

## Design and Construction of Rigid Inclusion Ground Improvement Projects

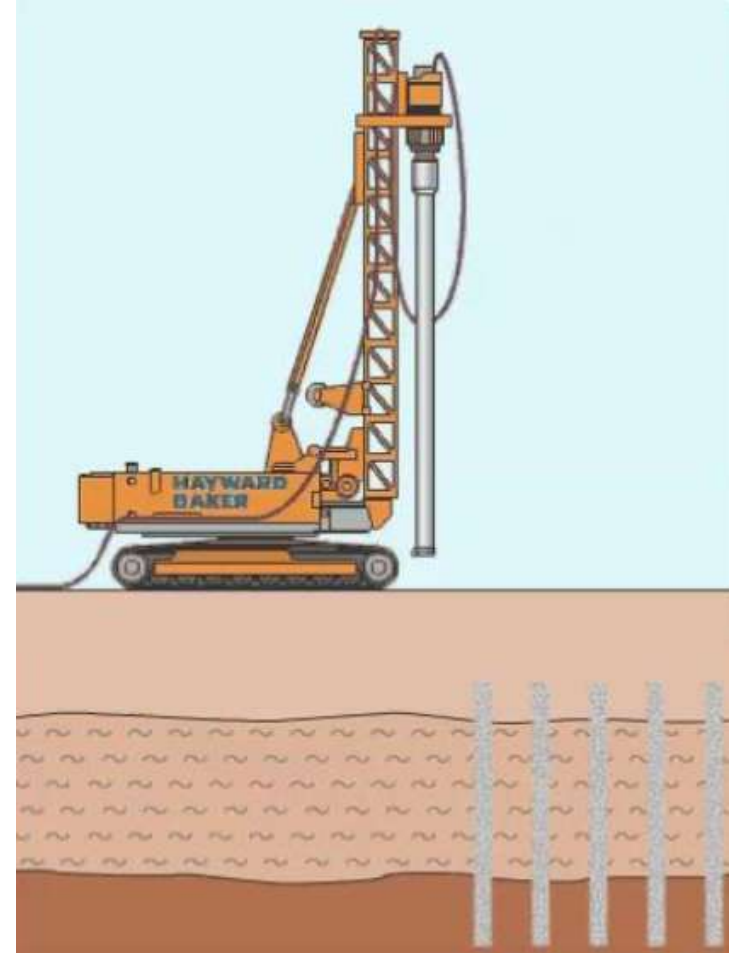
# What are Rigid Inclusions (RI)?

Grout or Cemented Aggregate Element used to Reinforce **Soft Soils**:

- ✓ Reduce settlement
- ✓ Increase bearing capacity

### Trade Names / Techniques:

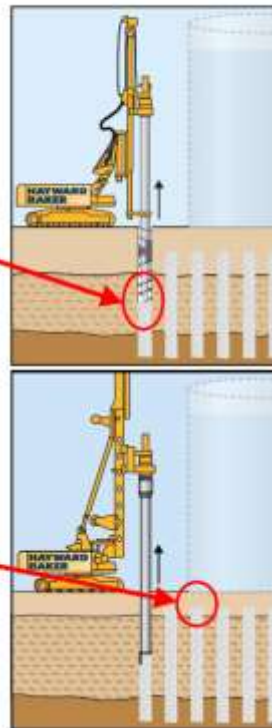
- Controlled Modulus Column (CMC)
- Grouted Impact Piers (GI)
- Geo-Concrete Columns (GCC)
- Cast-in-place Ground Improvement Elements (CGE)
- Controlled Stiffness Column (CSC)
- Augured Pressure Grout Column (APGC)



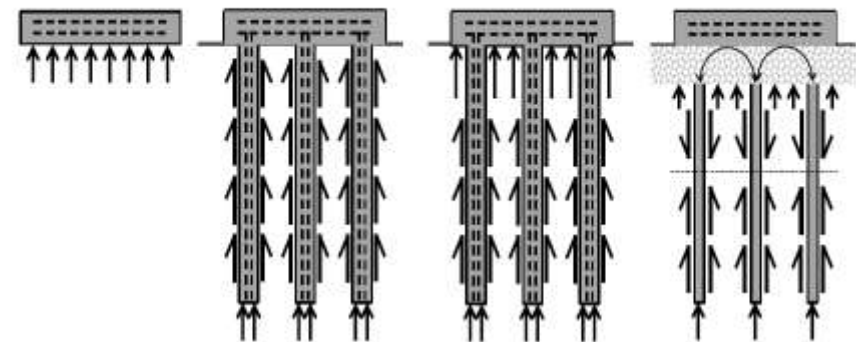
## Design and Construction of Rigid Inclusion Ground Improvement Projects

