

CSM

Cutter Soil Mixing

Methods



Mixing of self-hardening slurries with native soils by using a modified trench cutter technique is an innovative and effective method for constructing cut-off walls, earth retaining walls, foundation elements as well as soil improvement. CSM is used mainly for stabilizing soft or loose soils (non cohesive and cohesive). The equipment used, derived from Bauer's cutter technology. The applicability of the method is thus extended to much harder strata when compared to other methods of soil mixing.

Main advantages of the method are:

- High productivity
- The in-situ soil is used as construction material
- Very little generation of spoil (important factor in contaminated areas)
- No vibrations induced during construction
- Extended depths (up to 80 m) can be reached – when using rope-suspended units



Construction sequence

Preparation: Excavation of a guide trench for collecting surplus slurry

Step 1:

Positioning of the cutter head in wall axis. For Kelly-guided systems a guide wall is not required. It is, however, recommended for free-hanging systems.

Step 2:

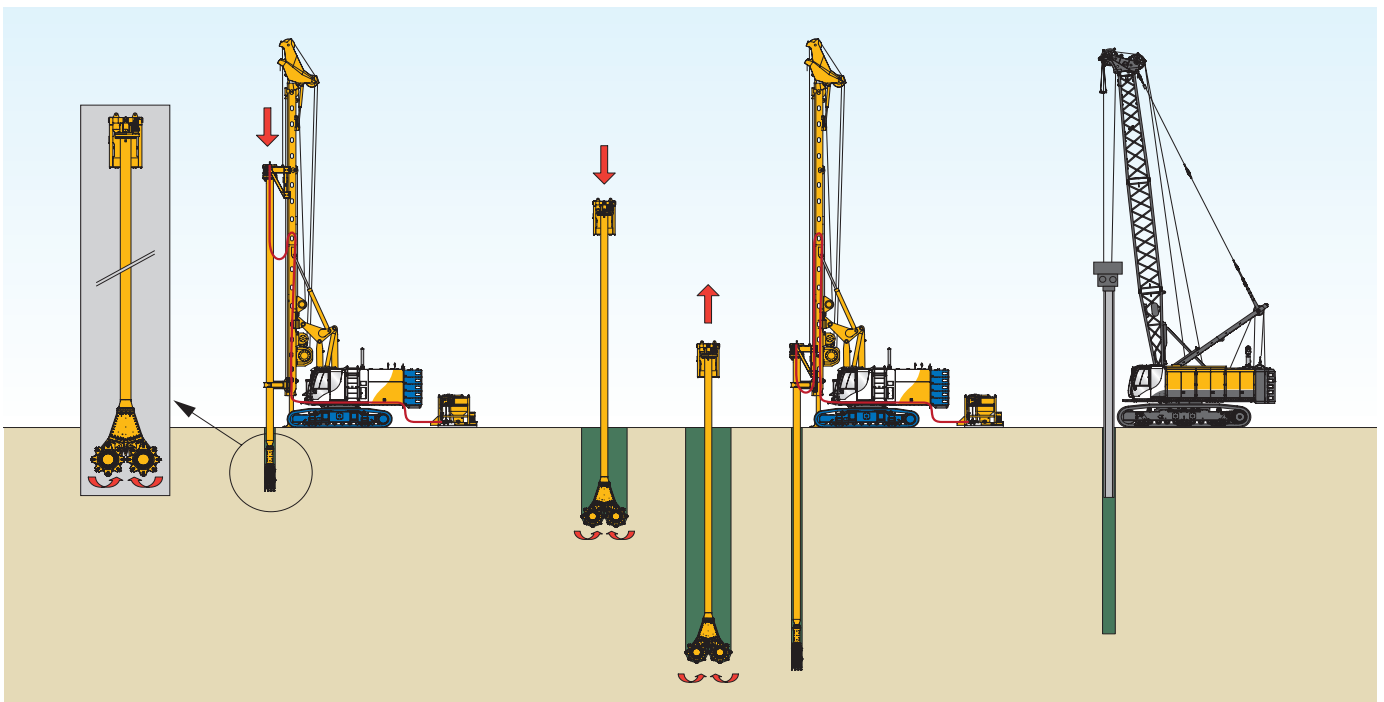
The mixing tool is driven into the ground. At the same time self-hardening slurry or bentonite slurry is added. The soil matrix is broken up by the cutting wheels and liquified by adding slurry. The rotating wheels and cutting teeth push the soil particles through vertically mounted shear plates that have the effect of a compulsory mixer.

