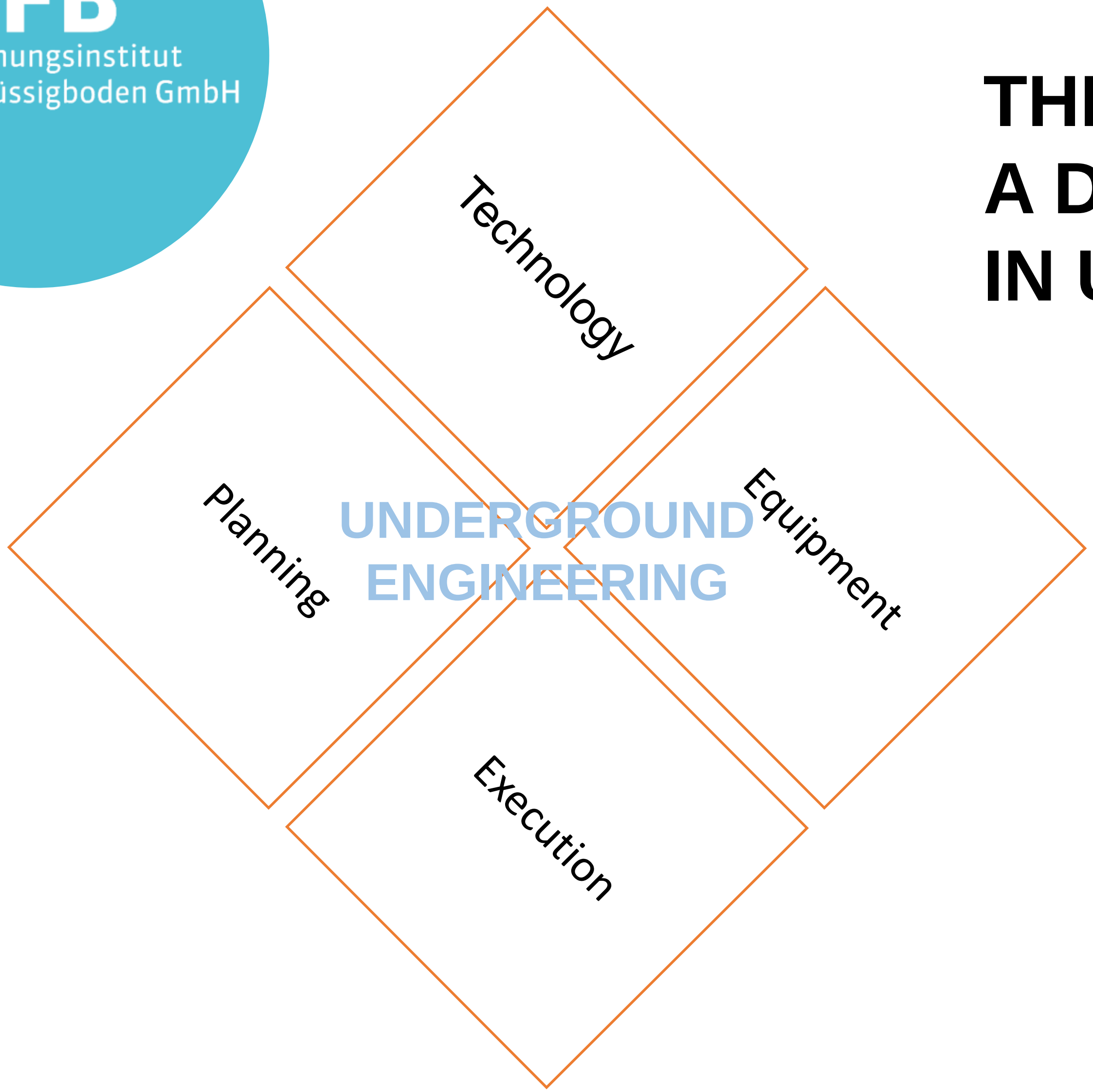
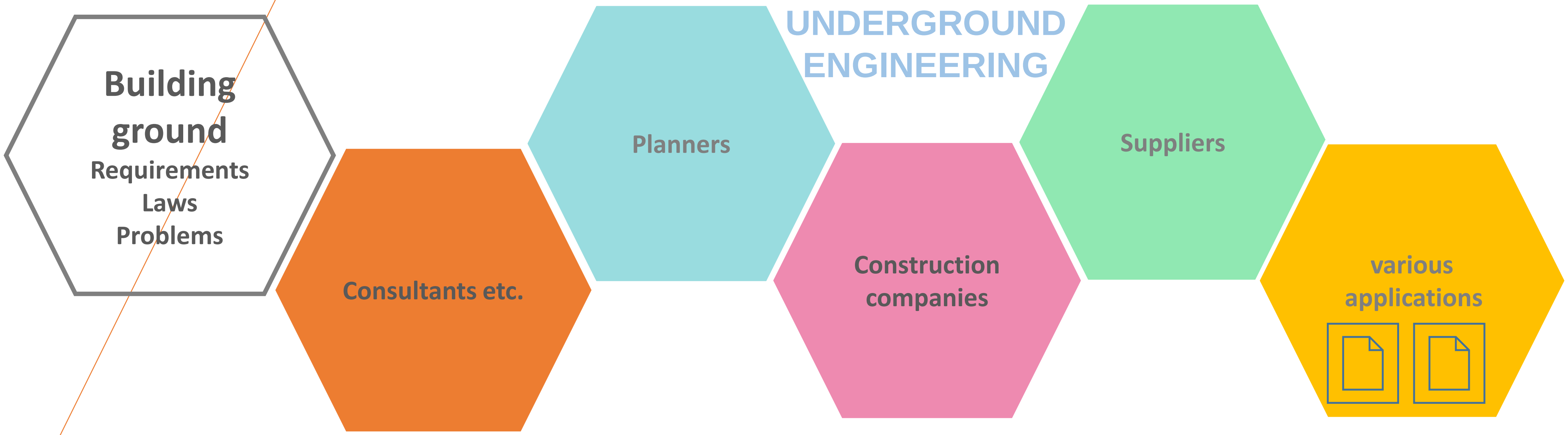
FiFB
Forschungsinstitut
für Flüssigboden GmbH

