Flowable Fill Guidelines based
on RAL quality mark 507

RAL GÜTEZEICHEN FLÜSSIGBODEN

OBJECTIVE QUALITY FOR SUSTAINABLE CONSTRUCTION

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Guidelines for planners and implementers

1. Definition of the term "flowable fill"

Flowable fill, according to the RAL quality mark 507 (RAL-GZ 507), is a cohesive, frictional reconsolidating material in the group of temporarily fluid backfilling materials.

Flowable fill is a process which makes it possible to temporarily convert all common floors and aggregates into a fluid form.

In a second step, the flowable fill is reconsolidated without external compression work with controllable technological end properties, and without rigid hydraulic binding agent structures.

The source floor is recreated to display typical behaviour.

This allows for the original, enlarged and unhindered restoration of any trench. Alternatively, the cured properties can be specifically controlled, which can be specified for technological or constructional reasons.

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2. Classification of temporarily fluid backfill materials

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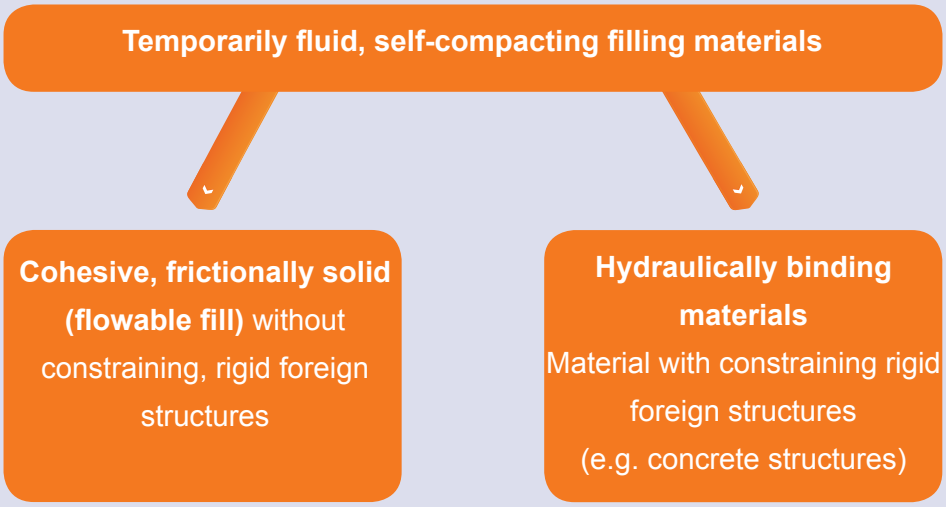
temporarily fluid self-compacting backfill materials classification.



2.1 Group 1 – cohesive, frictionally solid (flowable fill)

Properties

- Reconsolidation through the stable incorporation of mixing water into the material structure, resulting in the increase of friction and heightened cohesion between the soil particles
- Maintenance of typical soil characteristics, even with changes in external conditions (e.g. moisture, load, temperature etc.)
- Conservation of the initial soil's mechanical properties
- Avoid impurities in the soil and thus varying load-bearing characteristics and settlement behaviours, water permeability and vibration transfer in the backfilled areas
- Can be created from any excavation material (soil) as it is not dependant on constraints (such as basic milieu) for the strengthening reaction of hydraulic binding agents
- Individual characteristics can be modified without creating a filling area which reacts as a soil-mechanical foreign body
- Created through the combination of mixing and activation processes, meaning it is not purely a mixing process
- The volume of added water remains in the material in the form of stable compounds, which enables Flowable fill volume stability even in the case of not self-supporting grain structures (e.g. clay)

2.2 Group 2 – hydraulically binding materials

Properties

- Representation of compounds of hydraulic binding agents with sand, RC material or soil
- Reconsolidation creates impurities which overlay the characteristics of the source material
- and change the soil-mechanical properties of the source material
- This results in material properties which cannot adapt to e.g. moisture-dependant changes and
- leads to atypical impurities in the soil
- cannot be created from any excavation material (soil)
- Creation through pure mixing processes
- The volume of added water must evaporate, diffuse and drain, which causes shrinkage in non-self-supporting structures

3. How can you tell the difference?

The necessary expert knowledge has to be attained in order to carry out correct and competent quality assurance. The RAL Gütegemeinschaft Flüssigboden e. V. offers this within the framework of qualifications.