Step 3:

After reaching the final depth the mixing tool is extracted while self-hardening slurry is added.

Step 4:

Reinforcing elements required for structural purpose can be inserted into the mixed wall. Therefore, steel beams (mostly H-beams) can be installed into the not yet hardened fresh mixed panels. The distance of the beams and beam cross sections are designed on the basis of the applied loads.

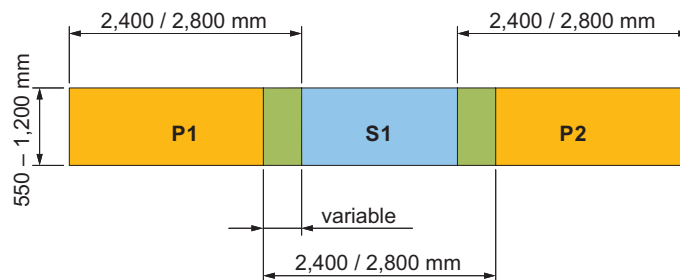


Construction Sequence

A continuous wall is formed in a series of overlapping primary and secondary panels. Overcutting into fresh adjacent panels is called „fresh-in-fresh method“.

The cutter technique also allows the “hard-in-hard method”, whereby secondary panels are cut into the already hardened primary panels.

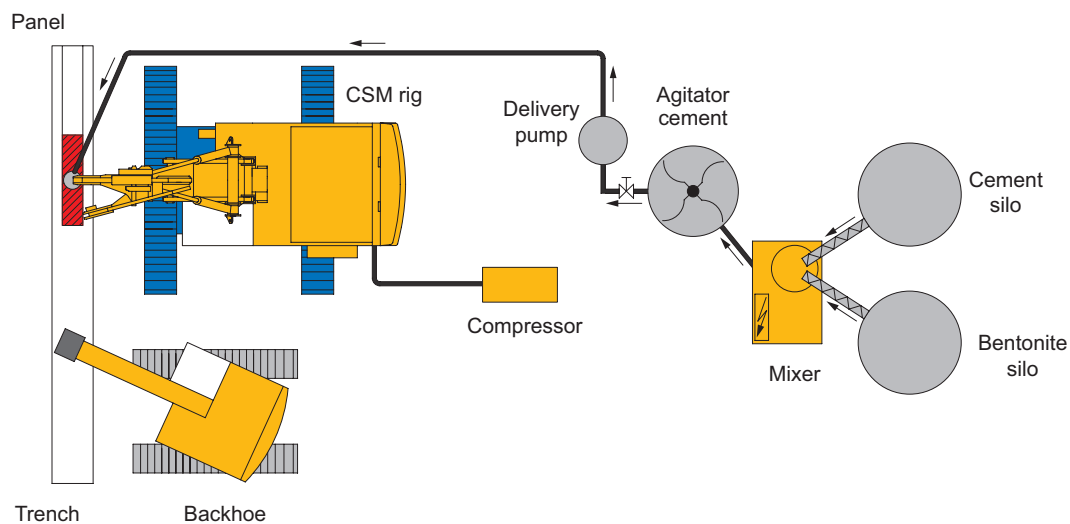
The cutting and mixing procedure can be executed in two ways - in the one-phase or the two-phase system.



