19-Nov-19

Quality control in Deep Soil Mixing
State of the Art

Build on us

SOLETANCHE BACHY

SIMSG ISSMGE

TC 211

Deep soil mixing : Called as well « Deep Cement mixing » in Asia

Mechanical mixing of the in-situ soil with an hydraulic binder

Goal is to create soil cement material with improved properties

Geometry of the volume of treated soil is given by the geometry of the tool and its motion

There are globally two means of incorporating the binder :

either as a powder => Dry method

or as a liquid (binder + water + additives –if needed -) => Wet method

This presentation focuses on wet method, as it represents the majority of the applications

Reminder : QC/QA programme as per DFI Guidelines

A good QC/QA Program Plan will indicate how construction parameters will be determined prior to beginning the production work, how those parameters will be monitored, recorded, and reviewed, how deficiencies observed during review of the construction records will be addressed, and how the results of the quality assurance testing will be used to modify construction parameters being used on a real time basis to suit conditions encountered.

Summary

SOLETANCHE BACHY

Preliminary lab trials

European Standard EN 14679

Execution of geotechnical works only
Very few information about preliminary lab trials.
Lab trials are specified to be mandatory if the construction company cannot justify having treated similar soils with similar construction conditions

Deep Foundations Institute – Deep Soil Mixing Guide - 2016

Bench testing may be performed by the Owner prior to bidding a project to establish the feasibility of using DMM and/or to provide the DMM Contractor with an indication of the binder amounts required. Alternately or additionally, the DMM Contractor may choose to perform bench testing after being selected to perform the work to provide an initial estimate of the binder required to meet the project acceptance criteria.

Our practice

Lab trials mandatory in any case with presence of organics or contamination
Could be optional if enough experience with the binder in similar ground conditions

Positioning and Verticality

Embedded GPS positioning is progressively implemented. Accuracy : 2-3 cm
No GPS precise on trenchers for the time being

Verticality measurement :

- With 2 no of inclinometers for CSM
- With inclinometer + azimuth for DSM
- Automatic verticality of blade with trencher

