Ground Improvement Techniques

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Introduction and Objectives

- To provide an overview of the more common ground improvement techniques available

- To consider those systems currently accepted by NHBC together with NHBC requirements

- What can go wrong !!
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What is “ground improvement”

One definition I found:-

The process in which in-situ soils are improved for the support of the foundations
but some sites have little or no in-situ soil eg open cast coal mines and quarries

A better definition might be:

*The process in which sites are improved to enable development*
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Common Ground Improvement Techniques

- Placement of Engineered Fill
- Vibro Compaction (and their variants)
- Dynamic Compaction
- High Energy Impact Compaction
- Rapid Impact Compaction
- Soil Improvement/Stabilisation
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Engineered Fill
Engineered Fill

- Probably the “least risk option” for NHBC as the quality of the fill material can be controlled from the start and the methodology is well known.

- Selected fill material—either recovered from stock piles on site or imported—is compacted in specified layers using specified plant using geotechnical principles.

- The method of compaction is described in the Department of Transport Specification for Highway Works.

- Satisfactory performance of the fill material must also be demonstrated.
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Vibro Compaction
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Vibro Compaction

Loose sands or granular fill

Densified material
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Vibro Stone Columns

- Reinforce weak granular and clay soils
- Economical site treatment
- No spoil to remove
- Problems in soft clays
- Problems on “gassing” sites
Concrete columns act like piles
Economical
No spoil to remove
Problems in soft ground
Problems in newly filled sites
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Dynamic Compaction
Dynamic Compaction

- Highly effective in loosely compacted soils
- Cost effective on large sites
- Generally not suitable on cohesive soils and silty soils with a high water table (liquefaction risk)
- Potentially significant noise and vibration
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High Energy Impact Compaction
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High Energy Impact Compaction

- Most effective in granular and/or loosely compacted soils
- Can be effective on large sites
- Generally not suitable on cohesive soils and silty soils with a high water table (liquefaction risk)
- There is some noise and vibration
- The depth of improvement has, in our experience, fallen short of contractor claims (typically 1.5m max versus 3m +)
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Rapid Impact Compaction
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Rapid Impact Compaction

- Most effective in granular and/or loosely compacted soils
- Cost effective on smaller sites where depth of improvement required is relatively shallow
- Particularly well suited for landscaping and road areas
- Generally not suitable on cohesive soils and silty soils with a high water table (liquefaction risk)
- There is some noise and vibration
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Soil Improvement/Stabilisation

“Stabilisation” – defined as the permanent alteration of the mechanical and geotechnical properties of a soil by the addition of a binder (e.g., cement or lime)
Soil Improvement/Stabilisation

- “Improvement” – the temporary alteration of the geotechnical properties of a soil to facilitate conventional engineering placement
- NHBC currently accepts “Improvement” but not “Stabilisation”
- NHBC are currently co-funding a research project with BRE to look at NHBC’s future stance on “Stabilisation”.
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NHBC Requirements

- Well documented in NHBC Standards Chapter 4.6

- Where treatment is full depth, a suitably designed raft foundation or reinforced concrete strip would normally be acceptable

- Where treatment depth is partial, a suitably designed raft foundation only would normally be required

- A suitably experienced Engineer independent of the specialist contractor, to carry out the foundation design and to confirm the required load/settlement performance of the ground improvement
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NHBC Requirements

Verification tests to confirm compliance with NHBC Performance Standards

- Measurement of placement density and air void ratio – typically minimum placement density 95% maximum dry density and maximum air voids ratio 5%

- Plate bearing tests

- In-situ large scale load tests
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NHBC Requirements

- Plate bearing tests and placement density measurement are normally used as verification tests of *workmanship*.

- Large scale load tests eg dummy footing tests (where reinforced strips are proposed) or zone tests (where raft foundations are proposed) are an appropriate verification test of the *design*.

- So what’s the difference?
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NHBC Requirements

Plate test bulb of pressure

Strip foundation bulb of pressure

20 kPa at 0.9m depth

20 kPa at 1.8m depth
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NHBC Requirements

Plate test bulb of pressure

Raft foundation bulb of pressure

20 kPa at 0.9m depth

20 kPa at 5.5m depth
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Case Studies

Some cautionary tales
Case Study 1- Vibro concrete failure
Case Study 1- Vibro concrete failure
Case Study 1- Vibro concrete failure
Case Study 1 - Vibro concrete failure

Finished ground level

- Fill makeup & Capping Layer
  - Contaminated fill
- Very soft alluvial soils
- Medium dense gravel
Case Study 1- Vibro concrete failure
Case Study 1 - Vibro concrete failure

Fill makeup & Capping Layer
Contaminated fill

Very soft alluvial soils

Medium dense gravel

Vibro concrete columns
Note: jagged cross section

Downdrag?
Case Study 2- Stone column failure

- Infilled gravel pit between 3m and 4m deep
- Fill material comprised clay fill overlying domestic refuse
- Ground treatment comprised bottom fed, vibro replacement system using stone columns
- Depth of treatment varied between 2.5m and 3.5m
- Reinforced strip foundations with ground bearing slab
Case Study 2 - Stone column failure
Case Study 2- Stone column failure

- cracking of properties some 5 to 8 years after construction completed in 1986
- structural damage was considered to be due to a loss of support to the base of the stone columns due to biodegradation of the underlying domestic refuse in the untreated zones.
- Remedial works included piling works and construction of suspended ground floors
Other stone column failure mechanisms

Stone columns

Bulging

Made ground

Very soft alluvial soils

Competent stratum
Case Study 3- Raft tilt failure
Case Study 3 - Raft tilt failure

- Rainfall
- Poorly compacted clay fill
- Rising groundwater
- Infilled open cast coal mine
Case Study 5- Raft tilt failure

Inundation settlement

Infilled open cast coal mine
Case Study 3- Raft tilt failure

Notes:
1. Figures above represent height of brick curve above lowest (zero) point.
2. 1 represents pin number.
Case Study 3- Raft tilt failure

Height of pin 6 above rear left corner pin 16

Date
Height of pin 6 (mm)

28-Aug-99  15-Mar-00  01-Oct-00  19-Apr-01  05-Nov-01  24-May-02  10-Dec-02  28-Jun-03  14-Jan-04  01-Aug-04

Pin 6 data
Case Study 3- Raft tilt failure
Case Study 3- Raft tilt failure

- Options of jacking property back using piles as a reaction system and as permanent support
- Or demolish and rebuild property
- However to expedite the conclusion of the claim, the NHBC bought back the house
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Thank you for listening

and finally

NHBC Technical Services are here to assist you.

Please don’t hesitate to ask one of us on 0844 633 1000
Raising standards to protect homeowners