4. Status of classification by the ZTV-A and the FGSV construction principles (ZTV-A)

Excavating traffic areas causes a long-term disruption of soil density, stratigraphic sequences and the bonding of the layers of the trafficked construction area. It is therefore necessary to re-recreate a trafficked construction area in a manner that ensures a condition which is technically equivalent to the original area.
The construction materials used and the manufacturing and installation must adhere to the requirements of the "Additional Technical Contract Conditions" and guidelines and standards, or that proof of adherence is provided through relevant inspections.

This statement by the ZTV-A includes the fact that construction errors can only be avoided if the backfilled material adheres to the soil-mechanical behaviour of the surrounding area once it has been installed. Otherwise, it will become a "foreign body" and reacts differently to the area surrounding the backfill. This is one of the greatest causes for construction damage.
The efforts of FGSV working group 5.3.2 resulted in this important statement by ZTV-A being incorporated into the principles of the leaflet draft for "temporarily fluid, self-compacting backfilling materials composed of soils and construction materials" (version March 2010).
The principles were initially fulfilled by flowable fill without rigid, forcing hydraulic binding agent structures which overlay the soil characteristics

Guidelines for planners and implementers

5. Physical and construction characteristics

- typical soil behaviour in avoidance of impurities in the substrate during reactions which are biomechanically identical to the surrounding area eliminates road damage
- avoiding unfavourable pipe angles or their deterioration through insufficient gusset compression or shrinkage of the backfilling material
- no damage through the material and protection of the pipe surface from mechanical damage or chemical influences
- non-settling filling of pipe trenches and prevention of pipe and road damage
- stable and secure installation of pipelines without future changes
- structural strength during static and dynamic loads on the backfilling area through superstructures and traffic load without creation of rigid foreign particles
- protecting pipes from dynamic loads (bedding damages, damage to pipe connections and junctions etc.)
- prevention of inadmissible subsequent hardening of the backfilling material beyond the level of drying of argillaceous soil
- technological suitability for supporting new installation technologies which accelerate construction progress and improve installation quality
- environmentally and ecologically sound re-use of the excavated material and avoidance of exchange material (fulfilling the Recycling and Waste Management Act)
- explicit acceptance of materials by pipe manufacturers in order to avoid liability issues

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6. What do building contractors need to take into account?

The advantages of flowable fill construction are not only based on quality and the fulfilment of high environmental legislation requirements, they are also related to completely new technologies with high financial, qualitative and time-based benefits. Flowable fill construction allows contracting authorities to ensure sustainable temporal, material and financial objectives. Theses benefits can only be used if planners who did not obtain knowledge of these new possibilities during their studies are able to access practical information.
In the framework of building specifications and tenders, it is not only conventional materials which should be replaced by flowable fill. An exacting technological, technical and logistic description must be carried out to allow construction companies to take advantage of the economical benefits of these new technologies in their calculations. Otherwise, contractors are at risk of only comparing materials without considering that the technologies which are connected to flowable fill processes lead to significant savings in labour and machining times.
Quality assurance starts in the planning phase, with the development of specific guidelines for manufacturing and implementation which is tailored to the particularities of various construction sites. Quality assurance should be firmly in the hands of a qualified specialist who is bears responsibility for the results, has gained the necessary knowledge and can submit proof of qualifications. Quality assurance should take place during planning within the contractual relationship with the building contractor.

The services of qualified specialist planners, who can attain these qualifications within the framework of the services provided by RAL Gütegemeinschaft Flüssigboden e. V., are perfectly suited for this.

7. What items need to be covered in a contract between building contractor and construction company (in terms of flowable fill)?