THE LIQUID SOIL METHOD
A DISRUPTIVE INNOVATION
IN UNDERGROUND ENGINEERING

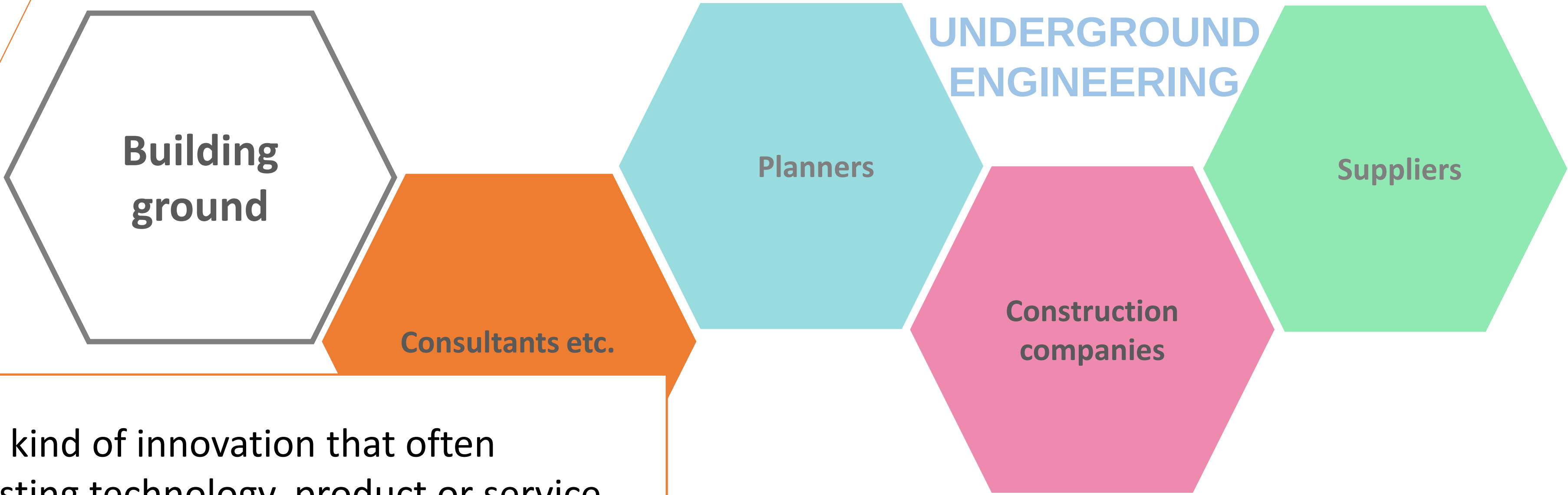


READY FOR THE SUBTERRANEAN REVOLUTION

DISRUPTIVE INNOVATION – LIQUID SOIL



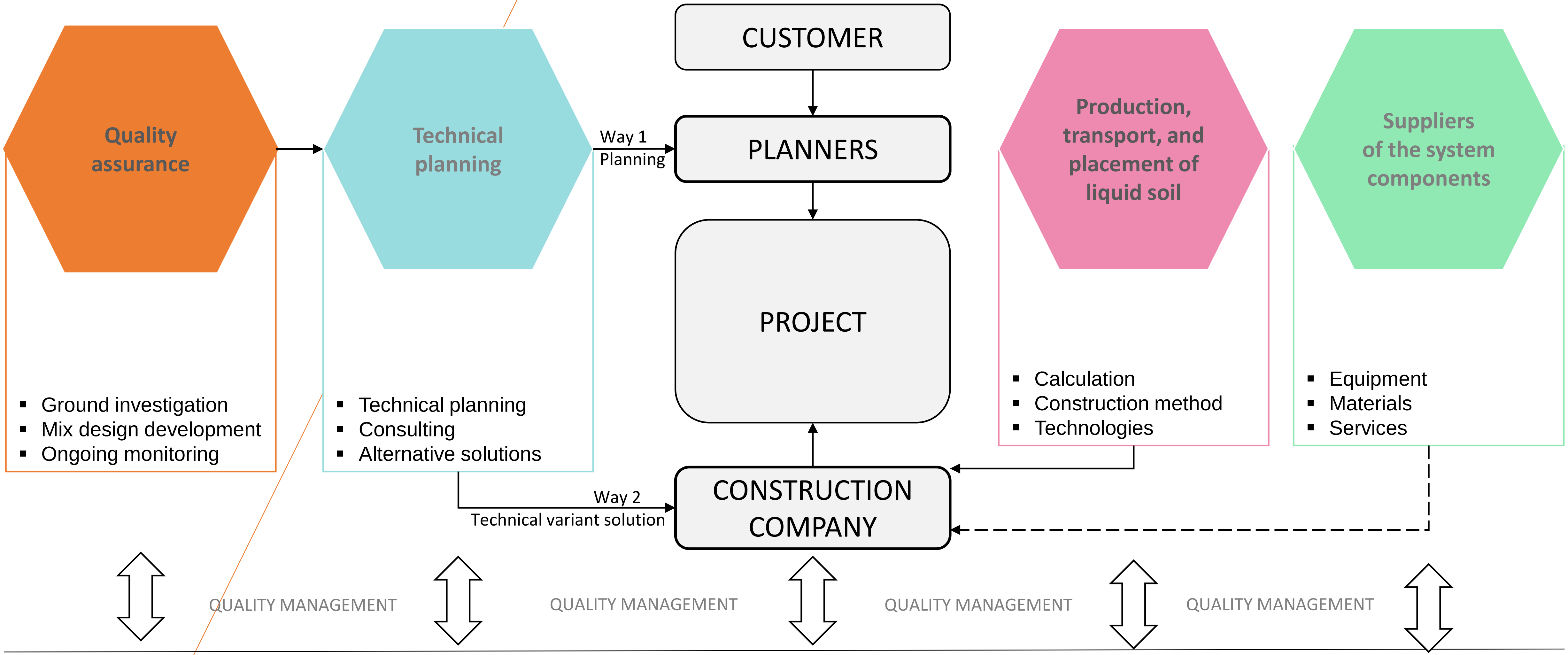
DISRUPTIVE INNOVATION – LIQUID SOIL



Disruptive innovation: is a kind of innovation that often completely replaces an existing technology, product or service, and thus changes the market fundamentally.

The liquid soil method fundamentally changes many civil engineering solutions, the respective technologies, the required equipment, products and services, and thus replaces old solutions step by step.

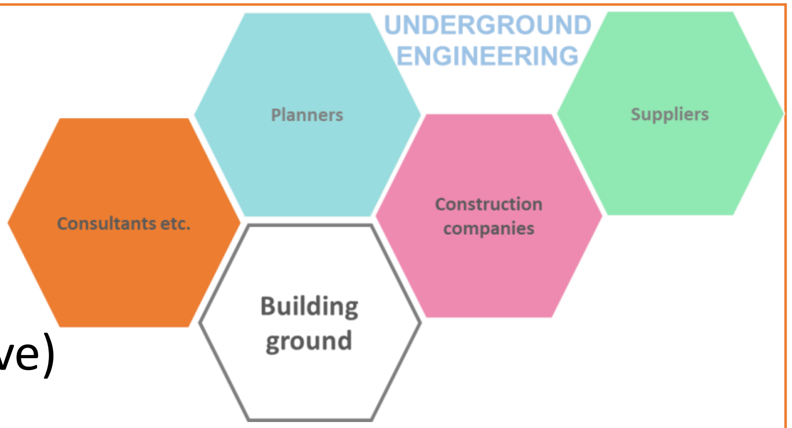
CONCERNED BUSINESS PROCESSES IN UNDERGROUND ENGINEERING



- RAL GZ-507: is a quality mark and quality standard, similar to a German DIN standard, but with stricter requirements. Testing institutes accredited by RAL supervise and verify the application of the liquid soil method according to RAL-GZ 507, and enforce required standards. The „RAL Gütegemeinschaft Flüssigboden e. V.“ (RAL Quality Association for Liquid Soil) offers educational programmes for users, in cooperation with the developers and practitioners.
- For more information, see also www.fi-fb.de; www.ral-gg-fluessigboden.de (only in German)

0 PRIORITY ISSUES

In the introductory lecture, some of the various new and fundamental changes in the respective fields of applications will be described, and the basics of the method will be explained using floating laying of collector pipes in groundwater as an example.



1. Disruptive changes due to the liquid soil method
2. Short presentation of the liquid soil method (example above)
3. Reasons for the development and history
4. Technical and economical constraints, eg space, groundwater, construction costs, crises
5. Physical mechanisms of action and their consequences, eg uplift and the development of PLA, measurement devices, technology, statics, software etc.
6. Example of an innovative and disruptive technology from the field of sewer construction
7. Impact of changed cost structures on the results and the calculation
8. Summary and outlook

Unbiased examples

1

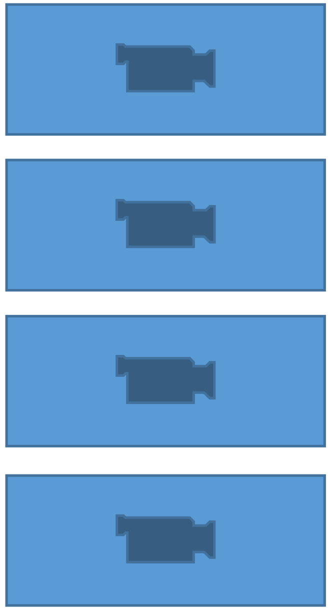
CHANGES AS A CONSEQUENCE OF THE DISRUPTIVE EFFECT

1. Material flow and conservation of resources
2. Significance landfill and soil exchange
3. Required space
4. Construction logistics and auxiliary processes
5. Technology and cost structures
6. Techn. properties of LS during constr. phase + later
7. Construction processes and speed
8. Building company structures, eg gang
9. New solutions promote economy, eg worth-less marshland can become building land
10. Technology for LS production and placement
11. The role of renting machinery
12. Trench lining solutions
13. Requirements resulting from technology and uplift regarding pipes and components
14. Excavated and delivered materials
15. Relations with people living nearby
16. Content of education and training
17. Planning
18. Cost accounting and calculation
19. Calculation and verification methods
20. Quality assurance and required aids
21. Management and costs of the operation
22. New possibilities of urban development
23. Lifetime – economic advantages
24. Insurance aspects, eg in case of floods

Presentation of the method – one typical application

2

Example: floating pipe laying – one of the over 160 applications of liquid soil according to RAL-GZ 507 known so far



Examples of projects

1. Construction in and under water
2. Lübeck, Germany – building on mud (gyttja)
3. Karlsruhe, Germany – tunnel construction
4. Düsseldorf, Germany – Hardtstraße

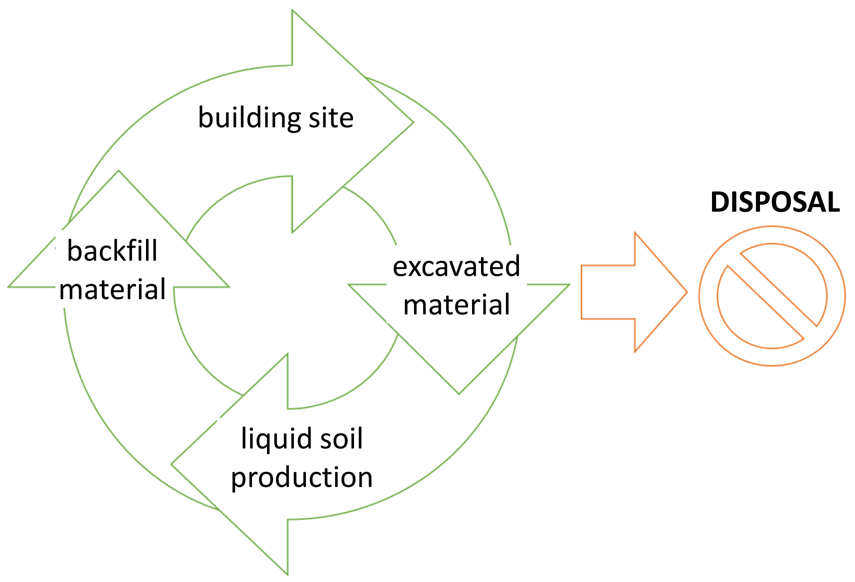
WHAT IS FUNDAMENTALLY CHANGED BY THE LIQUID SOIL METHOD?