One-phase system

During the penetration (downstroke) phase, cutting, mixing, liquifying and homogenising is performed while pumping the binder slurry and compressed air into the soil. As a rule of thumb about 70 % of the total slurry volume is pumped during this phase. The backflow of soil and binder slurry is collected in the pre-excavated trench or stored in a settling pond to be removed off site later.

In the upstroke phase the remaining volume of binder slurry is blended into the soil. The speed of extraction can be higher as the majority of the binder slurry has already been mixed with the soil in the downstroke phase.



Advantages of the one-phase system:

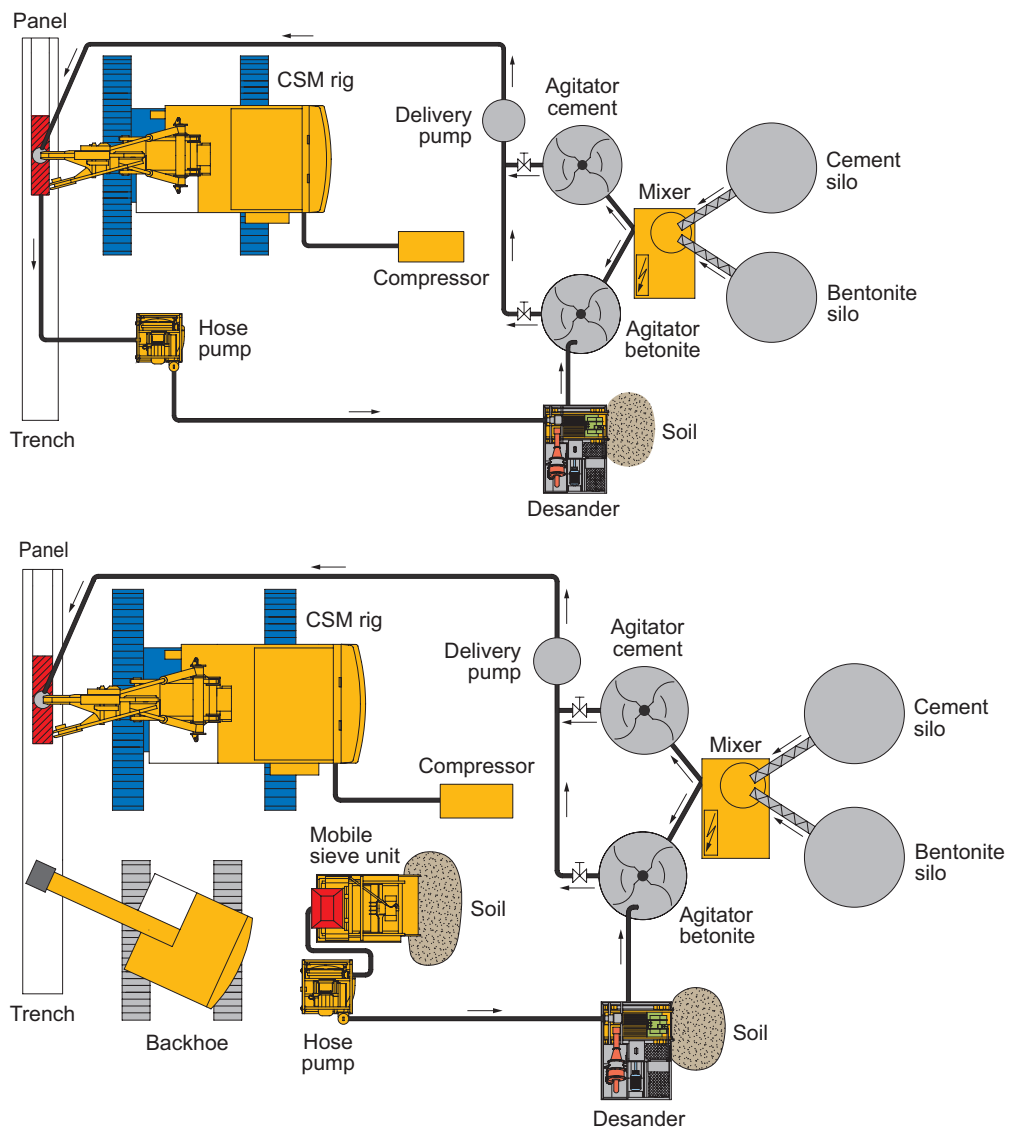
- No auxiliary desanding circuit required
- Higher speed of extraction
- Preferred application in easy and uniform soils, depth range < 20 m

