pile Caps

Photograph courtesy of BBCEL

Construction - Rolling Out Reinforcement

Photograph courtesy of BBCEL

Construction - Anchor Trench

Photograph courtesy of BBCEL

Construction - High-Visibility Warning Layer

Photograph courtesy of BBCEL

Performance

- The embankment is still under construction
- Final piles were installed in mid November 2009.
- Instrumentation: Rod and plate settlement gauges above some of the pile caps, with the aim of monitoring the settlement of the pile group
- Construction is going well.