Rigid inclusions

Efficient reduction of settlement

Benefits

Rigid inclusions are a ground improvement method using high deformation modulus columns constructed through compressible soils to reduce settlement and increase bearing capactiy. This allows the use of shallow foundations to support structures on compressible soils. Soil reinforcement with rigid inclusions reduces settlements very efficiently (with a reduction factor in the range of 3 to 8) and structure construction works can, in most cases, start immediately after ground improvement.

Ground improvement efficiency depends on the stiffness relationship between the soil and the columns. Load from the structure is distributed to the soil and columns via a load transfer platform or rigid foundation.

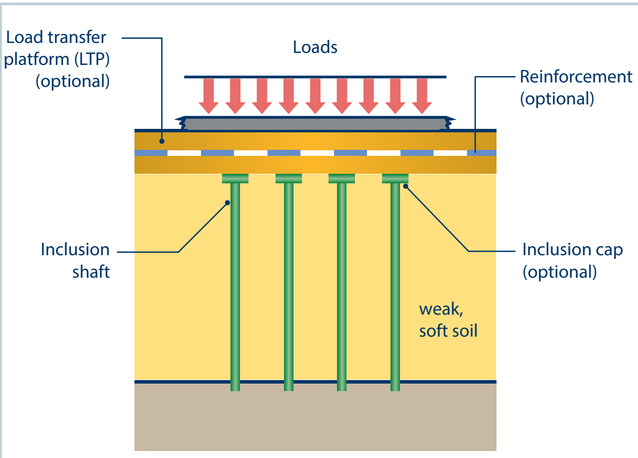


Figure 1: Different components of a complete foundation on rigid inclusions

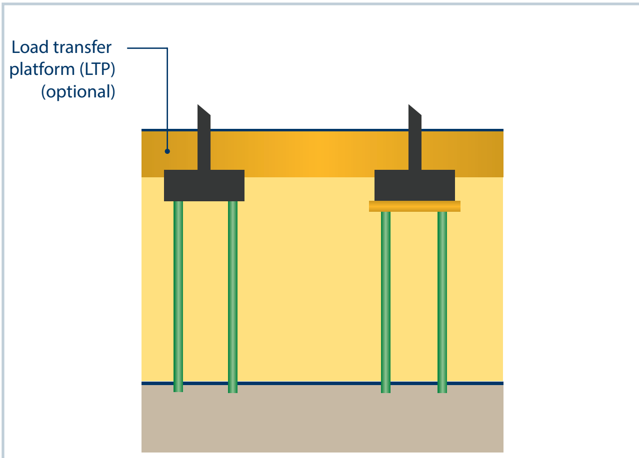


Figure 2: Footing with / without LTP

Applications

- Industrial and commercial buildings
- Embankments for roads and rail
- Storage tanks and terminals
- Residential buildings
- Warehouses
- Public buildings
- Industrial flooring
- Wind turbines

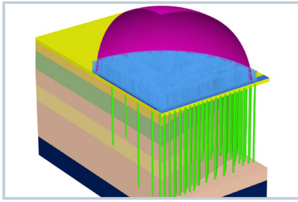
Rigid inclusions can be used in all construction sectors. They are applied under footings with or without a load distribution layer (LTP). They can also be used under floor slabs and embankments. Based on the initial compressibility of the soil the spacing between the rigid inclusions is adapted to suit the allowable settlement of the project.

Technical highlights

- Proven method to reduce settlement and to increase the bearing capacity of weak soils, even for high loads
- Applicable with or without load distribution layer
- Minimal spoil
- Can be applied for most types of structures and most types of soils
- Allows for quick starting of construction works

Design

Rigid inclusions design uses a combination of finite element methods (FEM) or the load transfer method (LTM) developed using Keller KID software. The design models all possible behaviours between the soil, columns, foundations and any LTP.



FEM modelisation of a silo

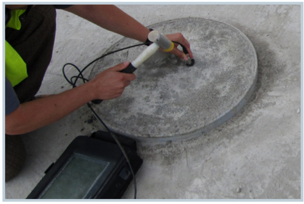
Quality assurance

Rigid inclusions elements are controlled before, during and after installation to ensure the highest quality of solution. A variety of tests can be carried out including:

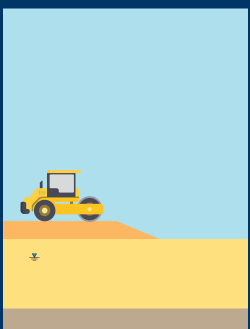
- Trial fields for verifying columns production parameters
- Digital recording and logging of the execution parameters
- Column integrity test, column load test, column material compressive strength tests and column diameter verification

The type and frequency of tests is closely related to the size of the project and the geotechnical context.

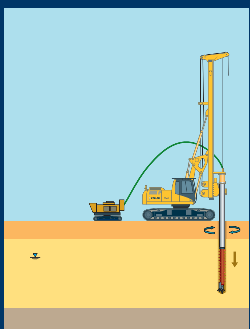
Load test



Integrity test

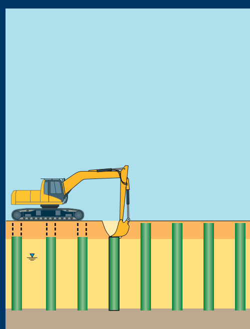


Working platform preparation
Filling and compaction of material for the working platform.

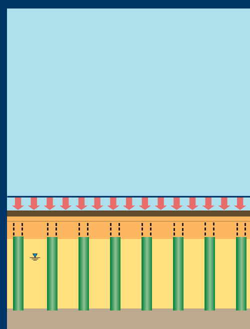


Locating and penetration
The rig is placed at the right location and data recording is started. Generally a displacement auger or vibrated tube is used to penetrate down to the designed depth.

Installation
Pumping concrete and pulling the tool upwards simultaneously. The concrete flows out of the tube and supports the bore.



Cutting
If the concrete is fresh cutting is executed by mechanical means and if the concrete has hardened a hand jackhammer is used.



After rigid inclusion work
Additional compacted gravel layer placed beneath the bottom of the foundation.

Case study: Alexandra Dock, Liverpool

At the site of a former warehouse in Alexandra Dock, Liverpool, Keller installed 4412 columns consisting of 340mm diameter rigid inclusions driven down into the dense sands.

As with any distribution warehouse, supporting the floor to the specified tolerance was the most important aspect of the project. Finite element analysis was undertaken to model settlements at various spacings of columns and thicknesses of mattress. At Alexandra Dock the floor columns are at centres of 2.5m and overlaying these is a 500mm thick mattress consisting of heavily rolled 6F2 stone, which acted as a load transfer platform.

The very dense sub base sitting beneath the old slab was suitable as a piling mat. Once the stiff column was installed the upper part of it was removed down to the base of the granular mattress and replaced with dense gravel. The mattress was then topped up in thickness.

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