Example: floating pipe laying

1

Material flows and thus, building site logistics

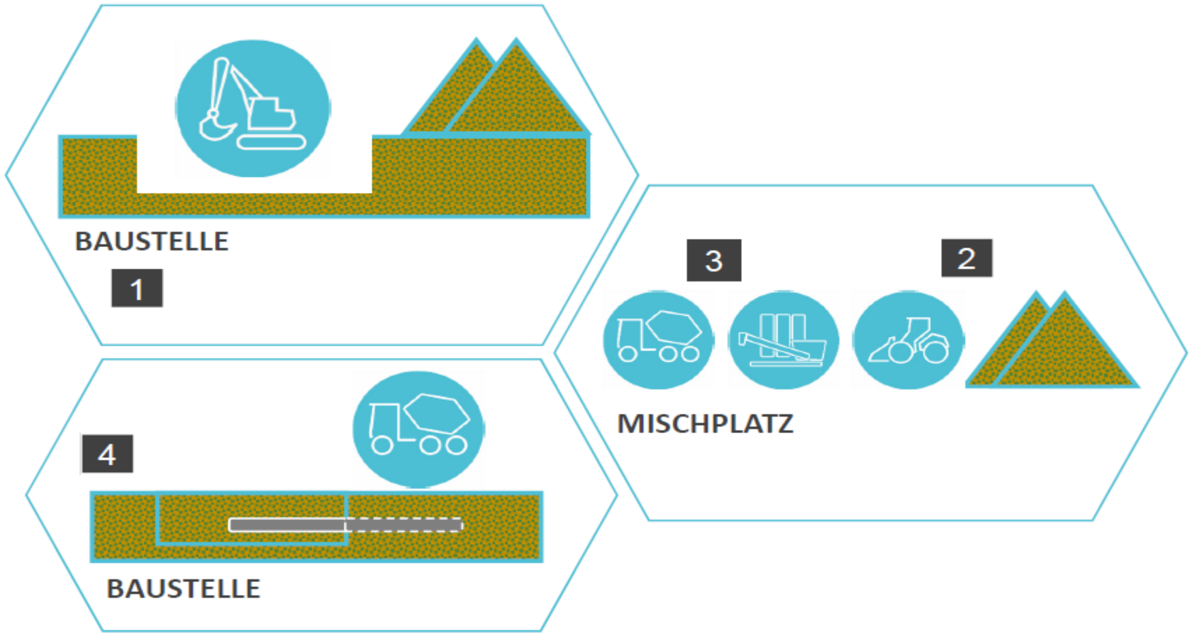
Reuse of the excavated material according to the (German) national regulations on waste recycling management (KrWG)



Example: floating pipe laying

1

Material flows and thus, building site logistics



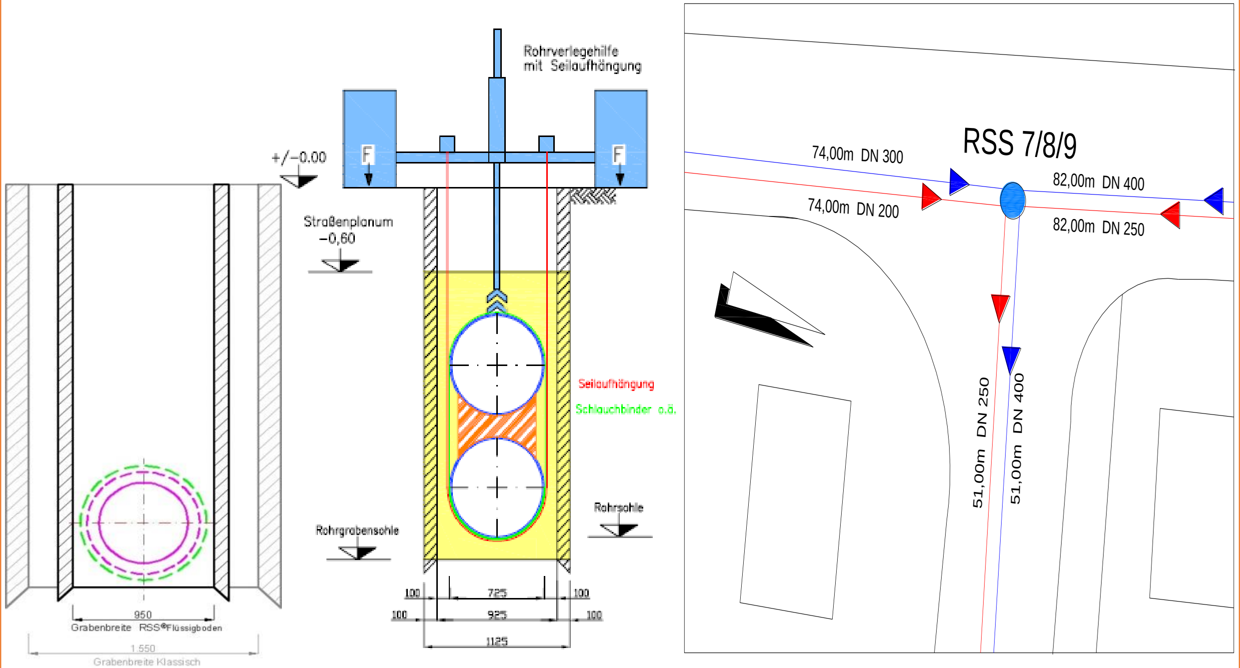
Transportation processes are basically restricted to the building site, and so they are minimised!

1. Excavation of the soil
2. Treatment of the soil
3. Production and placement of liquid soil

Example: floating pipe laying

1

Material flows and thus, building site logistics



No zones to be excavated that are only needed as space for compacting machinery and works

1. Less road construction waste
2. Faster construction works
3. Less storage on site
4. Less transportation equipment
5. Less space required on site

Example: floating pipe laying

2

Technological changes

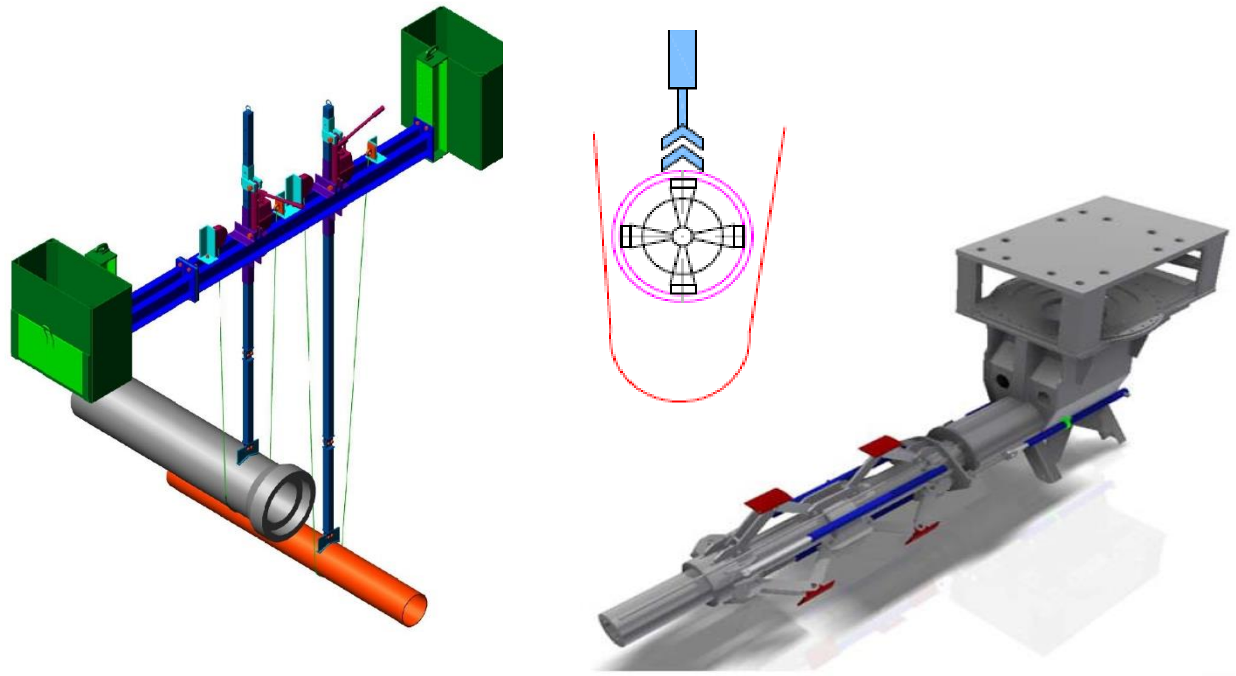
Fundamentally changed technology

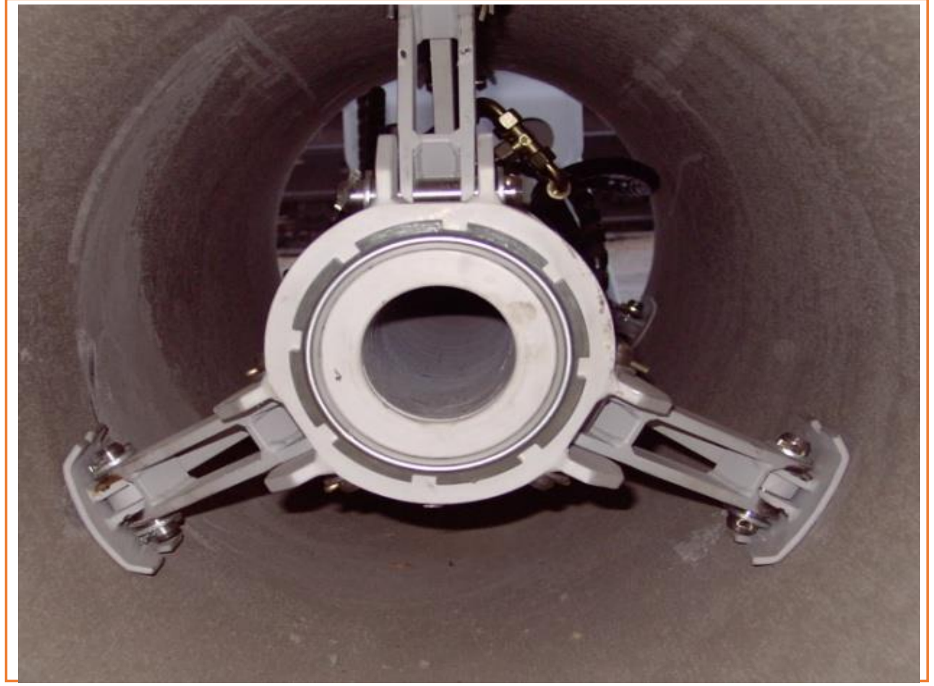
1. No dewatering required
2. No danger of damage for buildings
3. No sheet piles required
4. Solution for groundwater problems
5. no method of dock construction required
6. Scheduled construction
7. Other cost structure