- exact characteristic requirements of the filling material or flowable fill and the construction project to be implemented
- exact requirements in terms of technology and logistics
- exact requirements for adherence to environmental and emission laws
- exact requirements for the inspections and certifications, as well as a schedule for the quality assurance services
- exact requirements for the construction company's self-supervision
- exact statements regarding the responsibilities for quality assurance and the competencies of the external inspectors engaged by the construction company
- exact requirements for the qualifications and experience level of all participants in the project (planners, flowable fill manufacturer, construction company): Certification "Certified Quality Assurance Officer for Flowable Fill acc. to RAL quality mark 507"

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8. Role and task of a specialist planner for new applications

- must fulfil all construction and quality tasks needed for flowable fill installation provided that such tasks are not subject to the qualification requirements of residential water management experts and construction engineers
- is responsible for the groundwork which allows tenderers to both recognise the technological, technical and logistical advantages of flowable fill construction and implement these in their calculations
- supports project planners in the bid to tender, cooperates with them after awarding, advocates for the special characteristics of flowable fills with the tenderer and consults with them when needed
- bears responsibility for the correctness of these performance specifications and their feasibility
- accompanies the implementation and supports construction companies in the successful application of relatively new technologies
- takes over quality assurance at the construction site during flowable fill installation on behalf of the building contractor, as permitted based on the tender
- documents construction and evaluates it in cooperation with the building contractor and all involved parties, and suggests the use of reserves during the overall process

9. Quality assurance basics

- RAL quality mark 507 (RAL-GZ 507)
- Quality and inspection provisions
- Requirements for planning, manufacturing and quality assurance of flowable fill, its installation and the technical, technological, logistical and environmental protection principles, as well as the classification of self and external monitoring on the construction site, the initial inspection, the awarding of a quality mark as well as documents for quality assurance
- Qualifications of participants (training opportunities)
- Services
- Subject-specific training

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10. Possibilities for training and further education

Within the framework of training and further education, RAL Gütegemeinschaft Flüssigboden e. V. offers a certification for "Qualified Quality Assurance Officer for CLSM based on RAL quality mark 507", which is implemented in cooperation with the Regensburg University and the FiFB (Forschungsinstitut für Flüssigboden GmbH, private company).

Participants: Manufacturers and controllers of flowable fill

The training courses can be attended even without completion of the examination. In this case, participants are issued an attendance confirmation instead of a certificate.

The "Certified Quality Assurance Officer for flowable fill acc. to RAL quality mark 507" certification contains the following topics, among others:

- Flowable fill - a process and its possibilities
- Mineralogical basics of the flowable fill process and its quality assurance requirements
- Soil-mechanical basics of the flowable fill process
- flowable fill requirements in accordance with quality and inspection requirements
- flowable fill - theoretical and practical basics for the manufacturing, supply and installation of flowable fill
- Required specialist knowledge for the quality assurance of the flowable fill process
- Practical introduction to the testing methods of the flowable fill quality assurance system
- Current environmental laws/approval requirements for the process and manufacturing technology
- Specificities in the inspection of flowable fill in comparison to known soil-mechanical inspection methods
- Notable information for the manufacturing and transportation of flowable fill with the goal of a successful quality assurance in the manufacturing, transport and installation of flowable fill
- Application opportunities of mineral substances on the basis of the flowable fill process
- Possibilities for support of users by RAL Gütegemeinschaft Flüssigboden e. V.

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11. Sources and source discussion

DIN EN 1610 – controls the basic requirements for canal construction, which includes fluid backfilling materials such as flowable fill.
ZTVA-StB 97 – defines indirect requirements for the filling areas for purposes of restoration of the initial situation (technical equivalence compared to the original state), which simultaneously defines the indirect requirements for the backfilling materials: these can only restore the undisturbed situation if their properties during installation are similar to the characteristics of the surrounding area.