Two-phase system

The soil is liquified and homogenised in the downstroke phase by pumping bentonite slurry or water (in case of clay) into the soil. The backflow of soil and bentonite resp. water can be pumped to a desanding plant where the sand is separated from the slurry which is then pumped back to the rig.

When the backflow becomes too heavy for pumping, it can be removed by a backhoe from the trench onto a mobile coarse screen where primary separation occurs. Using a hose pump the fluid fraction is then pumped to the desanding plant unit for further treatment.

After reaching the final depth, the flow of bentonite resp. water is stopped and replaced by binder. On the upstroke movement cement slurry is mixed thoroughly with the fluidified soil. The speed of extraction and flow of binder are adjusted to ensure that the total calculated quantity of binder is blended with the soil.



Advantages of the two-phase system:

- No risk of getting stuck when working at extended depths or when the working process is interrupted, due to hardening bentonite slurry above the mixing tool
- Wear and tear on the cutting wheels is reduced by using binders
- Preferred application in difficult soil conditions and for extended depth

Productivity Factors

The average productivity is highly influenced by the following site parameters

	Favourable	Unfavourable
Soil structure	uniform soil structure	layered soil structure
Soil type	loose to medium dense sandy silt	dense to very dense soil, cobbles and boulders embedded in soil, stiff or hard soil, cohesive or organic soil (reduction of the final strength)
Site geometry	long, straight wall sections	irregular wall layout
Wall depth	> 10 m	wall depth < 10 m (influence of non-productive periods such as moving, setting-up)

Slurry specifications

Main components:

- Cement (OPC or blast furnace cement CEM III/B 32.5)
- Water
- Bentonite (optional)

Optional additives:

Plasticizer
Retarder

Mix design

The mix design should always be determined by suitability tests prior to the start of construction. The following tables give values for an initial design of the mix proportions. They should be used for reference only.

Bentonite suspension

(for fluidifying the soil in the two-phase system)

- Approx. 20 – 40 kg bentonite/m³ slurry
- 400 l slurry/m³ soil (minimum quantity for fluidifying the soil)

Binder slurry (typical mix design)

	Cut-off wall	Retaining wall
Cement kg/m ³ slurry	250 – 450	750 – 1,200
Bentonit kg/m ³ slurry	15 – 30	0 – 30
w/c ratio	2.0 – 4.0	0.5 – 1.5

The soil conditions:

Particle size distribution, grain size, fines content, organic content, density, SPT values, porosity, groundwater level, chemical contaminations are the main influencing factors in regards to applicability of the system and characteristics of the final product.

Wall characteristics

	Cut-off wall	Retaining wall
Compressive strength q_u	0.5 – 2	5 – 15 MPa
Permeability	Approx. 1×10^{-8} m/sec	
Cement	100 – 200	200 – 500 kg/m ³