Example: floating pipe laying

3

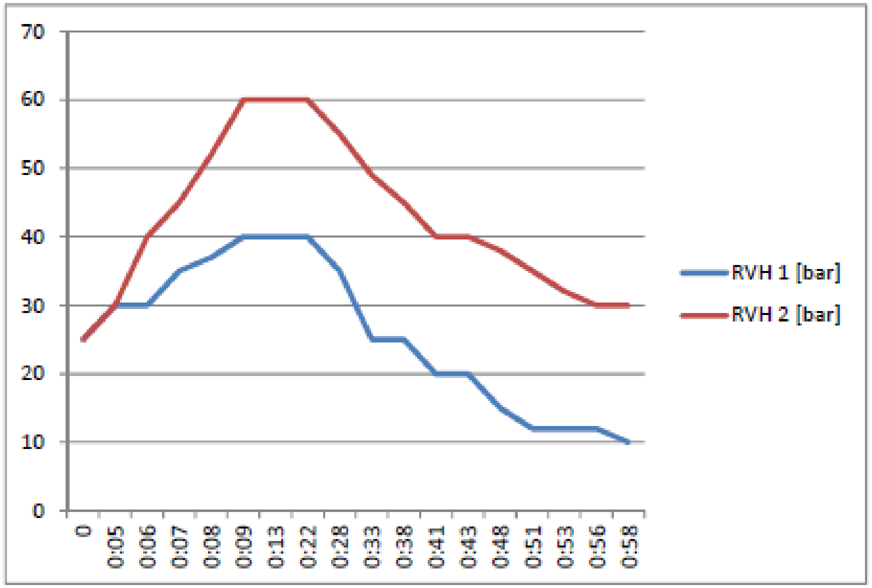
Technical changes





Example: floating pipe laying

4 Changes in the quality assurance



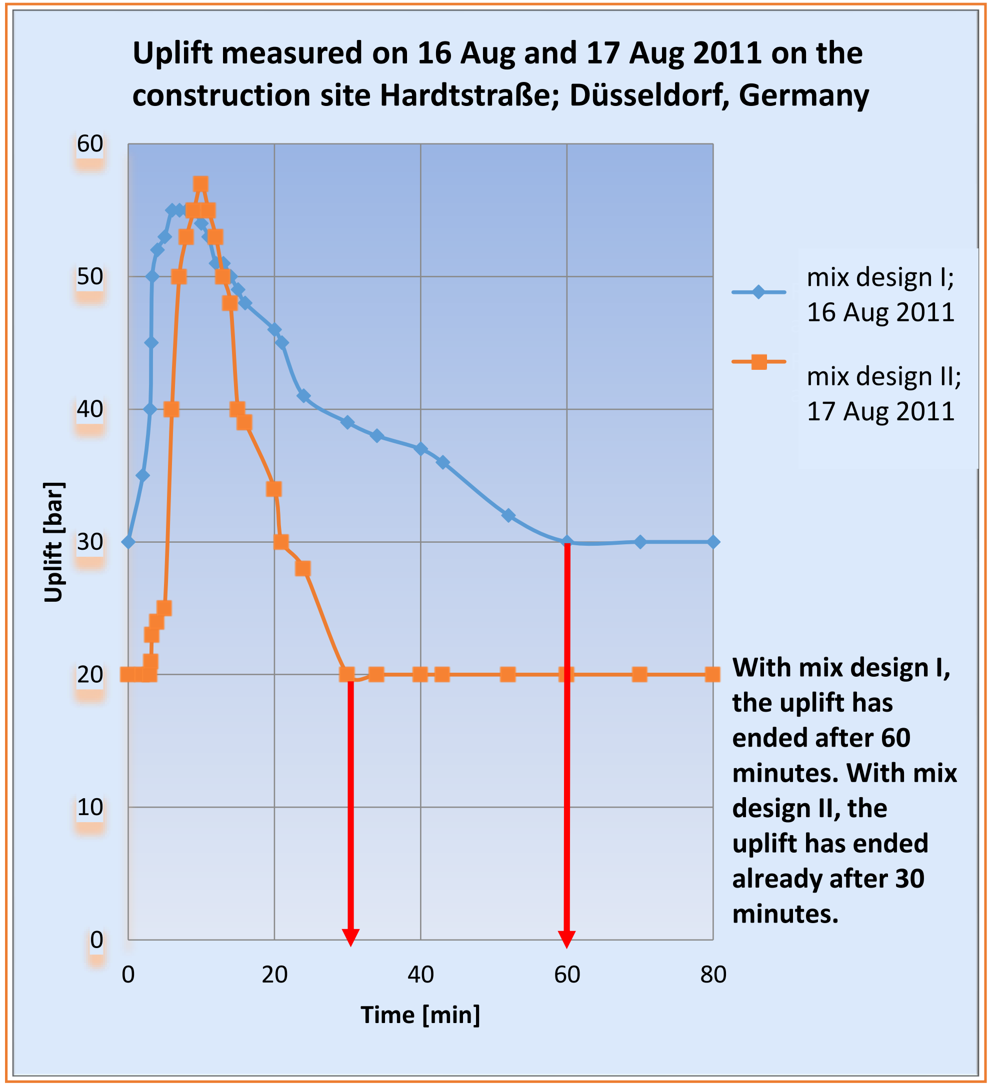
Refixierungsverlauf vor Ort in der Größenordnung von knapp einer Stunde

Example: floating pipe laying

5 Technological properties of liquid soil (LS)

Liquid soil has technologically relevant properties, which can be modified in a targeted way to improve the construction progress or to solve problems in a different way

1. Modification of duration of solidification
2. Variation of the pumpability
3. Manipulation of the viscosity without changing the final properties
4. Uplift can be controlled
5. Rheological properties adequate for underwater placement
6. Timing depending on the rheological properties etc.



Example: floating pipe laying

6 Pipe lengths chosen according to the uplift

Figure 1

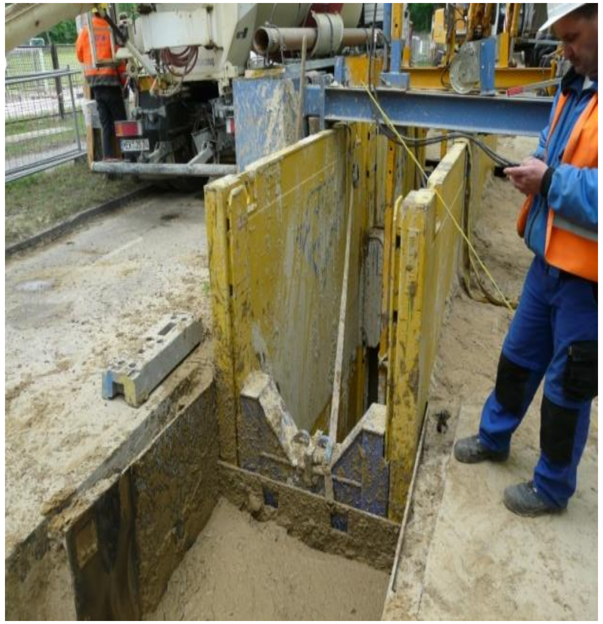


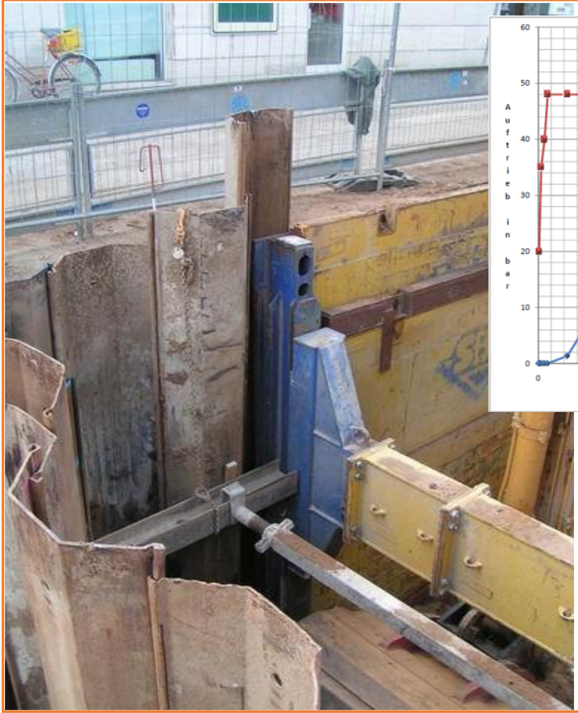
Figure 2

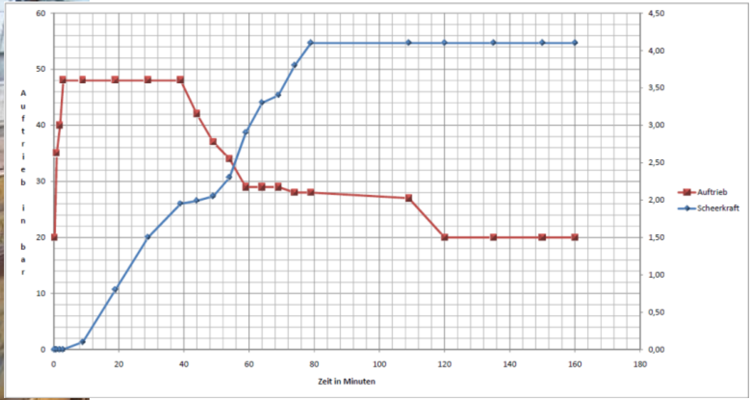
Technology and thus construction output depend on pipe lengths