The quality and inspection requirements of RAL Gütegemeinschaft Flüssigboden e. V., quality mark 507 – determine the requirements of flowable fill in the sense of restoration of the initial soil conditions, meaning the soil-typical properties of the backfilling area.

Technical dictionary

12. Technical dictionary - explanatory notes

To differentiate between several meanings, related objects or subjects or cursive entries in brackets create a reference to the general context.
(marked in orange in the example)

Adhesion: N attraction *(gravity)*

The part of speech (abbreviated) is listed after the word and marked with a top and bottom line, e. g. adjective = ADJ, adverb = ADV, pronoun = PRON, noun = N ...
(marked in orange in the example)

Adhesion: N attraction *(gravity)*

A short explanation follows the word.

In addition, word groups are listed in this document, as their relationship to flowable fill creates certain combinations which occur repeatedly in this context.

Adhesion: N attraction *(gravity)*Adhesion forces hold molecules in different phases or materials together, such as glass and water. With a flowable fill, adhesion is only relevant for the formation of sliding layers made of water in a non-solid state, which affects the subsequent creation of surface-protecting layers.

Activator: N catalyst *(Chemistry)*
Hydraulic activators are usually used. Other materials are also suited as activators, though they are currently not as economical. Hydraulic activators are cements which have a suitable
and required hydration process. They withdraw water from the added plasticiser quickly at a defined point in time. This causes the sliding layers to be broken down, while friction builds up at the ground particles of the fill matrix. As a result, the previously fluid material becomes plastic. Afterwards, the remaining water is absorbed and bound by the stabiliser which was also added in the process.

German Soil Protection Act (BBodSchG): N
(Law)
A German federal law which came into force in 1999, and which forms the bulk of federal soil protection laws, in combination with the soil protection acts of the federal states. Demand since 2012: unlimited re-use of excavated soil and 70% re-use for non-hazardous construction and demolition waste

DIN standard: is a voluntary standard developed by a working group of the DIN Deutsches Institut für Normung, which standardises material and immaterial objects. DIN standards are created based on suggestions and initiatives by interested persons (usually the German economy), where all parties conform to the standards.
DIN standards are based on the guaranteed results of economy, technology and experience and serve the general public. They are developed in the norming process.

R & D: stands for Research and Development

Technical dictionary

Flowable fill: N backfilling material *(underground construction)*
is a frictionally cohesive, self-compacting material belonging to the temporarily fluid, self-compacting backfill materials family. It can have a consistency of plastic to fluid, where the soil-mechanical properties of flowable fill are controllable. Flowable fill does not have closed, rigid, forcing foreign substances e.g. through hydraulic binding agents.
In reconsolidation, flowable fill displays high volume stability due to permanently stable water binding in the bulk of added water, and contains no polluting additives. It therefore has no objectionable effect on the soil (BBodSchG) or the soil-groundwater path.
(detailed information at: www.ral-gg-fluessigboden.de or www.de.wikipedia.org/wiki/Flüssigboden)

Flowable fill process: N manufacturing process *(underground construction)*
This manufacturing process enables any type of excavated soil, industrial or natural aggregates, as well as other mineral substances to be made temporarily flowable, to reinsert them so they self-compact, thereby restoring a situation in which they are similar or identical to soil in the soil-mechanical and physical sense.

Friction: N friction *(Physics)*
is the property of inhibiting a movement which occurs between solids or particles which touch. There is a difference between external friction between touching surfaces or bodies and internal friction between neighbouring particles in the flowing deformation of fluids and solids.
The latter is a technologically relevant characteristic for the flowable fill process but also part of the power which controls the absorption capabilities of loads on soil.

Trench width: N permissible width determined based on static measurements (underground construction) by DIN EN 1610. When installing flowable fill,
the minimum trench width based on DIN EN 1610, 6.2.2 can be undercut. Because: point 6.2.3 of the DIN EN 1610 states "...if staff members never enter the trench, e.g in the case of automated installation techniques" refers to installation techniques which make entering the trench avoidable, which can be useful in the case of fillable flow processes and the required tools (pipe installation tools).