### Advantages and Applications

- ▶ Transfer loads through weak strata to a firm layer below
  - Bulging hazard for aggregate piers
- ▶ Load can be partly carried by soil
- ▶ Shallow spread footing design
  - No structural connections to elements
- ▶ Minimize spoils



### Rigid Inclusion Design



Shallow (Raft)  
Foundation

Pile (Deep)  
Foundation

Combined Piled-  
Raft Foundation

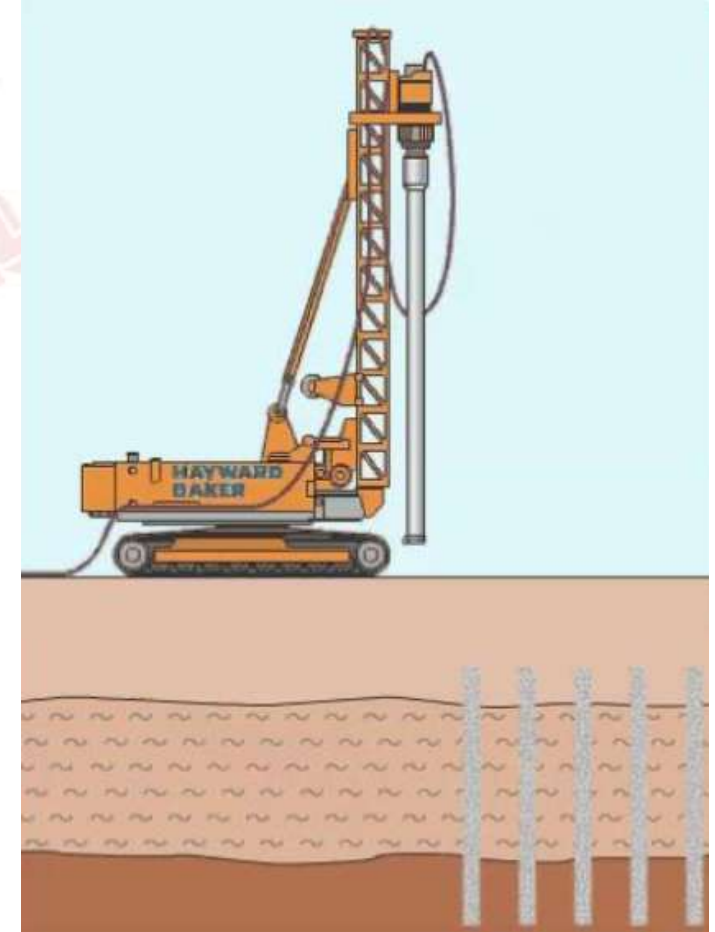
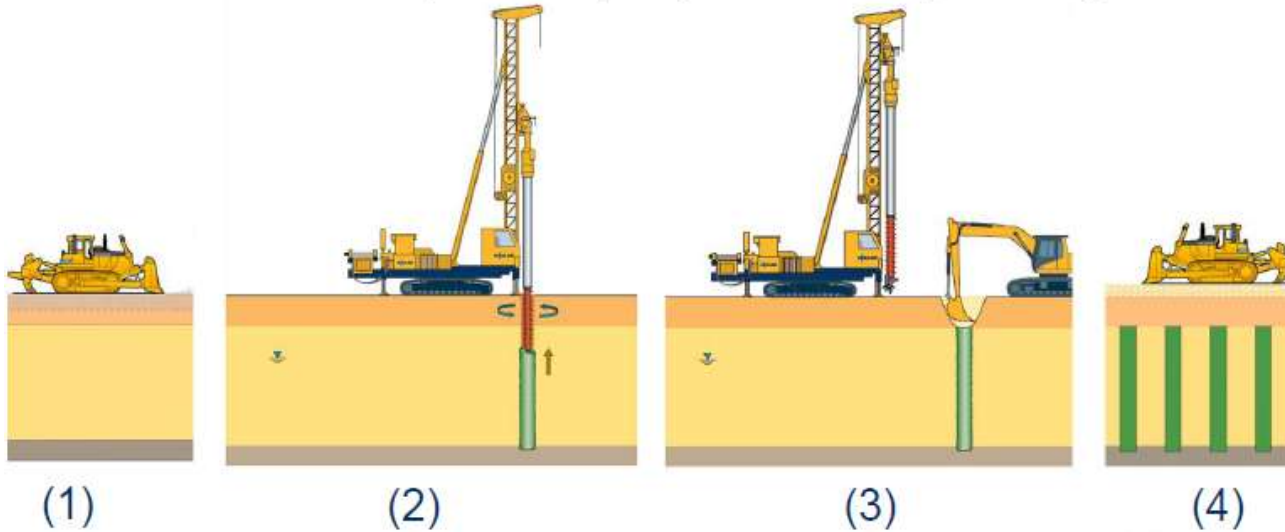
Rigid Inclusions