Verticality as well as GPS coordinates are shown on reports

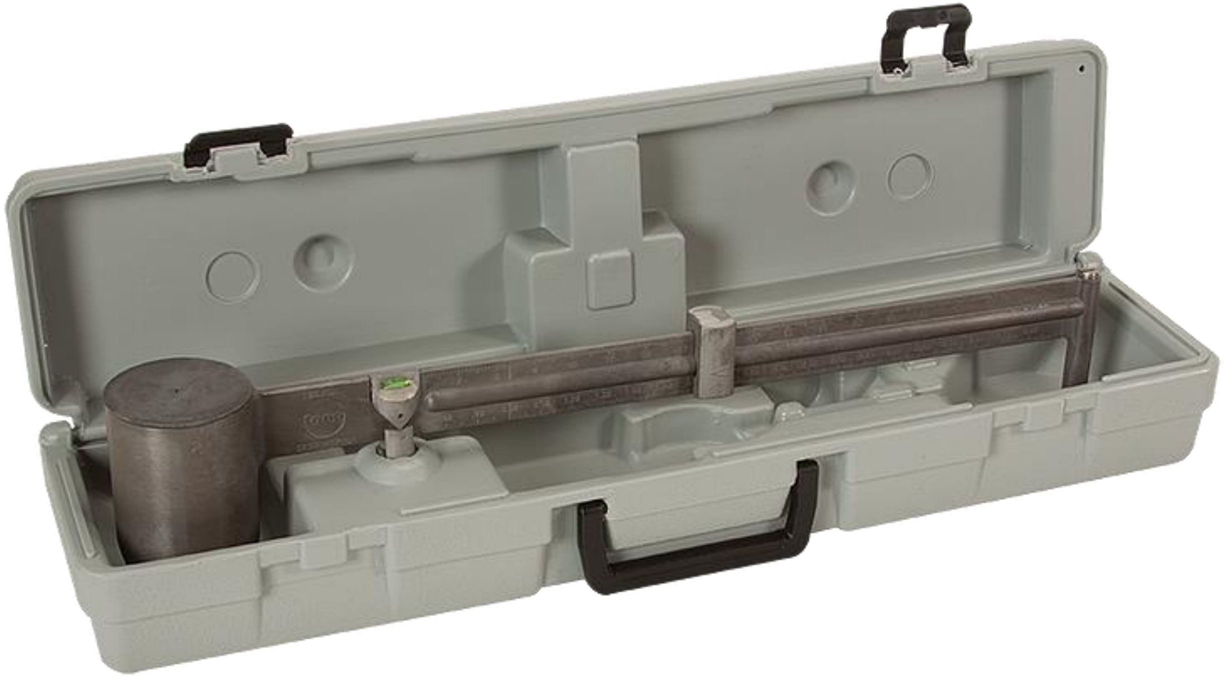
Grout properties

On daily basis, rheology of the treatment grout is controlled

Specific gravity (mandatory) – Additional Marsh funnel viscosity (in presence of bentonite or other additives)

Regularly, samples of grout are taken for UCS testing in laboratory. Usually tests are done at different curing times

7 / sometimes 14 / 28 days.



Construction Parameters

All deep mixing rigs are equipped with a full set of sensors.

Equipment parameters : hydraulic pressures (torque), rotation speed, rate of penetration, depth, verticality, GPS, …

Additional parameters: engine parameters (CANBus), …

Grout parameters : flow-rate, pressure, specific gravity

Mixing factor (Blade Rotation Number) and Grout volumes are computed in real time.

At a minimum, these 2 parameters are displayed.

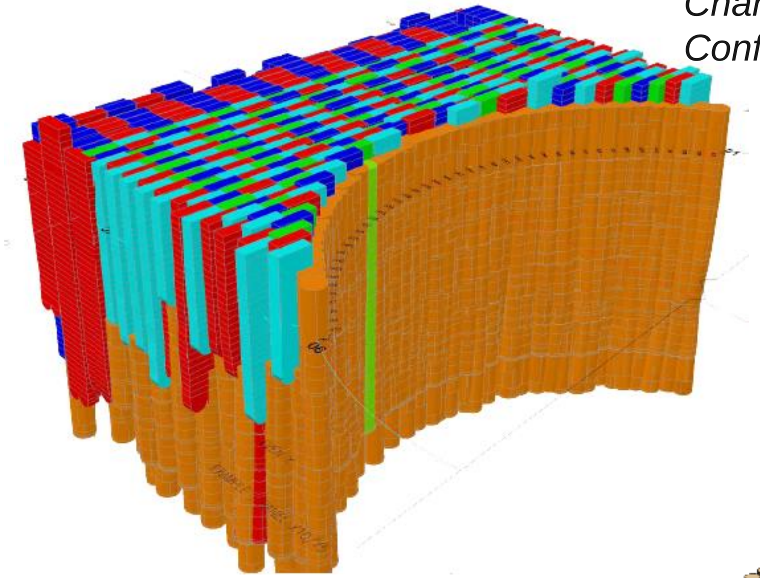
Real time display at distance, on mobile devices or computer in site office

Once treatment is achieved, **data are transmitted wireless** (GPRS / Radio / Wifi / Bluetooth)