Site Examples



Cut-off wall for dyke rehabilitation



Retaining wall and underpinning for a heritage building



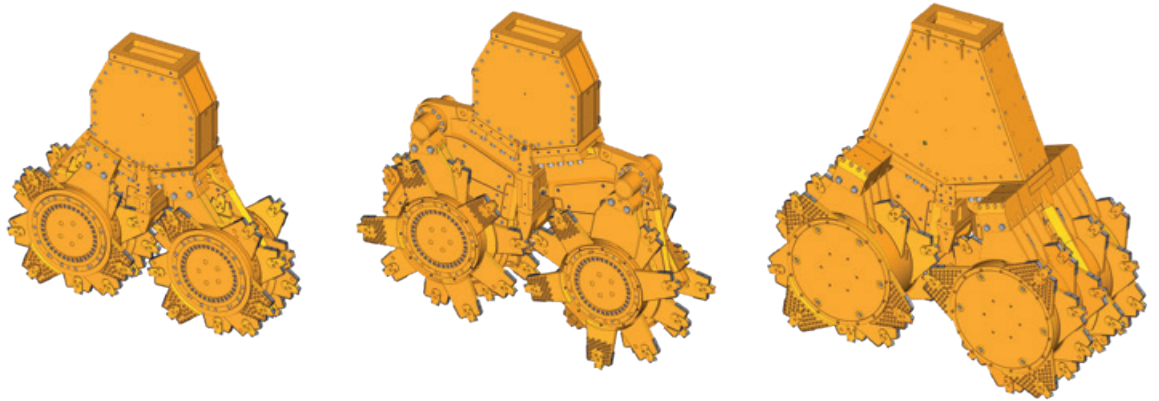
CSM wall for start shaft microtunneling



Corner formation retaining wall



BCM Cutting and mixing head



	BCM 5S	BCM 5	BCM 5L	BCM 10
Max. torque	50 kNm	50 kNm	50 kNm	100 kNm
Max. rotating speed	40 rpm*	40 rpm*	35 rpm*	30 rpm
Height	2.2 m	2.2 m	2.6 m	2.8 m
Panel length	2,400 mm	2,400 mm	2,800 mm	2,800 mm
Panel width	550 - 1,000 mm	550 - 1,000 mm	550 - 1,000 mm	640 - 1,200 mm
Weight (with wheels)	4,900 - 6,000 kg	4,900 - 6,000 kg	5,800 - 7,100 kg	8,500 - 10,800 kg

* depending on operating mode

Types of wheels

The wheels are designed to cut and loosen the soil matrix and then to mix it with the slurry. The soil type dictates whether more emphasis needs to be put on the wheels' cutting or mixing capability. The use of symmetrical tooth holders in conjunction with the application of DC teeth allows trouble-free breaking up and mixing of the soil in both rotational directions. A cutter wheel mixing set does consists of four identical mixing wheels.

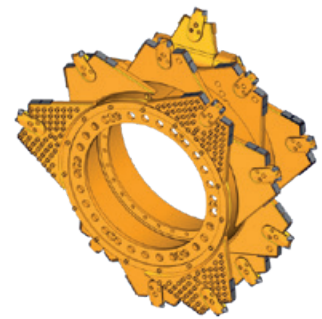
Four tooth holders in one row of teeth

- Loose to dense non-cohesive soil
- Gravelly soil with stones, cohesive soil
- Good mixing capacity (due to four tooth holders)



Three tooth holders in one row of teeth

- Dense non-cohesive soil, gravelly soil with stones
- Hard cohesive soil
- Good cutting capacity (due to three tooth holders)



Kelly-Guided CSM Rigs

Mono Kelly (round)



The BCM unit is supported by a Mono Kelly system. For smaller rigs and for a maximum depth of approx. 20 m, a round Kelly bar (Ø 368 mm) is used.

A rotating device enables the CSM unit to be turned + 45° to - 90° when a BG drill rig is used as base carrier.

Mono Kelly (round)

	Mixing head	Mixing depth m	Engine power kW	Extraction force kN	Overall height m	Operating weight t	Optional rotation device
BG 33 (BT 85)	BCM 5 / BCM 10	20.0	345 / 405	580 / 830	28.6	96	yes
e-BG 33 *	BCM 5 / BCM 10	20.0	405	580 / 830	28.6	96	yes
BG 36 (BS 95)	BCM 5 / BCM 10	20.0	403 / 433	580 / 830	28.6	100	yes
RG 16 T	BCM 5	14.5	563	260	21.9	75	no
RG 19 T	BCM 5	17.5	563	200	24.7	74	no
RG 21 T	BCM 5	20.0	563	260	27.6	87	no
RG22 S	BCM 5 / BCM 10	20.0	563	400	26.1	87	no
RG 27 S	BCM 5 / BCM 10	23.0	563	400 / 600	30.7	129	yes



* Cable electric

Technical data and pictures of CSM systems mentioned are only examples.