1. Statics depend on uplift
2. Pipe length depends on uplift
3. Trench lining depends on pipe length
4. Technology depends on position of the PLA relative to the trench lining
5. Rheology can be used to mitigate uplift
6. Output figure 1 : 2 = 2 : 1

7 Example: floating pipe laying

Required trench lining depends on technology



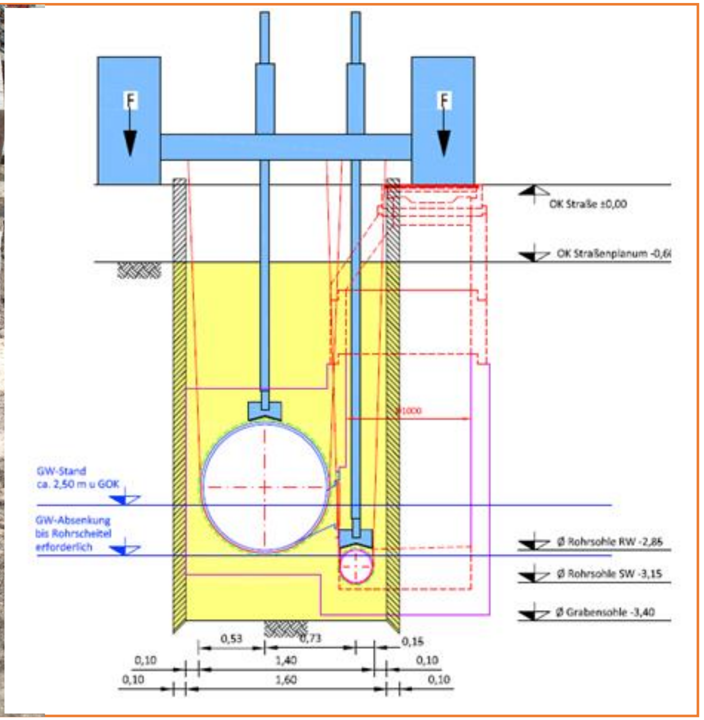


Due to the narrow trench a sheet pile wall is not needed

1. Parallel shoring is economic
2. No problems with piling
3. Minimised dynamic loads
4. Better protection of buildings
5. Faster construction processes
6. Higher construction output
7. Improved efficiency

8 Example: floating pipe laying

New technologies – without water retention and without piling

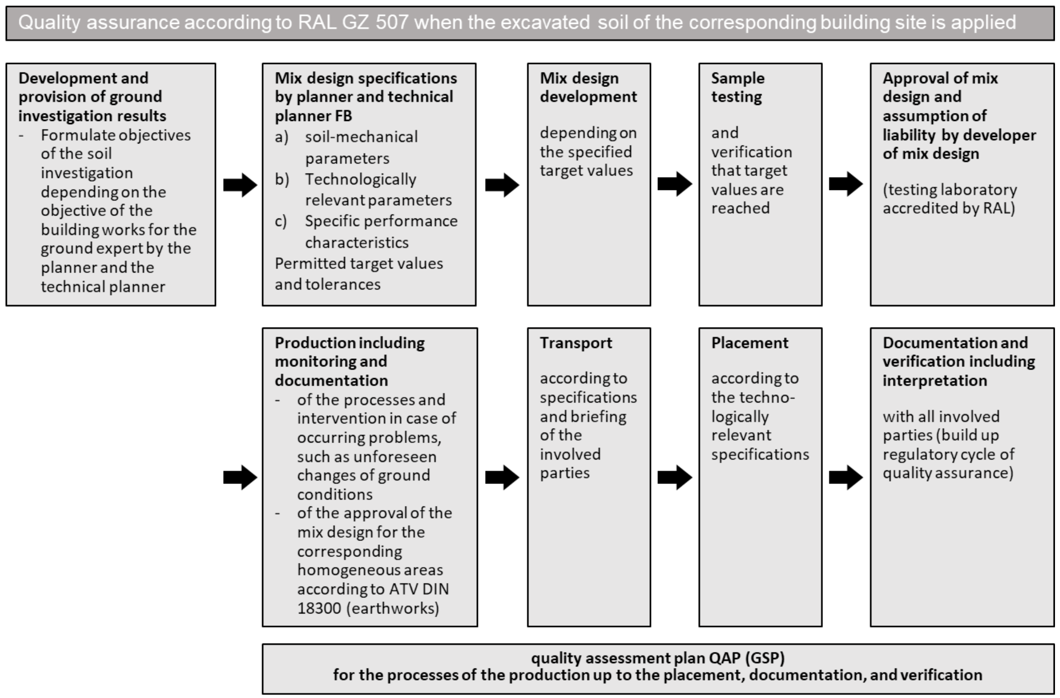


When building with LS in the groundwater and on non- or low-bearing grounds like mud (gyttja), the local soil conditions must be the focus of the planning

1. Other verifications required, such as frictional forces towards the trench wall
2. Other aims of the planning influencing the quality assurance plan
3. Three groups of LS properties, can be attuned to the aims of the project, see quality assurance according to RAL-GZ 507

Example: floating pipe laying

9 RAL-GZ 507 – Basis of quality assurance of liquid soil



When building with LS in the groundwater and on non- or low-bearing grounds, the local soil conditions must be the focus of the planning

1. Other verifications required, such as frictional forces towards the trench wall
2. Other aims of the planning influencing the quality assurance plan
3. Three groups of LS properties, can be attuned to the aims of the project and are testable

9 Example: floating pipe laying

RAL-GZ 507 – Basis of quality assurance of liquid soil

Quality assurance according to RAL GZ 507 when the excavated soil of the corresponding building site is applied

Development and provision of ground investigation results
- Formulate objectives of the soil investigation depending on the objective of the building works for the ground expert by the planner and the technical planner

➡

Mix design specifications by planner and technical planner FB
a) soil-mechanical parameters
b) Technologically relevant parameters
c) Specific performance characteristics

Permitted target values and tolerances

➡

Mix design development

depending on the specified target values

➡

Sample testing

and verification that target values are reached

➡

Approval of mix design and assumption of liability by developer of mix design

(testing laboratory accredited by RAL)

➡

Production including monitoring and documentation
- of the processes and intervention in case of occurring problems, such as unforeseen changes of ground conditions
- of the approval of the mix design for the corresponding homogeneous areas according to ATV DIN 18300 (earthworks)

➡

Transport

according to specifications and briefing of the involved parties

➡

Placement

according to the techno-logically relevant specifications

➡

Documentation and verification including interpretation

with all involved parties (build up regulatory cycle of quality assurance)

quality assessment plan QAP (GSP)
for the processes of the production up to the placement, documentation, and verification

Example: floating pipe laying

9

GüPrB GZ 507 – Basis of quality assurance of liquid soil

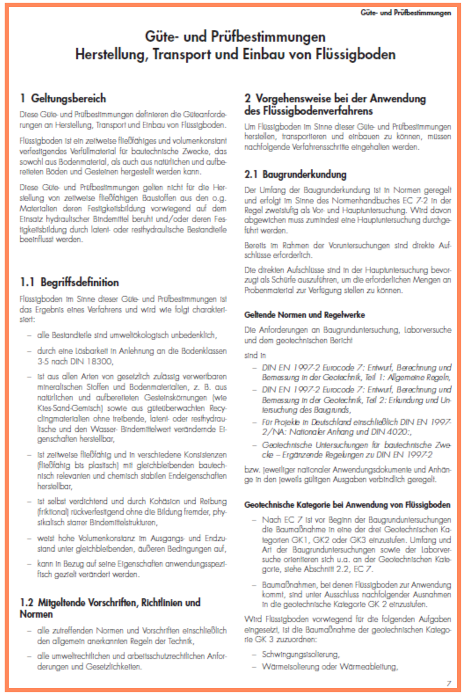
RAL
GÜTEZEICHEN
FLÜSSIGBODEN

Flüssigboden

Gütesicherung
RAL-GZ 507

Ausgabe Januar 2014

RAL
DEUTSCHES INSTITUT FÜR GÜTESICHERUNG UND KENNZEICHNUNG E.V.



Güte- und Prüfbestimmungen

Güte- und Prüfbestimmungen
Herstellung, Transport und Einbau von Flüssigboden

1 Geltungsbereich

Diese Güte- und Prüfbestimmungen definieren die Güteanforderungen an Herstellung, Transport und Einbau von Flüssigboden.

Flüssigboden ist ein zeitweise fließfähiges und volumenkonstant verfestigendes Verfüllmaterial für bautechnische Zwecke, das sowohl aus Bodenmaterial, als auch aus natürlichen und aufbereiteten Böden und Gesteinen hergestellt werden kann.

Diese Güte- und Prüfbestimmungen gelten nicht für die Herstellung von zeitweise fließfähigen Baustoffen aus den o.g. Materialien deren Festigkeitsbildung vorwiegend auf dem Einsatz hydraulischer Bindemittel beruht und/oder deren Festigkeitsbildung durch latent- oder resthydraulische Bestandteile beeinflusst werden.