Automatic data processing. Reports are issued immediately

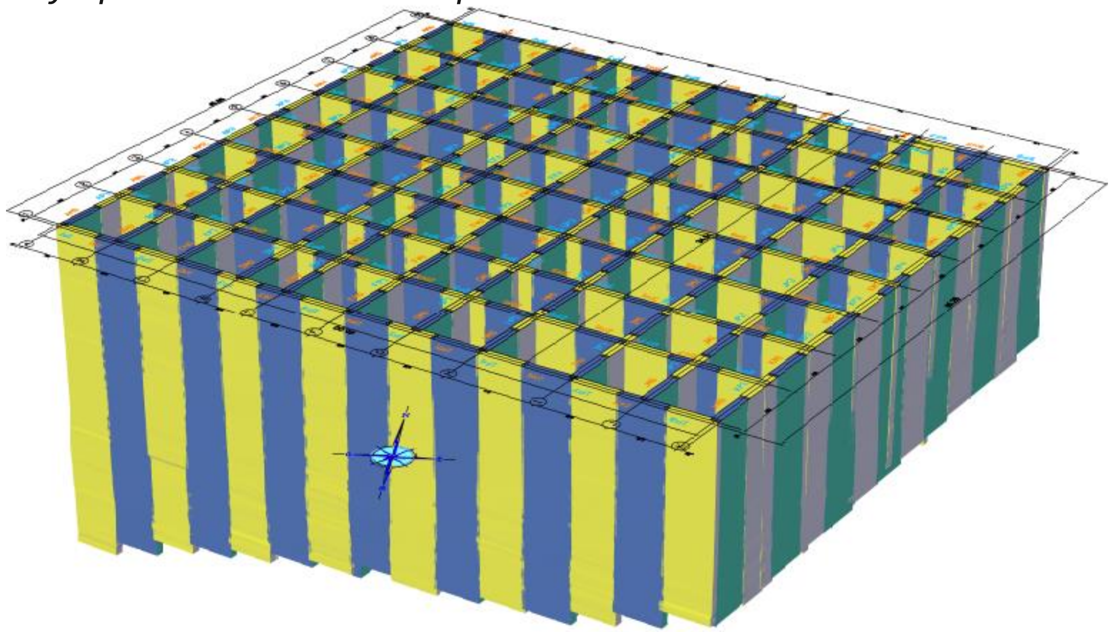
As built 3D models

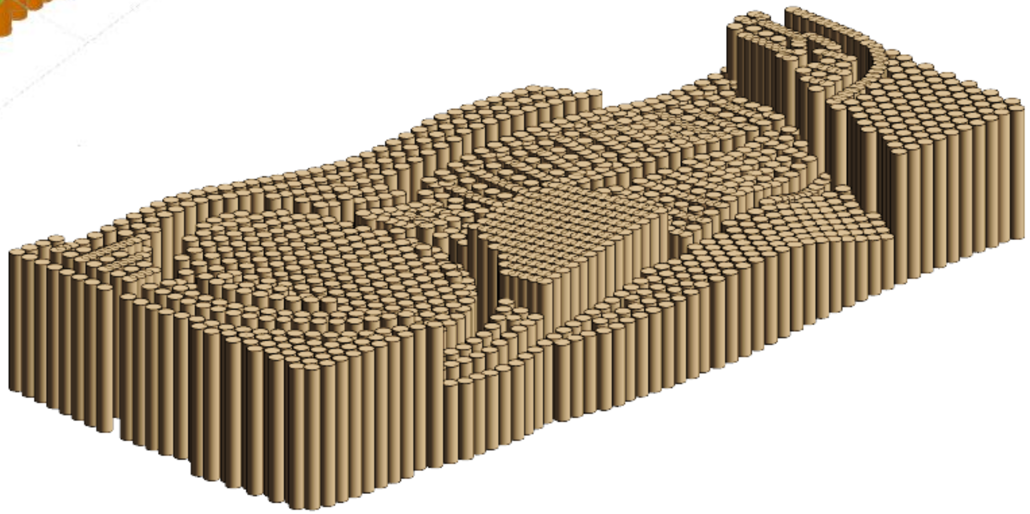
Ground Treatment by Combination of CSM and Jet-Grouting in Hong Kong
Chan and al. - ASCE – Grouting 2017 Conference, Hawaii, 2017



Geomix Caissons against liquefaction

Benhamou and al. - ISSMGE - TC 211 International Symposium on Ground Improvement IS-GI Brussels 2012





Design and construction aspects of deep soil mixing of soft alluvium and peat across the proposed King Edward Memorial Park Foreshore work site
Talby and al. - DFI – Deep Mixing Conference, Gdansk, 2020

Wet grab sampling

Wet grab sampling consists in taking samples of the fresh soil cement mixture **at depth**.

Samples are casted on site in cubes or cylinders , then stored on site for a proper curing.

Then samples are transferred to a lab for testing.

The sampled material must be representative of the in situ mixture.

When doing samples, coarser elements (bigger than 1/5th of the sample dimension) can be removed when casting to avoid early breaks when testing.