Ground seepage: N erosion of soil
(soil mechanics)
Ground seepage is understood to be a side-ways erosion of soil through the exertion of forces, whereby the soil is often displaced along a slippage surface. The cause for this is the exceeding of shear strength, which describes the resilience of the soil.

in situ: a Latin term meaning "on site", "locally", "in place"

Real value: N actual value *(soil mechanics)*
means a measured value. The real value should be as close as possible to the target value. The ideal scenario: real value = target value.

cohesive, frictionally reconsolidating:
Reconsolidation through the stable incorporation of water in the material structures of the flowable fill, with the effect of initial formation of friction forces, and the subsequent increased cohesion between soil particles and flowable fill in the reconsolidated state. The volume of added water remains in the form of stable bonds in the material, which enables high volume stability of the fillable flow, even in the case of not self-supporting grain structures (e.g. clay).

Cohesion: N bonding strength *(soil mechanics)*
Cohesion forces hold together molecules, such as in a drop of water. Cohesion in soil mechanics is the sum of cohesive forces holding soil particles together. They are forces which

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are only effective at very small particle sizes through their (electro-static) surface reactions. They become a defining characteristic of these materials, e.g. in the case of clay (not to be confused with the capillary cohesion of sand), arise in the pores due to capillary forces, approach zero in cases of water saturation or dehydration and can trigger annual cracking in sand-embedded KMR.

Contractor procedure: N̲ Backfilling technique under water *(underground construction)*
The flowable fill is inserted into a concrete chute through a funnel. The lower end of the funnel must always be below the surface of the freshly added flowable fill. This prevents the flowable fill from mixing with the liquid above it. The concrete chute must be continuously pulled upward during the process. A thick casing is necessary on the sides.

Life-Cycle Management Law (KrWG): N̲
is the central federal law of German waste legislation. It regulates the handling and securing of the environmentally-friendly management of waste, and promotes life-cycle management.

Mohr voltage circuit: *(physics)*
is a process, developed by Christian Otto Mohr, for the geometric representation of normal and shear stress within a cross section which is encumbered by forces and momentums – here the cross section of a test specimen – in the construction practice of the soil cross sections which need to be resilient.

Plasticiser: N̲
The aggregate which enables temporary fluidity of backfilling material etc. is referred to as a plasticiser. A plasticiser is responsible for keeping added water in a fluid state in the flowable fill or soil matrix. It enables the creation of a water film or sliding layer between the soil particles, which also facilitates the temporary fluidity of the relevant soil matrix. Specifically altered layer minerals have proven to be reliable plasticisers for flowable fill. Even small amounts are able to absorb high volumes of water in soil in installation conditions and in a stable manner.

RAL:
RAL is an independent institution which is responsible for the creation of the RAL quality mark. RAL Quality Associations are in charge of awarding these quality marks. Quality Associations which are certified by RAL are comprised of particularly quality-consciousness service providers and manufacturers.

RAL quality mark:
Only those associations which have voluntarily submitted to strict RAL quality and testing regulations are given the right to bear the RAL quality mark. Adherence to these regulations is ensured through regular monitoring by the association and third parties. There are currently more than 160 RAL quality marks for thousands of products and services. They are awarded by 130 RAL Quality Associations with more than 9,000 member companies from all industry branches, both domestic and international.

RAL quality mark 507:
The RAL quality mark 507 stands for the neutrally-monitored high quality of flowable fill. The following criteria must apply. Various types of excavated material can temporarily be transformed into a plastic or flowable state with controllable technological characteristics. Subsequently, they can be reconsolidated with the constructionally-relevant properties of the source material, or with specifically altered characteristics. This process avoids the formation of rigid, forcing foreign structures which supersede the source material's properties, preventing the formation of impurities under streets and any possible damages (tears and settlement). Polluting substances which endanger the dynamic of soil and groundwater are not added.

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Degree of refixation: N degree of reconsolidation *(soil mechanics)* is the measurement for the remaining plasticity of the flowable fill.

