Hybrid Grouting – an innovative Technology

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Special Topic

Standard grouting equipment is limited to cement-based or organic grouting gear. Recent developments in grouting technology allow cement-based or organic grouting on a single mobile grouting platform.

Tunnelling • Mining • Geotechnics • Injection • Grouting • Mixing • Technology • Innovation

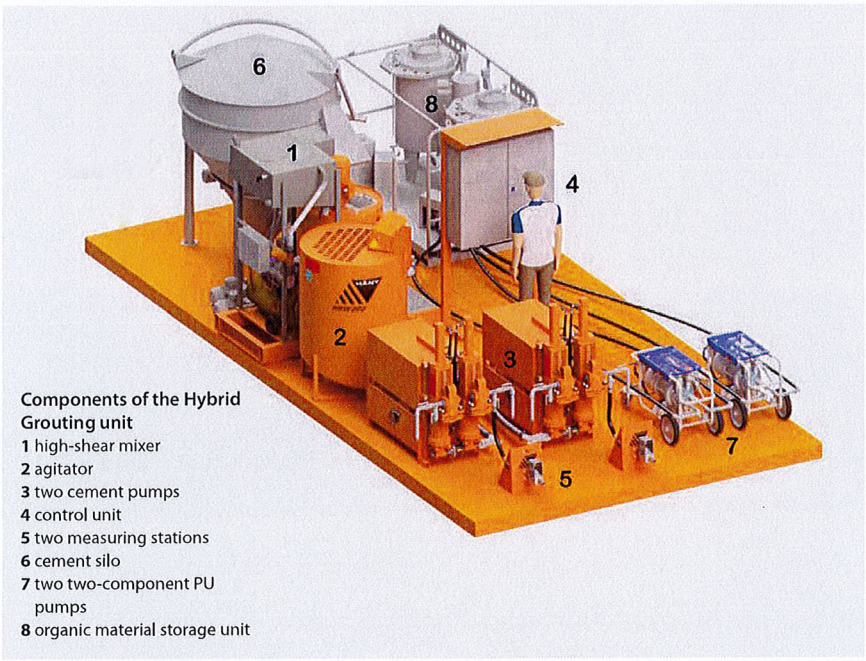
1 Introduction

Grouting has a long history in underground construction and emphasises sealing or consolidating weak or water-bearing ground conditions. Organic grouting is primarily carried out in complex ground conditions or areas of heavy water inflow. These circumstances place high demands on equipment and materials. For example, the grouting unit must be mobile due to the constantly changing sequences of excavation and grouting works. And the grouting unit must handle various types of grouting materials and additives to adapt to changing ground and site conditions and objectives.

Standard grouting equipment is limited to either cement-based or organic grouting gear. This limitation has made grouting in underground construction considerably more difficult until now. However, with recent developments in grouting technology, both the cement-based, and the organic grouting technology can be utilised on a single mobile grouting platform (Fig. 1). Because this grouting system can process both grouting materials individually or simultaneously with different mixing ratios, it is dubbed Hybrid Grouting [1].

The advantages of this unique system are apparent when it is used to stop water inflow. Extensive water flow paths can effectively and quickly be closed using a high proportion of PU resin in the hybrid grout mix. The PU resin proportion can then be lowered until the water inflow stops completely. Subsequently, the ground can be further sealed and consolidated with pure cement suspension without being washed out. [2 ,3]

Hybrid Grouting combines the advantages of economical, cement-based grouting and the advantages of highly reactive resin injections. Furthermore, with Hänny Hybrid Grouting technology, processes are fully automated and enable controlled and efficient grouting operations.