Mono Kelly (rectangular)



For greater mixing depths, the BCM unit is held and guided by a Mono Kelly with rectangular cross-section (600 x 340 mm). On demand the rectangular Kelly can be extended above the height of the rig mast. The full string length is made of sectional pipes. The connectors are covered with protection shields to ensure a flush surface.

Optionally steering flaps at the lower end of the Kelly bar (see picture right) can be used to improve the verticality of the CSM panel.



Interlocking system

	Mixing head	Mixing depth m	Engine power kW	Extraction force kN	Overall height m	Operating weight t	Optional rotation device
BG 33 (BT 85)	BCM 5 / BCM 10	36	345 / 405	580 / 830	43.0	126	yes
BG 36 (BS 95)	BCM 5 / BCM 10	36	403 / 433	580 / 830	43.0	130	yes
BG 45 (BS 95)	BCM 5 / BCM 10	43	433	580 / 830	48.9	174	yes
BG 55 (BS 115)	BCM 5 / BCM 10	45	563	460 / 910	48.9	200	yes
BG 72 (BT 180) *	BCM 5 / BCM 10	53	709	860	60.5	300	yes
RG 27 S	BCM 5 / BCM 10	30.5	563	400 / 600	36.5	135	no



* On request

Technical data and pictures of CSM systems mentioned are only examples.

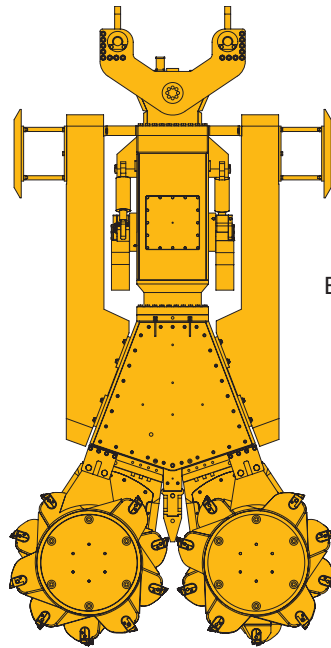
Rope-Suspended CSM Rigs

Tandem Cutter

Rope-suspended CSM rigs can reach big mixing depths with minimized rig dimensions. The machine concept can be offered in different variants.

The basic components are:

- base carrier
- hose handling system
- boom
- mixing unit



BCM 10 Mixing unit



Tandem Cutter Standard on MC 64



Tandem Side Cutter on MT



	Tandem Cutter		
	Standard on MC	Standard on MT	Side Cutter on MT
Hose handling system and boom	not turnable	not turnable	turnable
Overall height (m)	6.6 - 8.1	on request	
Working width (m)*	8.0	on request	
Max. mixing depth (m)	80	80	80
Installed power (kW)	563	345 / 405	345 / 405

* Width perpendicular to panel axis
 Technical data and pictures of CSM systems mentioned are only examples.

Recommended additional equipment for ensuring an efficient working sequence

For one-phase and two-phase system:

- **Slurry mixing plant** / min. capacity 20 m³/h
- **Feed pump** frequency controlled slurry pump with remote control, capacity depends on volume of panel and speed of mixing. (typically: 200 – 600 l/min, 12 – 15 bar)
- **Agitator tank** approx. 3 – 5 m³ (as buffer for cement slurry)
- **Silos** for cement and bentonite with screw conveyors
- **Hydraulic backhoe** for excavation of guide trench, maintenance of working platform, handling of backflow
- **Hoses** for conveying cement or bentonite slurry from the agitator to the rig. Typically 1,5" or 2" rubber hose (length to suit site requirements)
- **Air compressor** – recommended 7 – 14 bar / 7 – 10 m³/min (for air-assisted mixing)
- **Service crane with vibrator** – optional
for inserting universal beam of retaining walls (crane size depends on dimensions of beams)