Non destructive controls

Pumping tests

Excavations

Ultrasonic Wave velocity measurement

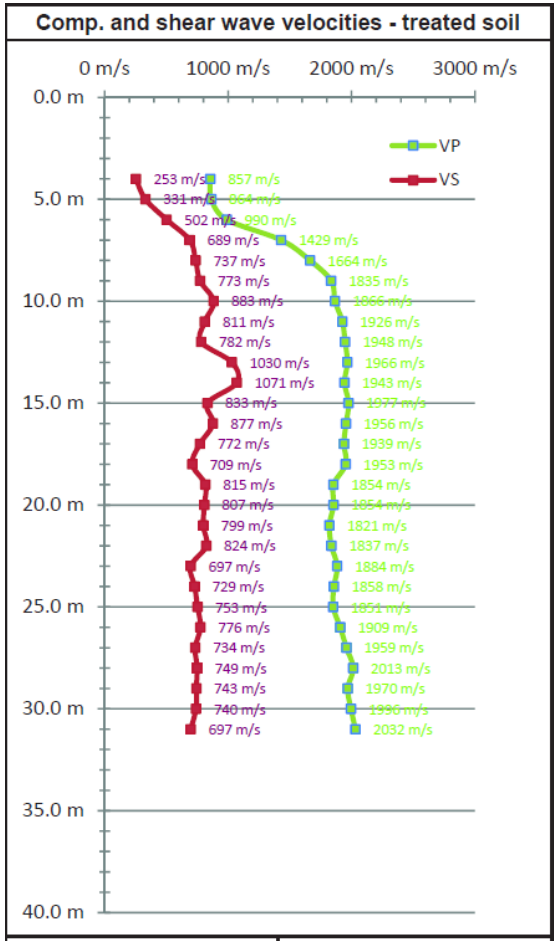
Influence of mixing and curing conditions on the characteristics and durability of soils stabilised by deep mixing

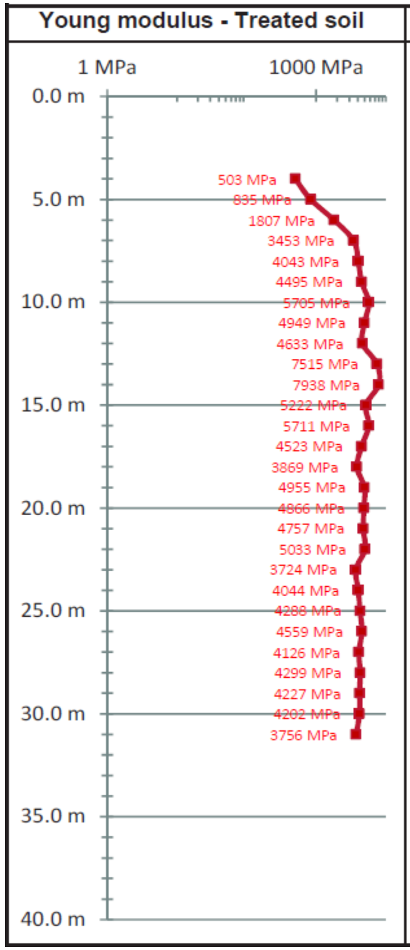
Guimond-Barrett, PHD report, University of Le Havre, France, 2013