Components of the Hybrid Grouting unit
1 high-shear mixer
2 agitator
3 two cement pumps
4 control unit
5 two measuring stations
6 cement silo
7 two two-component PU pumps
8 organic material storage unit

Fig. 1: Hänny hybrid grouting unit consisting of cement grouting gear and organic grouting gear
Source: Hänny, Desoi

2 Hybrid Grout Mixes

Hybrid Grout, as mentioned above, consists of two grout agents:

- Cement-based grout
- Organic grout

Cement-based grouts are essentially a mix of cement and water in a given ratio optionally combined with inert materials such as fly-ash, bentonite, and additives like calcium chloride or sodium silicate to increase stability or decrease the setting times. These mixtures create suspension grouts in which solid particles are more or less evenly distributed (floating). The cement reacts with the water (hydration), and the grout mix changes continuously from a liquid through stiffening, solidifying, and hardening into a solid cement paste. The start of solidification of cement-based grouts is usually a couple of hours and can be modified to as little as even a few seconds.

Organic grouts consist of two or more synthetic components (such as urethanes, sodium silicates, and acrylamides) in a given ratio that forms a gel, a solid precipitate, or a foam.

Hybrid Grouting mainly uses a combination of cement and polyurethane resins. However, projects are also known that have combined cement grout with sodium silicates or acrylic gels.

Polyurethane grouts come in two forms, single component and plural component, with variations in reaction time, reaction with water, expansion characteristic, and flexibility. Two-component grouts commonly used in underground construction are mixed with a fixed ratio of 1 : 1. "*The polyurethane is formed by an exothermic polyaddition reaction of polyol (A-component) and isocy-*

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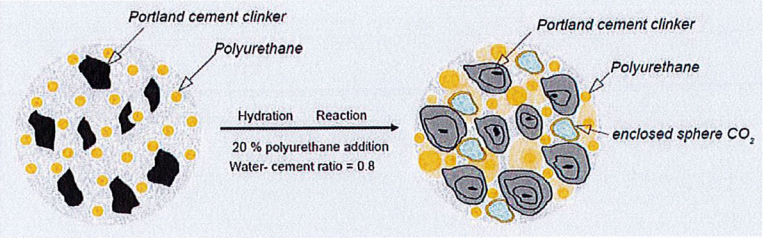

Fig. 2: Schematic illustration of cement-polyurethane mix reaction [4]

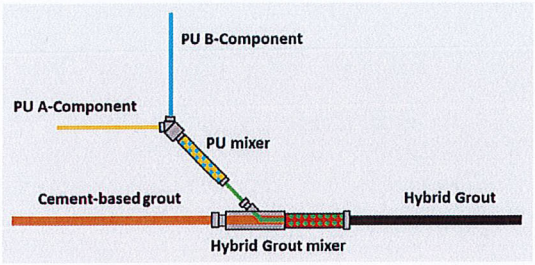

Fig. 3: Scheme of mixing gear of the cement slurry and polyurethane resin consisting of a PU mixer, and a bypass with a Hybrid Grout mixer
Source: Häny

anate (B-component). In the presence of water, carbon dioxide and urea are combined with the isocyanate as a side reaction. As a result, the carbon dioxide is formed directly in the polyurethane structure and causes the polyurethane to expand." [4]

"When polyurethane is added to a cement grout mix, the polyurea dehydrates the water from the cement paste. The reduction of the water and heat generation by the proportion of the PU acts as an accelerator and thickener on the cement grout mix. The reaction acceleration causes a shorter hydration phase and leads to a stabilizing effect on the combined cement-polyurethane grout at the same time. The polyurethane is embedded in the cement grouting mix and forms during the hydration phase an initial structure due to the progressive polyaddition reaction, which stabilizes the grouting mix's wash-out effects. The quality of the combined products is the adequate dispersion and homogenization of the initial products during the mixing process. Fig. 2 schematically shows the emplacement of PU within the cement paste." [4]

3 Hybrid Grouting Mixing Technology

Hybrid Grout is created by mixing polyurethane A-component and B-component, and in the second step, by combining the polyurethane with the cement-based grout. The scheme of the mixing gear is shown in **Fig. 3**. *"The PU is formed by mixing the A-component [yellow] of polyol and B-component [blue] of isocyanate through a static mixer [PU mixer], which is fed downstream through a bypass to the cement line [orange]. The final cement-polyurethane grout mix [black] is generated by a second static mixer [Hybrid Grout mixer]."* [4]

4 Hybrid Grouting Unit

The Häny Hybrid Grouting unit consists of a cement grouting unit and an organic grouting unit. The equipment is installed on a mobile platform as shown in **Fig. 1**. The unique feature of the Hybrid Grouting unit is the pump control system. This enables fully automated cement-based and organic grouting on a single platform.