Slurry Mixing System BAUER MAT CMS-30 and slurry pump EP 14-400

Additionally for two-phase system:

- **Agitator tank** as buffer for bentonite slurry
- **Feed pump** – optional pumping of reflux slurry from trench to desanding plant
- **Desanding plant** – optional e. g. BAUER BE 250
- **Mobile sieve unit** – optional for pre-screening not pumpable, dense reflux slurry

Control of production parameters

Parameters are displayed on the monitor of the rig operator. All CSM rigs are equipped with an electronic control system (B-Tronic).

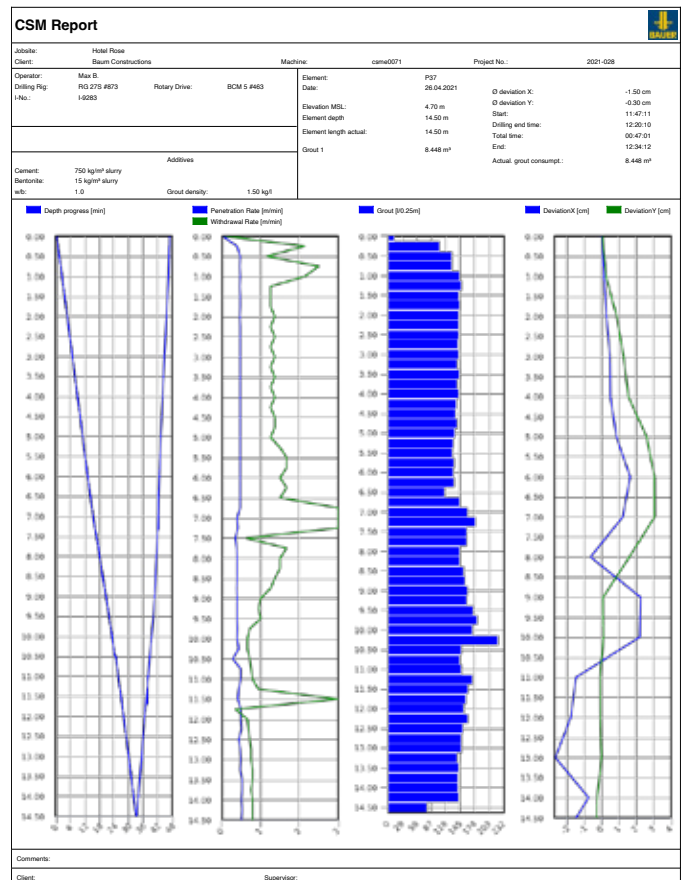
The B-Tronic system monitors, controls and records production parameters, such as e. g.

- Depth
- Quantity and pressure of slurry
- Pressure in trench at mixing head height
- Inclination (in 2 directions)
- Speed of mixing wheels
- General rig parameters



Documentation

All data registered during production can be created and printed for each individual panel in the form of a quality record.



In-situ sampling of soil mix material

Quality control of the completed soil mix elements is carried out on samples obtained either before or after the soil/binder slurry mixture has hardened.

Samples of the fresh soil mix material prior to hardening can be obtained by using a special sampling tool.



Obtaining fresh samples using a special sampling tool

In-situ samples of hardened soil mix material can be obtained by:

- Taking "horizontal" core samples with hand-held drills
- Drilling "vertical" core holes with drilling rigs used for exploratory boreholes
- Insertion of double-walled plastic tubes into the fresh soil/slurry mix elements and – after hardening – extraction of the inner tube together with the embedded hardened core



Horizontal core sampling with a hand-held drill



Cut-open inner plastic tube with hardened cover



Drilling "vertical" core holes



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Equipment



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Methods



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