Course of refixation: N describes the course of reconsolidation *(soil mechanics)* for flowable fill.

Friction angle: N angle of internal friction *(soil mechanics)*
is the angle at which a solid body or granular material can bear a load without slipping or failing. It is a measurement for friction and coarseness (or smoothness) of surfaces. In terms of bulk material,
this angle is called "repose angle" in the special case of largely absent cohesion, or "slope angle" in the case of backfill.

Relaxation: N transition *(soil mechanics)*
identifies the transition of a system's relaxation processes to its base state or a state of equilibrium (usually after stimulation or an external disruption). In solid-state physics and surface chemistry, the presence of altered inter-atomic distance at or near the solid-state surface is called (surface) relaxation. This case does not include a dynamic relaxation process in the sense of the definition above.

Rheology: N time dependency of flow characteristics *(physics)*
Describes the deformation and flow behaviour of materials, without taking the material's structure into account. Rheology is the science of material deformation and flow behaviour.

Bulk density: N volume weight *(physics)*
Also called apparent geometrical density. It defines the density of a porous solid body, based on the volume with pore spaces. Bulk density's counterpart is true density. Bulk and true densities of non-porous bodies are identical. The quotient of bulk and true densities is relative density. Higher true density in construction materials generally have a positive effect on sound insulation and a negative effect on thermal insulation.

Pipe installation tool: N tool *(underground construction)*
is a mechanical device which is used in the installation of one or more pipes, in various dimensions and materials, against buoyancy in flowable fill.

Shovel screener: N screening schovel*(construction machine)*
is a highly efficient auxiliary product for excavators and wheel-type loaders. It is especially well-suited for the preparation of soils. It can prepare all soil types the production of flowable fill. Any material, from coarse gravel to clay, can be processed. Grain sizes> 30 mm are reliably separated during preparation.

Shear plane: N connection of measuring points *(soil mechanics)*
is characterised by its slope – this is the angle of friction – and the distance at which it intersects the vertical axis. This distance constitutes cohesion. As such, the shear plane is the graphic representation of the sum of the cohesive forces and the recordable internal friction forces.

Shear force: N *(mechanics)*
The shear force is the force acting on a surface, the direction vector of which is parallel to this surface.

floating installation: special construction method below water *(underground construction)*
During a floating installation, pipes and cables are fixed and positioned with pipe installation tools. The trench is subsequently filled with flowable fill. With this construction method, it is not necessary to lower the groundwater level, as the flowable fill is capable of displacing the water in the trémie.

Shrinkage: N volume reduction *(physics)* is the change in volume of a material without removing material or exerting pressure. Shrinkages are the result of dehydration, cooling or chemical or physical transformation mechanisms.

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Vibration decoupling: N damping of the vibration transfer *(physics + underground construction)*
Vibrations, such as those caused by traffic, represent a significant potential danger for sensitive construction materials. One way to actively protect buildings is through the use of flowable fills, with special characteristics, which adhere to RAL quality mark 507 Internal processes in the flowable fill materials can transform and absorb vibrational energy. The geometric composition of areas where flowable fill is to be installed, its position relative to protective construction elements and other aspects are important factors in achieving optimal results.

Self-compacting: ADJ *(physics)*
a material achieves stable solidity without mechanical or force-based interventions.

Settlement: N*(physics)*
Settlement, in terms of construction and geological sciences, is the slow depression of a structure or rock body through gradual compaction of the subsoil. The cause of this subsidence is usually the weight of overlying masses, but can also be caused by volume reduction through dehydration, such as reduction of ground water or other shrinking processes. For structures, the majority of settlement cases can be ascribed to yield in loosened or backfilled soil. Its probable extent can be estimated if the soil structure and relevant/active structural load is known. Settlement also encompasses the subsidence of backfilled or integrated soil under its own weight. This can often be observed is cases of inadequately compacted backfills, backfilled utility trenches or, very often, with dams.