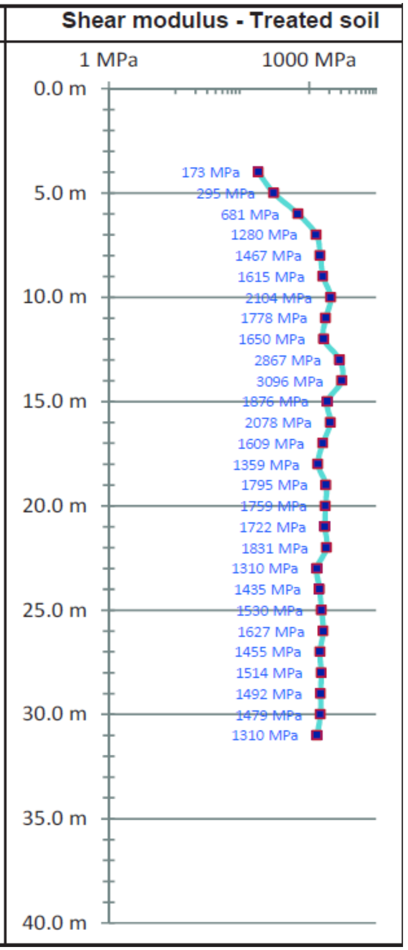
In situ Cross Hole testing

Deep soil mixing in soft and weathered chalk

Mathieu and al, Deep Mixing 2020, Gdansk



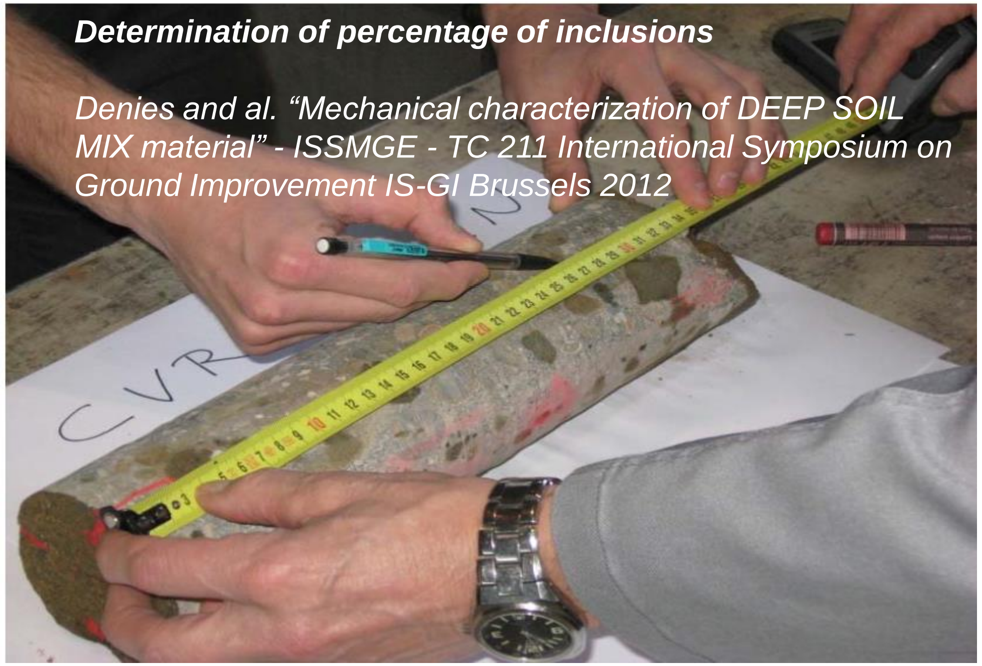




Destructive controls

Coring through the deep soil mixed mass is usually applied

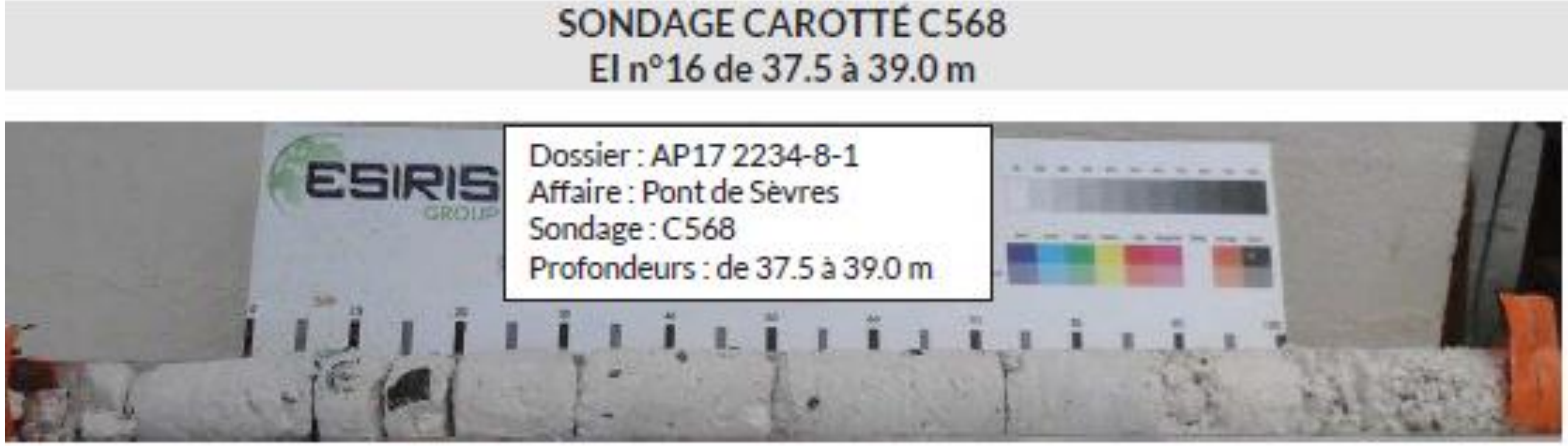
Needs to be done by trained operators + double/triple core barrel to get samples for testing
Very difficult when compressive strength is below 1MPa



Determination of percentage of inclusions

Denies and al. "Mechanical characterization of DEEP SOIL MIX material" - ISSMGE - TC 211 International Symposium on Ground Improvement IS-GI Brussels 2012

In situ permeability testing in mass treatment



Coring

Deep soil mixing in soft and weathered chalk
Mathieu and al, Deep Mixing 2020, Gdansk

Destructive controls

In situ permeability testing in “thin” cutoff wall may be not representative of the quality of the works done.