1.1 Begriffsdefinition

Flüssigboden im Sinne dieser Güte- und Prüfbestimmungen ist das Ergebnis eines Verfahrens und wird wie folgt charakterisiert:

- alle Bestandteile sind umweltökologisch unbedenklich,
- durch eine Lösbarkeit in Anlehnung an die Bodenklassen 3-5 nach DIN 18300,
- ist aus allen Arten von gesetzlich zulässig verwertbaren mineralischen Stoffen und Bodenmaterialien, z. B. aus natürlichen und aufbereiteten Gesteinskörnungen (wie Kies-Sand-Gemisch) sowie aus güteüberwachten Recyclingmaterialien ohne treibende, latent- oder resthydraulische und den Wasser- Bindemittelwert verändernde Eigenschaften herstellbar,
- ist zeitweise fließfähig und in verschiedene Konsistenzen (fließfähig bis plastisch) mit gleichbleibenden bautechnisch relevanten und chemisch stabilen Endeigenschaften herstellbar,
- ist selbst verdichtend und durch Kohäsion und Reibung (friktional) rückverfestigend ohne die Bildung fremder, physikalisch starrer Bindemittelstrukturen,
- weist hohe Volumenkonstanz im Ausgangs- und Endzustand unter gleichbleibenden, äußeren Bedingungen auf,
- kann in Bezug auf seine Eigenschaften anwendungsspezifisch gezielt verändert werden.

1.2 Mitgeltende Vorschriften, Richtlinien und Normen

- alle zutreffenden Normen und Vorschriften einschließlich den allgemein anerkannten Regeln der Technik,
- alle umweltrechtlichen und arbeitsschutzrechtlichen Anforderungen und Gesetzlichkeiten.

2 Vorgehensweise bei der Anwendung des Flüssigbodenverfahrens

Um Flüssigboden im Sinne dieser Güte- und Prüfbestimmungen herstellen, transportieren und einbauen zu können, müssen nachfolgende Verfahrensschritte eingehalten werden.

2.1 Baugrunderkundung

Der Umfang der Baugrunderkundung ist in Normen geregelt und erfolgt im Sinne des Normenhandbuches EC 7-2 in der Regel zweistufig als Vor- und Hauptuntersuchung. Wird davon abgewichen muss zumindest eine Hauptuntersuchung durchgeführt werden.

Bereits im Rahmen der Voruntersuchungen sind direkte Aufschlüsse erforderlich.

Die direkten Aufschlüsse sind in der Hauptuntersuchung bevorzugt als Schürfe auszuführen, um die erforderlichen Mengen an Probenmaterial zur Verfügung stellen zu können.

Geltende Normen und Regelwerke

Die Anforderungen an Baugrunduntersuchung, Laborversuche und dem geotechnischen Bericht

sind in

- *DIN EN 1997-2 Eurocode 7: Entwurf, Berechnung und Bemessung in der Geotechnik, Teil 1: Allgemeine Regeln,*
- *DIN EN 1997-2 Eurocode 7: Entwurf, Berechnung und Bemessung in der Geotechnik, Teil 2: Erkundung und Untersuchung des Baugrunds,*
- *Für Projekte in Deutschland einschließlich DIN EN 1997-2/NA: Nationaler Anhang und DIN 4020:,*
- *Geotechnische Untersuchungen für bautechnische Zwecke – Ergänzende Regelungen zu DIN EN 1997-2*

bzw. jeweiliger nationaler Anwendungsdokumente und Anhänge in den jeweils gültigen Ausgaben verbindlich geregelt.

Geotechnische Kategorie bei Anwendung von Flüssigboden

- Nach EC 7 ist vor Beginn der Baugrunduntersuchungen die Baumaßnahme in eine der drei Geotechnischen Kategorien GK1, GK2 oder GK3 einzustufen. Umfang und Art der Baugrunduntersuchungen sowie der Laborversuche orientieren sich u.a. an der Geotechnischen Kategorie, siehe Abschnitt 2.2, EC 7.
- Baumaßnahmen, bei denen Flüssigboden zur Anwendung kommt, sind unter Ausschluss nachfolgender Ausnahmen in die geotechnische Kategorie GK 2 einzustufen.

Wird Flüssigboden vorwiegend für die folgenden Aufgaben eingesetzt, ist die Baumaßnahme der geotechnischen Kategorie GK 3 zuzuordnen:

- Schwingungsisolierung,
- Wärmeisolierung oder Wärmeableitung,

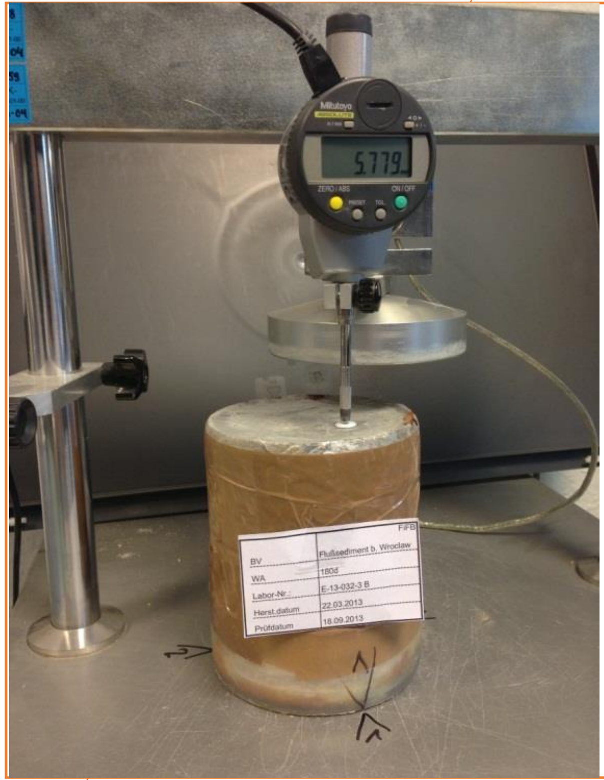
7

RAL Quality and Testing Specifications for Liquid Soil according to RAL-GZ 507 and their implementation starting with the planning and the ground investigation according to EC 7 or DIN 18300 (homogeneous areas)

Example: floating pipe laying

9

Quality assurance – Verification for soil typical behaviour



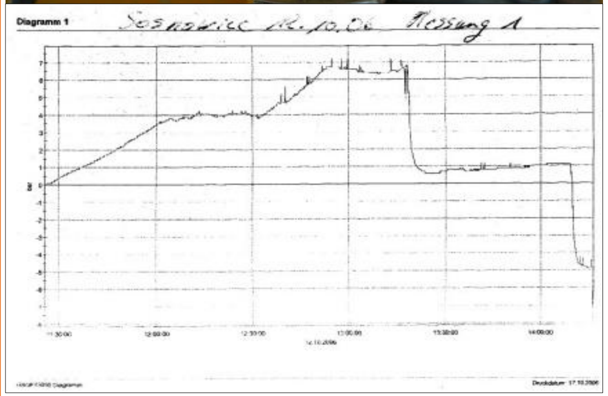
Example for the verification of *soil typical properties* in contrast to the properties of hydraulically setting materials

eg by:

1. Testing the material behaviour under changed placement conditions, such as
   - load
   - humidity
   - temperature etc.

9 Example: floating pipe laying

Quality assurance – technologically relevant properties



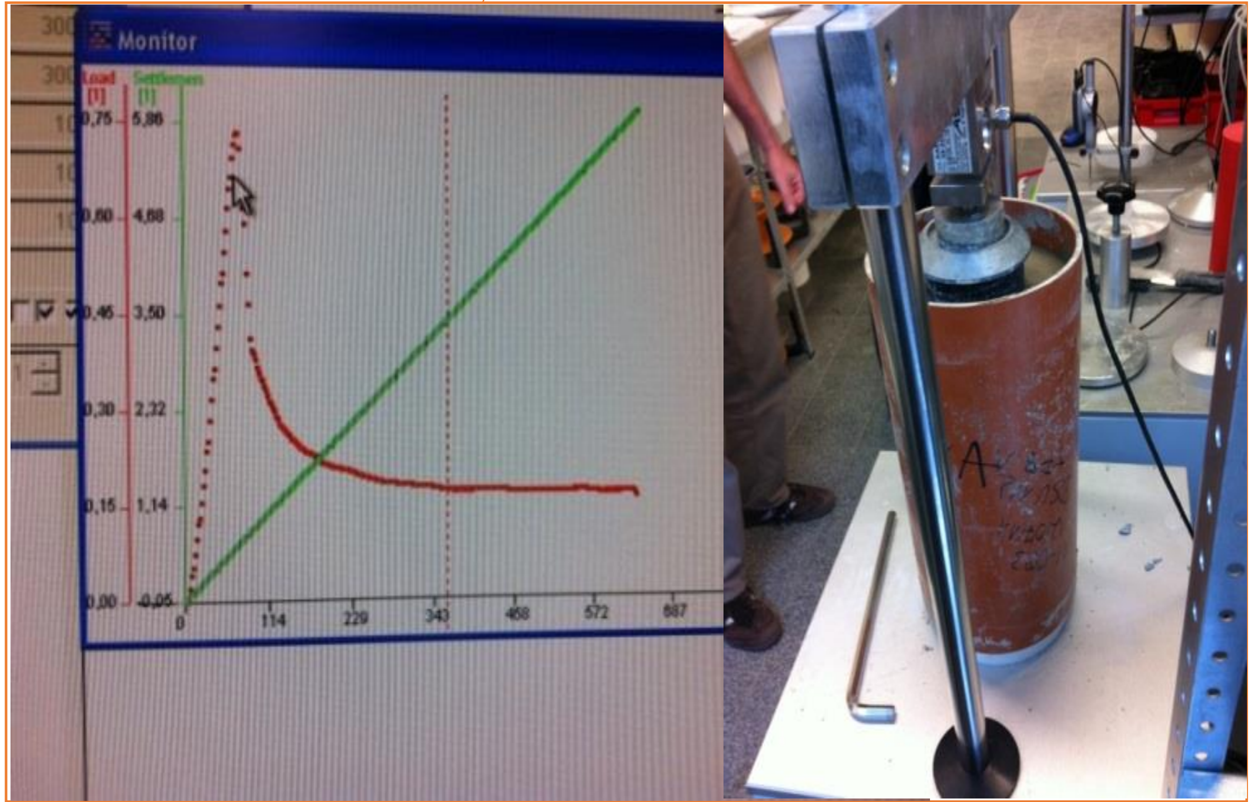
Example for the verification of *technologically relevant properties* – here in the case of a buoyancy measurement over time