Set point: N target value *(soil mechanics)*
generally describes the target value of a quantitative characteristic of a system where the actual value should deviate as little as possible. The set point is determined by a different system (e.g. technology, person). The ideal scenario: actual value = target value.

Stabiliser: N hardener *(chemistry)*
An aggregate, which further reduces the plasticity introduced into the construction trench by an accelerator, and as such promotes the return to the soil's source characteristics, is described as a stabiliser.
Caution: cement, incl. hydraulic binding agents, are ***not*** *suitable as stabilisers.*

Synchronised construction process: N construction phases withsimilar formwork *(underground construction)*

Thixotropy: N change through contact or integration of kinetic energy *(physics)*
is the rheological characteristic of non-Newtonian fluids when the viscosity reduces subject to mechanical forces (shear forces) and increases upon the release of energy. This characteristic also occurs with certain soils and can be employed in flowable fill processes in a technologically-targeted manner.
Examples:
1. The so-called ketchup bottle effect: Ketchup usually has to be shaken before it flows out of the bottle, and only recovers over a certain (short) time frame.
2. Behaviour through the kneading of certain plastic materials
3. Toothpaste, once squeezed from the tube, should sit on a toothbrush as a highly pasty product. Through the addition of kinetic energy while brushing or through a vibration toothbrush, the consistency of the paste changes.

Triaxial test: N pressure test *(soil mechanics)*
Pressure test on cylindrical soil or rock samples to determine material characteristics. During a conventional triaxial test, the cylindrical test specimen is subjected to pressure by a press, which applies pressure fluid along its circumference and in the axial direction (greatest compressive stress). The specimen is sealed with an impenetrable Teflon, rubber or metal membrane to prevent the ingress of the pressure fluid into its pore spaces. The triaxial test is an axial-symmetrical pressure test performed on homogeneous, cylindrical specimens.

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The CU test is a consolidated, undrained test which determines shear strength.
Individual tests on three identical specimens are required for the determination of shear parameters. Each individual test comprises these parts: saturation, consolidation and shearing

Environmental law: N *(law)*
Environmental law is the entirety of legal norms which support the protection of the natural environment and the maintenance of ecosystem functionality.

Trench shoring: Trench shoring includes construction measures and installations which support and secure the walls of trenches, pits, shafts and tunnels, as well as excavation walls and ceilings in trenches in underground, tunnel, underwater and mining construction. In Austria the term "Pölzung" is used, in Switzerland "Spriessung", as opposed to the German term "Verbau".
Trench shoring ensures a cavity in the case of collapse, earth slippage, ingress of water or erosion, and thus protects traffic routes, cable routing, working areas, machinery and people from dangers and impairments. Execution and structural stability of trenches are regulated by occupational health and safety regulations and relevant laws. Different cavities with specific requirements result in special techniques.
The mining sector has the greatest wealth of experience and tradition in trench shoring, and extensive tunnel construction projects have led to the current development of technologies. In terms of soil construction, superstructure and underground construction and pipe installation, the technologies used can roughly be distinguished into two points of view: In trench shoring the lateral securings rely on one another, in excavation shoring the shoring is ensured through grouted anchoring or clamping in the ground.

Construction techniques:

Essener-type shoring
This construction method is a slightly angled shoring with an embankment and grouted anchor. The embankment is secured through perpendicular dual IPB (with joining plates) every 1.5 to 2m. These are held by anchor heads. The interstices are covered with wire mesh or corrugated steel and steel wire fabric. They are protected against erosion with sprayed concrete.

Berlin-type shoring
This vertical construction method is used in e.g. underground rail construction or with easily drained foundation soil. Steel I-sections are rammed into the ground prior to excavation or installed into boreholes. With continued excavation, the compartments between individual beams is fitted or wedged with planks or squared timbers. Reinforced concrete parts or trench sheets can be used instead of wood. The distance between beams is
generally 1.5 to 3m. Berlin timber sheeting can be stabilised through horizontal bracing or rearward anchoring in the foundation soil.