Sample taken in depth during the execution of the cut off is usually more representative due to:

- Risk of deviation
- Risk of fracturing the soil mixed i.e. change of permeability
- Difficulty to define which ground water table to take into account (which side?)
- …

DFI soil mixing guide

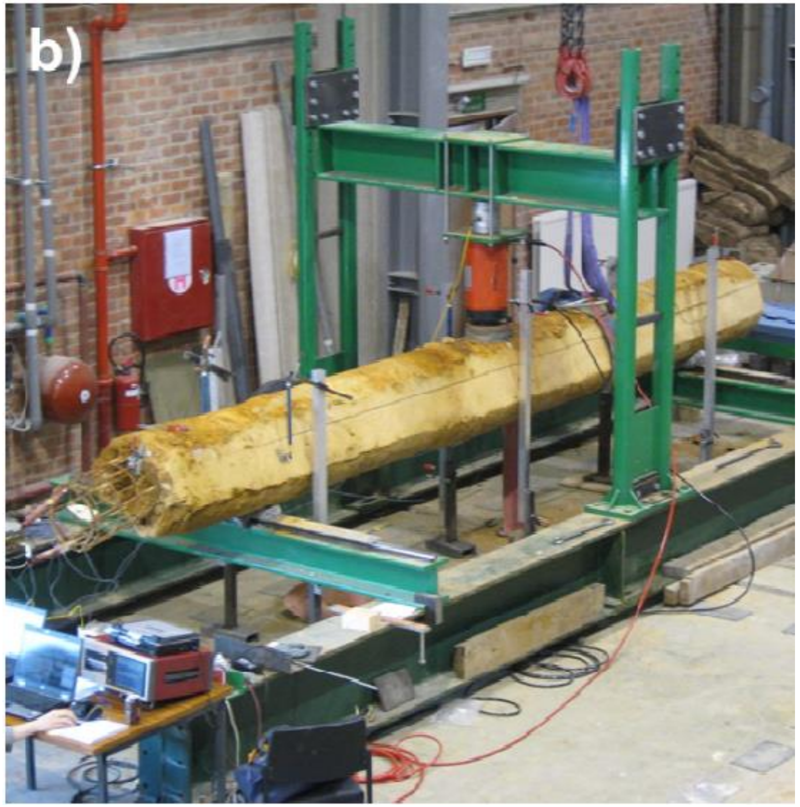
Minimum Wet grab sample and core sample frequencies

<table>
<tr><th>Application</th><th>Wet Sample</th><th>Strength Tests on Wet Samples</th><th>Permeability Tests on Wet Samples</th><th>Core Sample with Visual Inspection</th><th>Unconfined Compressive Strength on Core Sample</th><th>Visual Inspection of Wall</th></tr>
<tr><td>Temporary Earth Retention Wall</td><td rowspan="4">One wet sample per day (cast six (6) 3-inch x 6-inch cylinders (specimens) from each wet sample)</td><td rowspan="4">Test 2 specimens at 7 days
Test 2 specimens at 28 days
Reserve 2 specimens</td><td>Test 1 sample or every 40,000 SF of wall, whichever is greater</td><td rowspan="2">None</td><td rowspan="2">None</td><td rowspan="2">Daily during excavation</td></tr>
<tr><td>Permanent Earth Retention Wall</td><td rowspan="2">Test 1 sample per project or every 10,000 SF of wall, whichever is greater</td></tr>
<tr><td>Permanent Water Cutoff</td><td>1 core for every 20,000 SF of wall</td><td rowspan="2">Test 3 samples at 28 days
Reserve 2 specimens</td><td rowspan="2">Not applicable</td></tr>
<tr><td>Permanent Ground Improvement</td><td>None</td><td>One core taken during the first week of production work, and 1 core for every 15,000 CY of treated ground thereafter</td></tr>
</table>