The cement-based grouting unit consists of a high-shear mixer, an agitator, two cement pumps, mixing and pump control unit, and a cement silo with an inclined auger. In addition, an integrated measuring station in-

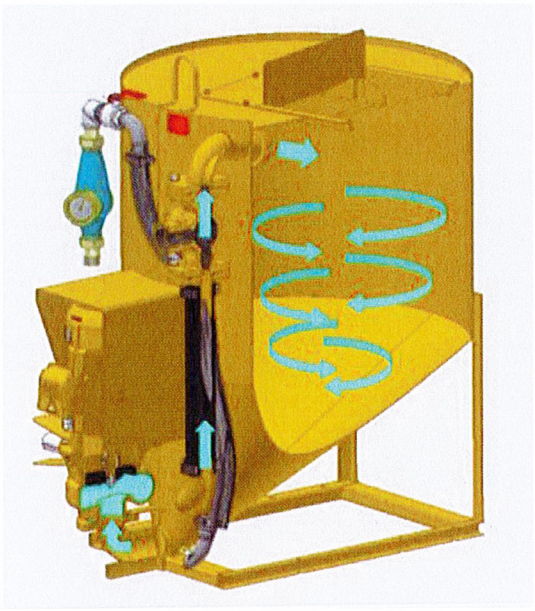

Fig. 4: Scheme of the mixing principle in a Häny high-shear mixer with a turbo mixer pump
Source: Häny

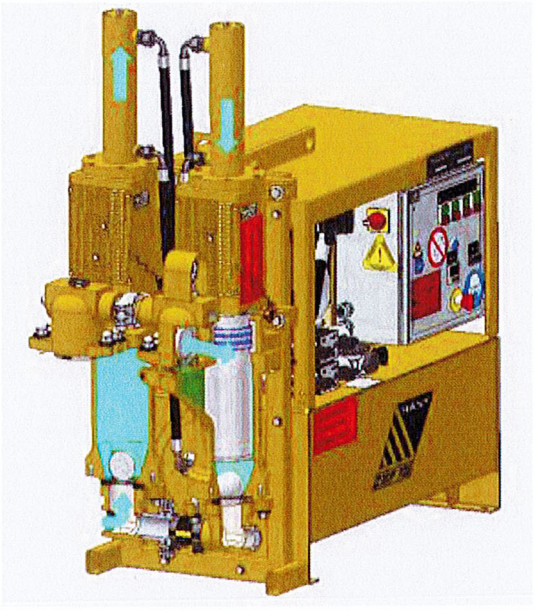

Fig. 5: Scheme of operation of a Häny Duplex pump
Source: Häny

corporating a flow rate and pressure sensor is built into each grout line. All devices are operated via a control panel (see **Chapter 5**).

The stability of the grout mix depends on the mixer's effectiveness in ensuring the cement particles' complete hydration and preventing lump formation. The Häny high shear mixers meet these requirements. As shown in **Fig. 4**, a turbo mixing pump with reverse vortex-type propellers achieves high hydraulic turbulence by circulating the entire tank content several times per minute. As a result, each particle is separated and individually wetted, creating a homogeneous and fully hydrated stable grout mix which resists intermixing with free water resp. groundwater.

Two-cylinder (Duplex) plunger pumps, as shown in **Fig. 5**, are commonly used for cement-based grouting operations in underground constructions. These pumps are synchronized so that the second plunger starts to displace the grout just before the first plunger has completed its stroke. Thus, the change of plungers creates only a minimal fluctuation of flow rate and pressure. The pumps must be equipped with precise pressure and flow control valves to allow stepless control and regulation of the injection process.