- ▶ Design of Rigid Inclusion ground improvement systems require the following components:
  - structural capacity of the rigid inclusion element
  - geotechnical capacity
  - load transfer platform mechanics

## Design and Construction of Rigid Inclusion Ground Improvement Projects

### RI System Installation Overview

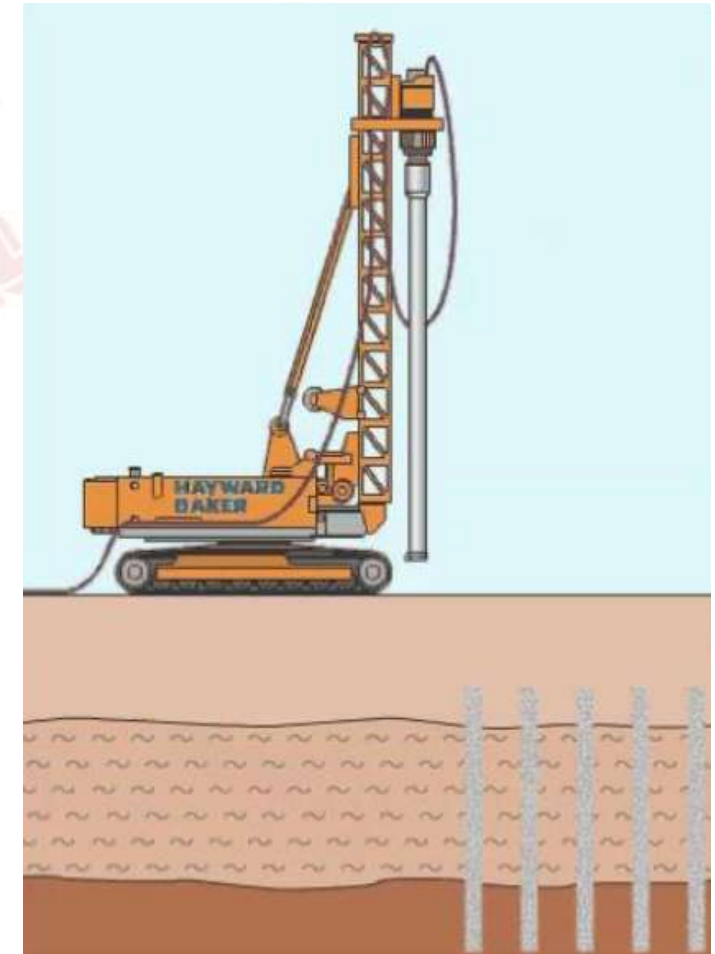
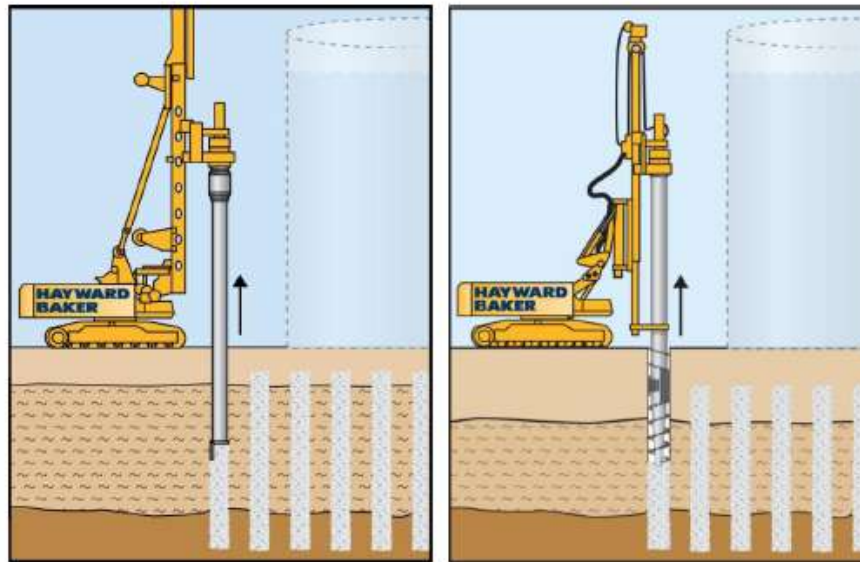
1. Working platform preparation and control
2. RIs are installed using displacement method to advance the element and grouted on withdrawal of the tool
3. Tops of RIs are lowered (as needed)
4. Load transfer platform (LTP) is installed per design