Load testing

Load test on deep soil mixing column (in lab)

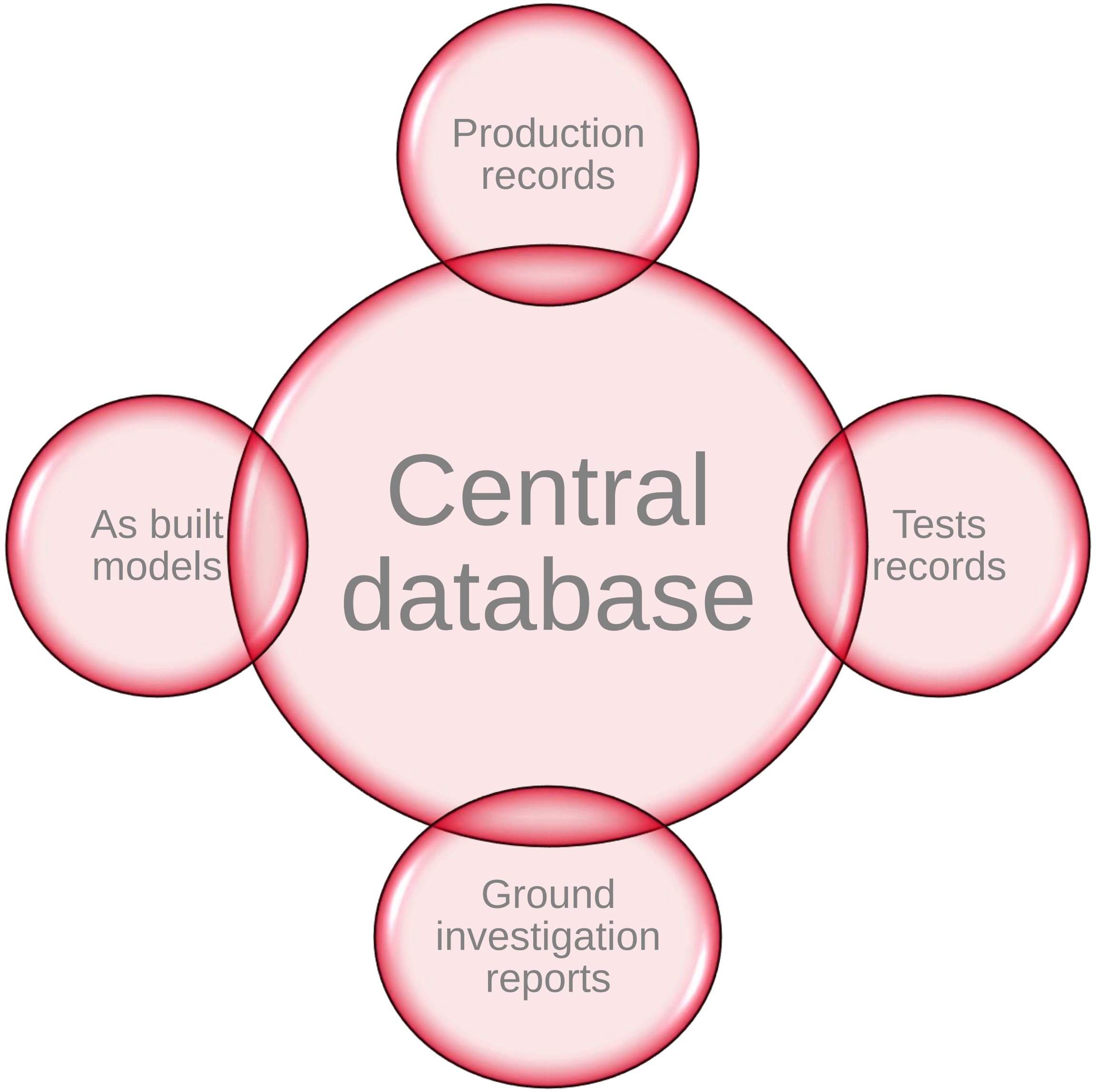
Real-scale tests on soilmix elements
Denies and al, 2014



Load test on deep soil mixing column (on site)

Underpinning works under shallow foundations in Blaj, Romania using Springsol technology
Magureanu and al, XVI Danube European Conference on Geotechnical Engineering, 2018

Big data


Production records
As built models
Central database
Tests records
Ground investigation reports

Thank you