Hamburg-type shoring
This vertical construction method is used in e.g. underground rail construction or with heavy foundation soil and pressing water. Vertical I-sections (IPB, IPE) with partly covered, vertical wooden beams. The beams remain as lost formwork. The I-sections are removed.
The reinforced concrete tunnel has an additional adhesive coating and load.-bearing wall (2-layer wall structure with a total thickness of 60 cm).

Shoring boxes
With shoring boxes, two large-format steel plates are installed into the excavated trench as a complete unit. They are pressed against the trench walls with attached spindles. With soils that do not have even a temporarily sufficient stability, the shoring boxes must be pushed in simultaneously with the excavation progress.

Slide rail shoring units
Shore-supported rails are installed in the trenches and then the shoring panels are inserted into

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the side rails. This has the added benefit of allowing for adjusted shoring depths during construction.

Bored pile wall
Boreholes are filled with in-situ concrete and steel reinforcement. This type of construction inhibits soil displacement in the area to a great extent. At greater heights, grouted anchoring is required. Three construction methods are distinguishable (secant pile walls, tangential pile walls, contiguous pile walls with escape paths for water).

Diaphragm wall (acc. to DIN 4126)
This type of construction is a closed reinforced concrete or fibre concrete wall up to a height of 100 m. Parallel to excavation with a diaphragm wall grabber, the open slot is filled with a bentonite suspension. Afterward, the reinforcement is lowered or concreted. The heavy concrete sinks to the bottom or displaces the bentonite suspension, which can be drained from the top.

Sheet pile wall
With this construction technique, steel sheet pile walls are rammed or pressed into the ground next to each other. The beams are formed in such a way that they interlink. After ramming them in, excavation can take place. Depending on depth, grouted anchors or braces have to be installed at specified distances. Sheet pile walls can be manufactured to be waterproof.

Viscosity: N liquid thickness *(physics)*
The higher the viscosity, the thicker (less fluid) the liquid; the lower the viscosity, the thinner (more fluid) the liquid, meaning it can flow faster under the same conditions. The important factor for flowable fill is whether it needs to be pumped or let in directly from the truck mixer. Different values are relevant here.
The term viscosity can be traced back to the typical liquid thickness of berries of the mistletoe plant genus (Viscum). This mistletoe was used to produce birdlime. "Viscous" thus means "sticky, thick as bird lime".

Soil and groundwater dynamics: Potable water is extracted from groundwater, which also feeds surface water (rivers, lakes, rain water which has not seeped into the ground). Pollutants from contaminated waster can enter into the human system through various ways, and endanger health and life. Ground and surface water are usually contaminated through suspended or dissolved pollutants, and can only be used as potable water after treatment.

Water-cement ratio (W/C ration):
water-binding agent ratio
is a parameter for construction materials with hydraulic binding agents. The value describes the relationship between the volume of mixing water and the volume of binding agent in a thickened mixture. It is especially important in concrete manufacturing. Values which are too high or too low impair the concrete's characteristics. The compressive strength in particular is reduced if the value taken as a basis for mixing calculations is not adhered to. Today, the term water-binding agent ratio is more applicable than the term water-cement ration. The binding agent is usually not composed of cement, but rather concrete additions such as granulated slag, pozzolan, fly ash, coal fly ash or silica fume which are added to Portland cement, as these are cheaper and often better. These additives must be factored into mixing calculations, in contrast to concrete additives. The required characteristics are, for example, slower hardening in the construction of retaining walls to reduce the heat produced by chemical reactions. This is achieved through the addition of fly ash.

Aggregates:
Aggregates for flowable fill are specific plasticisers, accelerators, specific stabilisers which can be described as having soil-like characteristics because they are made of materials which also occur in natural soil (e.g. clay minerals), as well as water or special limes.
Certain additives are unsuitable, namely those which cause macroscopic, rigid, linked, fixed characteristics which thus supersede the source material properties and generate deformation-resistant foreign structures in the soil.

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