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### How are RIs Installed?



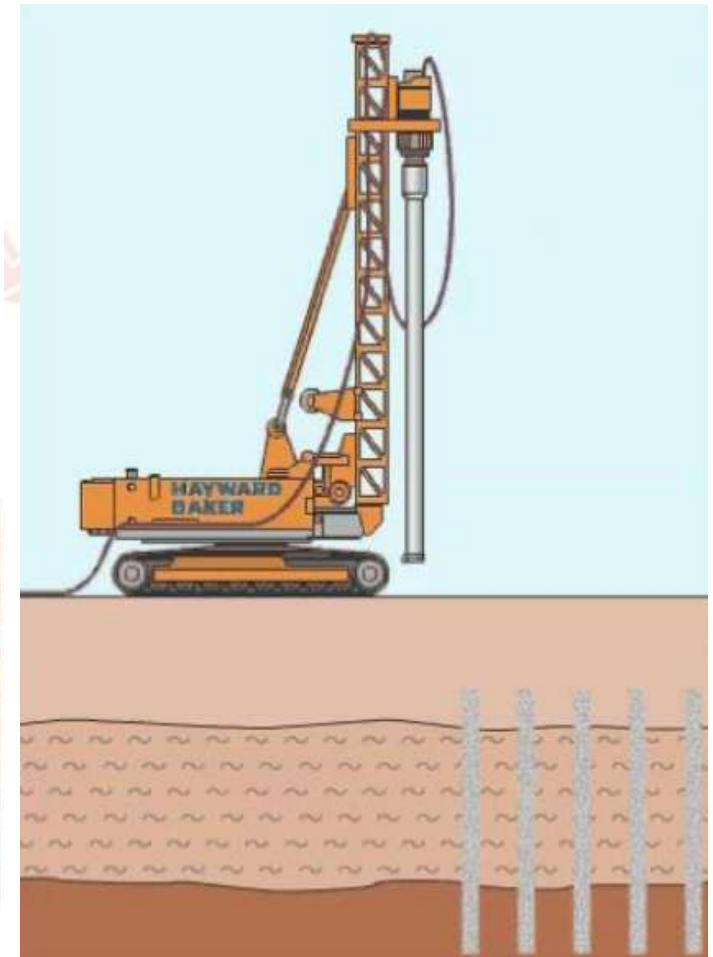
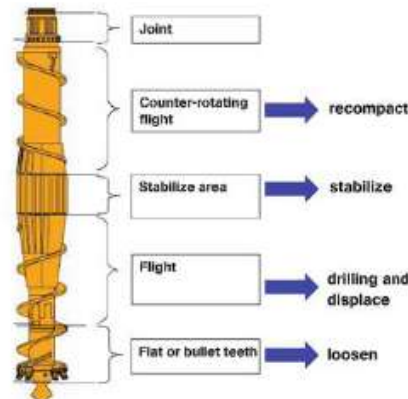
- ◆ Generally installed using *displacement* methods
- ◆ Typical diameters range from 12-inches to 18-inches