1. as verification that the pipes are installed without foreign pressures
2. verification of the longer lifetime of the pipes resulting from that
3. possibility to control the technological construction processes
4. possibility to optimise the technological construction processes eg constructing on slopes or fast solidification for early further works on the liquid soil

Example: floating pipe laying

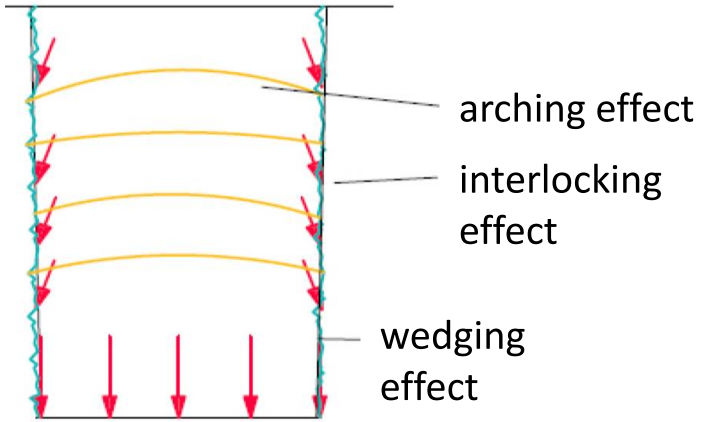
9

Quality assurance – Verification of special performance properties



Verification of frictional forces as example of the verification of *special performance properties*

here as basis for the position stability on non-bearing soils or FEM models for the subsoil



Example: floating pipe laying

10

Additional planning services required

5. Technological concept

6. Logistical concept

7. Concept of technical means

8. Using and evaluating advantages of urban planning

9. Necessary verifications

10. Environmental concept

11. Sample collection and control of the rheological properties

12. Tender phase

13. Quality assurance

The new possibilities of the LS method require additional/other planning services!

1. Mix design as part of the tender
2. focus technology
3. verifications adjusted to the LS and its application
4. new technologies involve other resources and other services with other cost structures

Example: floating pipe laying

11

Technological concept as part of the planning

The technological concept makes the processes and the required resources transparent and calculable

1. representation of the construction technology and of all steps of the construction process
2. specification of the required resources and the possible processes
3. specification of the special technological properties of the LS
4. optimisation if the processes
5. basis of the calculability of advantages

Example: floating pipe laying

12

Concept of technical equipment as part of the planning etc.

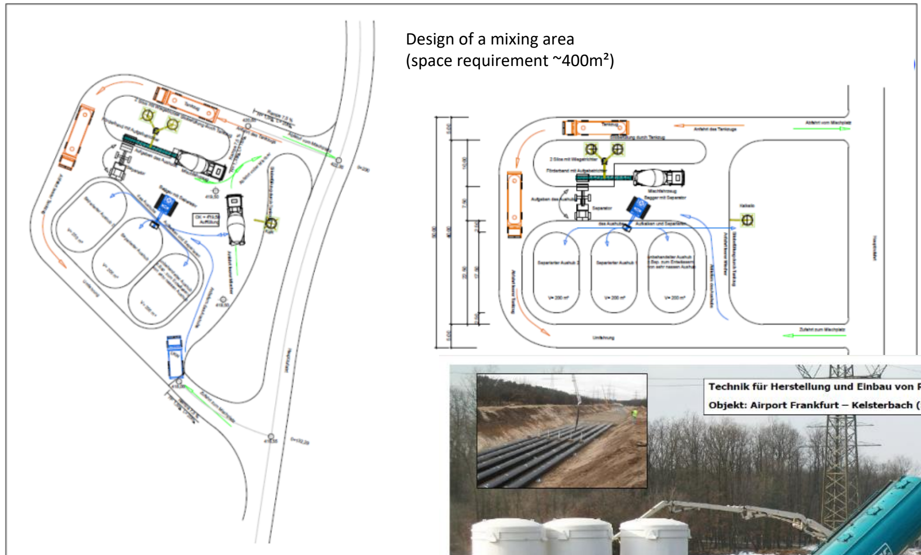
The equipment concept develops the requirements for the required technical means

1. composition of the required technical equipment and parameters
2. specification of the required resources and the possible processes
3. specification of the special technological properties of the LS
4. optimisation if the processes
5. basis of the calculability of advantages of the liquid soil method and the optimum use of the technological advantages

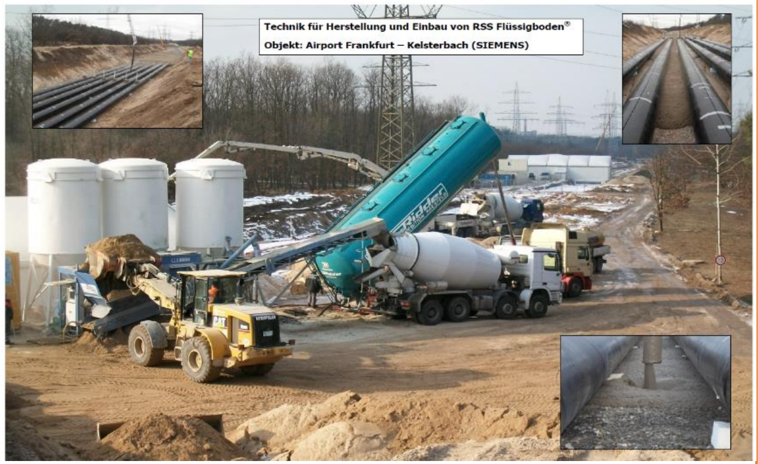
Example: floating pipe laying

13 Logistical concept as part of the planning

Design of a mixing area
(space requirement ~400m²)



Mixing location adopted to project
specific area situation
Example for a mixing plant



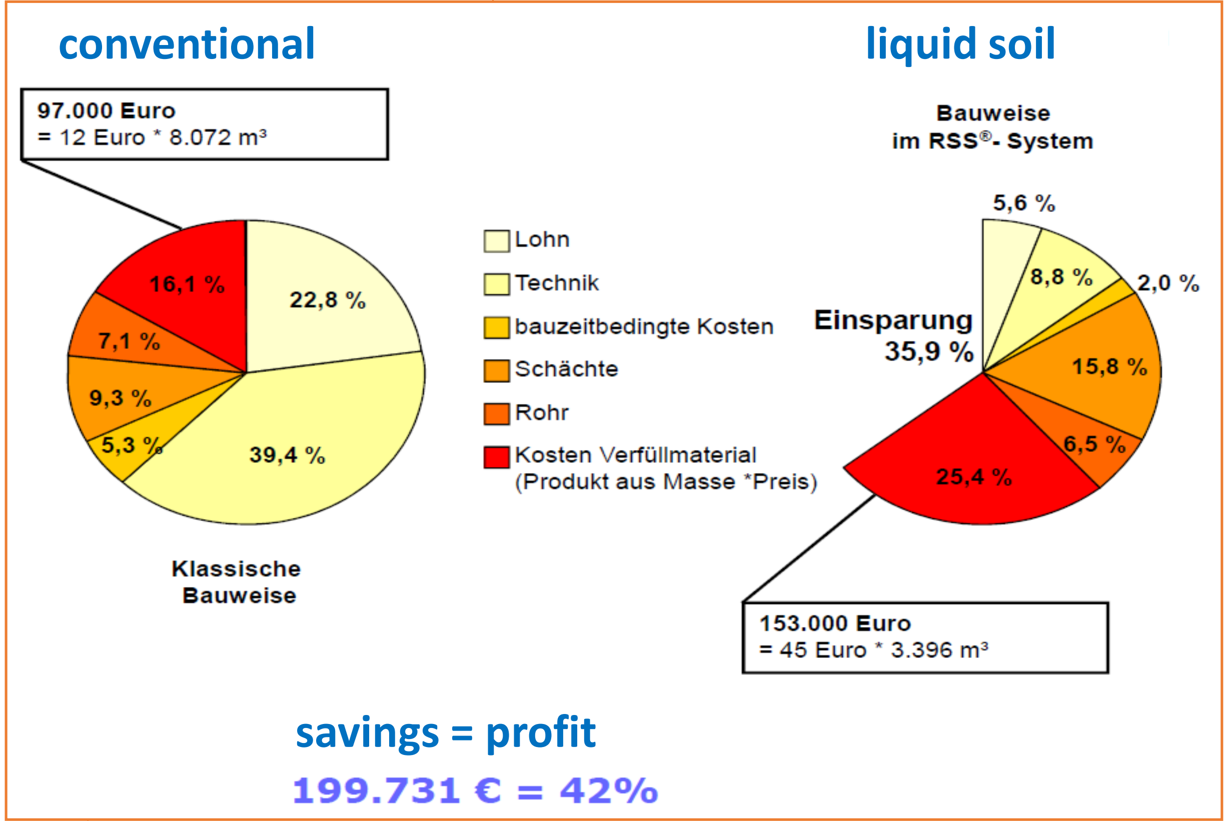
The logistical concept for securing optimised main and auxiliary processes of construction