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### RI Tooling

#### ◆ Displacement tooling benefits:

- Increases lateral stress in the subsurface
- Produces localized densification of granular soils
- Little spoil generated



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### Rigid Inclusion QC/QA Drill and Tooling

- ◆ Confirm proper diameter of displacement tool
- ◆ Match drill rig size, crowd force / torque / vibratory energy for subsurface conditions and refusal criteria. *Best selected by contractors.*

### Rigid Inclusion QC/QA Installation

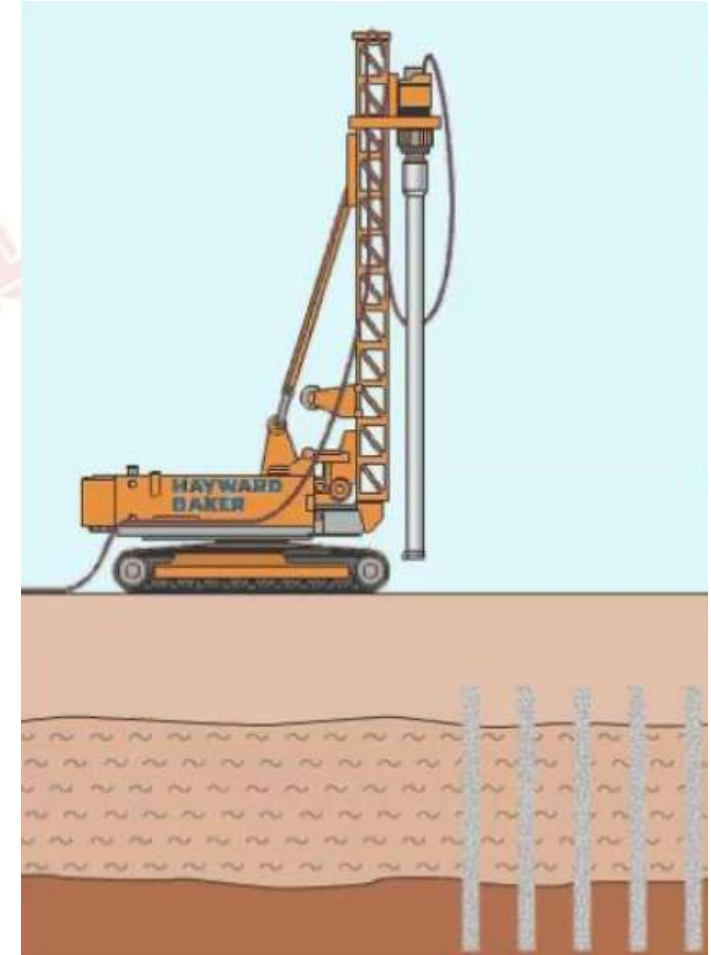
- ◆ Confirm Location and Verticality
- ◆ Monitor adjacent locations
  - Communication
    - Ground movement
    - Grout rise
    - RI top deflection
  - If there is communication, where does it occur? How much grout rise, etc.?
- ◆ Confirm Penetration Depth
  - Does it meet predetermined design depth
  - Does it meet refusal/termination criteria



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### Rigid Inclusion QC/QA Grouting

- ◆ Calibrate the grout pump
- ◆ If non-pressurized system is used, grout must be maintained with proper head level to build continuous grout column
- ◆ If pressurized system is used, determine the line loss and grout pressures
- ◆ Continually check grout quantities vs. delivered quantities
  - Does this match the theoretical volume (plus waste) of our element?
- ◆ Daily slump tests and cylinder preparation
  - Slump is typically 4 to 8 inches, but will vary with tooling and soil type
  - 28 day strength matches design strength



## Design and Construction of Rigid Inclusion Ground Improvement Projects

### Rigid Inclusion QC/QA Finishing

- ◆ Understand top-of-RI elevations vs. bottom of working elevation and Load Transfer Platform
  - Impacts constructability and design function
- ◆ Perform cut offs while grout is wet / fresh (typical)
  - Can be done after, with care