1. secures the optimum processes on the building site for supply, production, transport and placement
2. helps shortening the construction time
3. minimises the effort for transport processes and auxiliary processes
4. is a relevant part of the possibilities to reduce construction costs

Example: floating pipe laying

14

Cost calculation as part of planning



Different technological solutions have a different cost structure

1. this requires a technology-based cost calculation
2. the planner or calculator must have a profound knowledge about the technological processes and the technical means
3. there are already aids in the form of software to help calculate the cost differences of the different technological solutions

Example: floating pipe laying

15

Contents of the Quality Assurance Plan – Process of quality assurance on the building site

Development and provision of ground investigation results

The planner and the technical planner determine the objectives of the ground investigation depending on the objective of the construction task for the ground investigation expert

Requirements for the mix design specified by planner and technical planner (liquid soil)

a)Soil-mechanical parameters
b)Technologically relevant parameters
c)Specific performance properties
permissible target values and tolerances

Preliminary mix design

according to specified target values

Testing of samples

and verification that target values are achieved

Approval of mix design and acceptance of liability by the mix design developer

(testing laboratory accredited by RAL with special and proven competence for mix design development)

PROCESS OF QUALITY ASSURANCE OF LIQUID SOIL ACCORDING TO RAL-GZ 507

Production with control and documentation

a)of the processes and intervention in the case of problems such as unplanned changes of the soil conditions etc.
b)and re-approval of the mix design for the corresponding homogeneous areas according to ATV DIN 18300 (earthworks)

Transport

according to specifications and instruction of the involved personnel

Placement

according to the technologically relevant specifications

Documentation and verification including evaluation

with all involved parties (creation of a regulatory cycle of quality assurance**)**

Example: floating pipe laying

16

A specific project example – implementation in practice

Situation in Hanau, Germany

1. A collection main DN 2400 must be installed in groundwater
2. The building site is located in the city centre with very narrow streets
3. As river Main is very close, and the ground is sandy (fine quicksand), there is the risk of base failure already during the excavation works
4. The surrounding buildings, which are very close, are at high risk of being damaged due to problems occurring during the construction works
5. Sheet piling could affect the surrounding buildings
6. Rather high costs and long construction time

Solution in Hanau, Germany

1. Application of RSS Flüssigboden including the required technical equipment
2. and the technology of floating pipe laying
3. Talk
   - Planning
   - Implementation
   - Scientific findings

Example: floating pipe laying

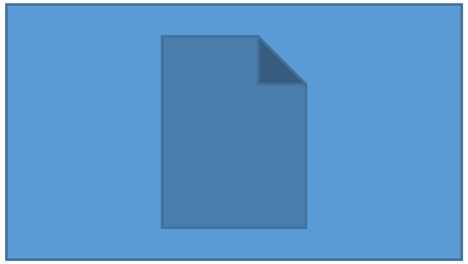
17

Cost calculation and tools for the selection of projects

Tools for the identification of particularly worthwhile projects

1. List of characteristic project features that signal high benefits
2. Tools for the qualified selection of suitable projects
3. Calculation tools for the quantification of production costs
4. Tools for the mathematical modelling of construction site processes for conventional or liquid soil technology

Tools for the identification of particularly worthwhile projects – 14 indications



Example: floating pipe laying

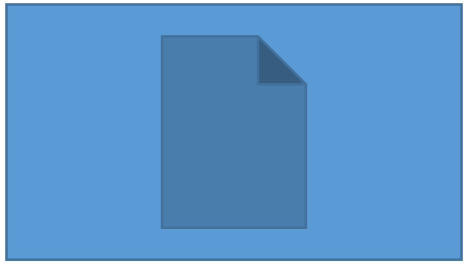
17

Cost calculation and tools for the selection of projects

Tools for the identification of particularly worthwhile projects

1. List of characteristic project features that signal high benefits
2. Tools for the qualified selection of suitable projects
3. Calculation tools for the quantification of production costs
4. Tools for the mathematical modelling of construction site processes for conventional or liquid soil technology

Project potentials



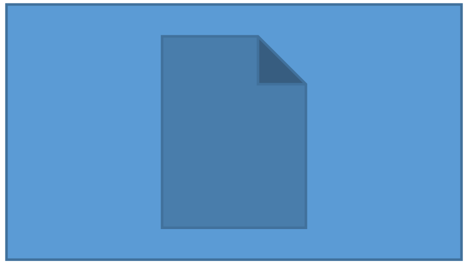
Example: floating pipe laying

17 Cost calculation and tools for the selection of projects

Tools for the identification of particularly worthwhile projects

1. List of characteristic project features that signal high benefits
2. Tools for the qualified selection of suitable projects
3. Calculation tools for the quantification of production costs
4. Tools for the mathematical modelling of construction site processes for conventional or liquid soil technology

Calculation LS production



17

Example: floating pipe laying

Cost calculation and tools for the selection of projects

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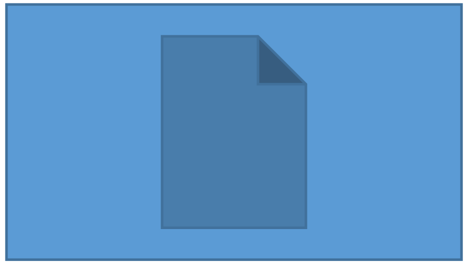
RSS CALK as a tool for the mathematical modelling of building sites



Example: floating pipe laying

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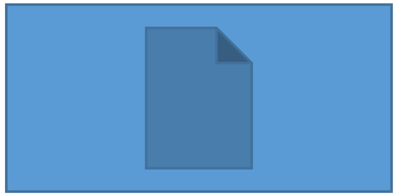
Cost calculation and tools for the selection of projects

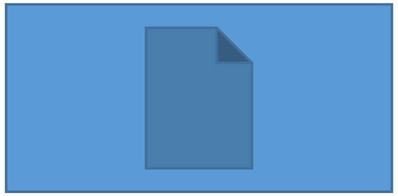
Tools for the identification of particularly worthwhile projects – LÜBECK Falkenstraße

1. Preliminary calculation
2. Post calculation

Tools for the identification of particularly worthwhile projects – LÜBECK Falkenstraße



RSS CALK preliminary calculation



RSS CALK post calculation

Need for training

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Focus issues of the necessary knowledge transfer

1. Material flow and conservation of resources
2. Significance landfill and soil exchange
3. Required space
4. Construction logistics and auxiliary processes
5. Technology and cost structures
6. New solutions promote economy,
7. eg worth-less marshland can become building land
8. Calculation
9. Technology for LS production and placement
10. Lining solutions
11. Planning
12. Calculation and verification methods

1. Quality assurance and required aids
2. Requirements for pipes and other components
3. Excavated and delivered materials
4. The role of renting machinery
5. Construction processes and speed
6. Relations with neighbours
7. Content of education and training
8. New possibilities of urban development
9. Lifetime – economic advantages
10. Insurance aspects, eg in case of floods
11. Building company structures, eg gang
12. Technological properties of liquid soil (LS) during construction phase and later on

SUMMARY AND OUTLOOK

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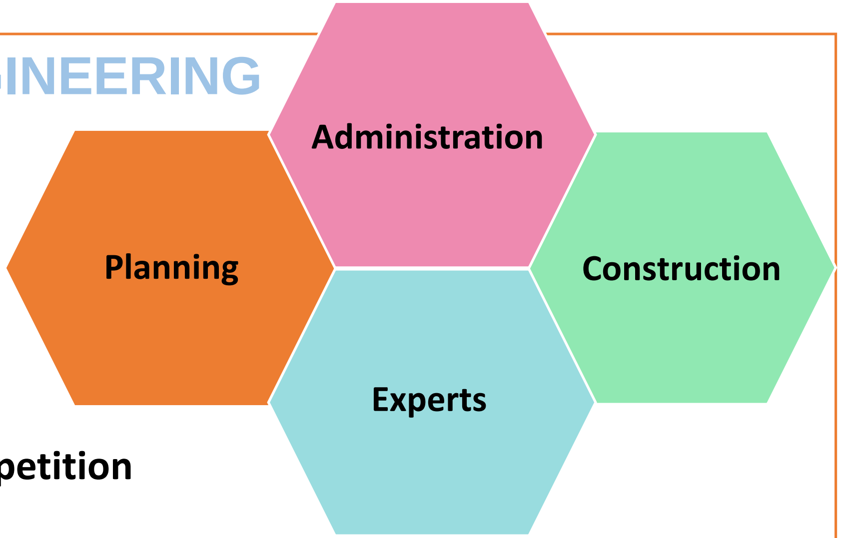
A serious change in the future underground engineering market

UNDERGROUND ENGINEERING



- **An opportunity you should not miss as an engineer**
- **An opportunity which is still a unique characteristic at present**
- **An opportunity the HTW Dresden offers their civil engineering students**
- **An opportunity which is going to be a German export hit**
- **An opportunity you can only seize with good training**
- **An opportunity with economic significance and advantages in the location competition**

That's why the HTW Dresden and the FiFB are developing an programme that allows to offer the necessary specialised knowledge, from the basics to a specialisation, including the possibilities to do internships, write and final theses and participate in R&D projects aiming at new fields of applications and new ways to optimise efficiency etc.