The grouting gear for organic resin processing consists of two polyurethane pumps and a resin storage unit. The polyurethane pumps are 2-component pumps and deliver both components at a fixed mixing ratio of 1 : 1. Double-acting reciprocating pumps are commonly used for organic grouting in underground constructions and are air driven. A double-acting reciprocating pump discharges on both the piston's forward and return stroke, and the flowrate can be considered constant with slight pulsation. These pumps must be equipped with precise flow control valves to control the injection process automatically.

5 Automation and Digitalisation of Hybrid Grouting

Another critical element of modern grouting technology is automation. Digital measurement and state-of-the-art control technology are required to control all essential parameters, record them digitally and enable rapid, accurate data evaluation.

With Hybrid Grouting, measuring the flow rate and pressure for each flow line of the material components is required. A magneto-inductive flow meter registers the flow rate of the cement grout mix – the flow rate of each polyurethane resin component is registered via an impeller flow meter. In order to exclude the pressure losses from the line and mixing system, a pressure gauge must be installed in the hybrid line. However, placing the pressure gauge in the hybrid line is not recommended. And the flow meter should not be installed in the hybrid grout line, since due to the high reactivity of polyurethane resin, there is a risk that deposits in the flow meter and may falsify the measured values. Instead, the grouting pressure should be measured in the cement line. The pressure losses can be determined using flow tests and free-discharge tests, and can be considered to determine the pressure criteria. In addition, pressure gauges are installed in each polyurethane component line to identify any pressure increases, e. g., due to blockages in the mixing system.

The measuring sensors and the individual pumps are connected to a control unit. **Fig. 6** shows the input parameters for the automatic control of the Hybrid Grouting process. For example, the flow rate of polyurethane can be set as a percentage of the cement flow rate (Additiv). Moreover, the grouting process can be automatically stopped via various stop criteria, e. g., a volume criterion (Menge), pressure criterion (Maximaldruck), and/or minimum flow rate criterion (Min. Durchfluss).

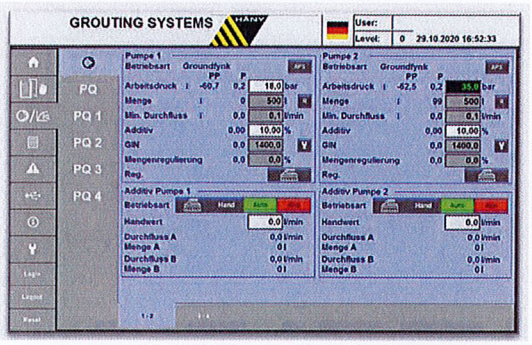

Fig. 6: Overview of pump settings for automatic control of hybrid groutings
Source: Häny and Groundfynk

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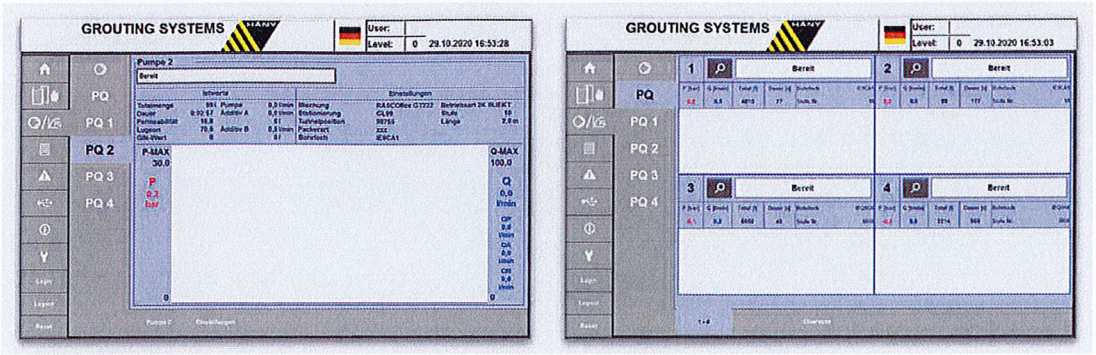

Fig. 7: Graphic overview of the control panel for one (left) or up to four pumps (right)
Source: Häny and Groundfynk

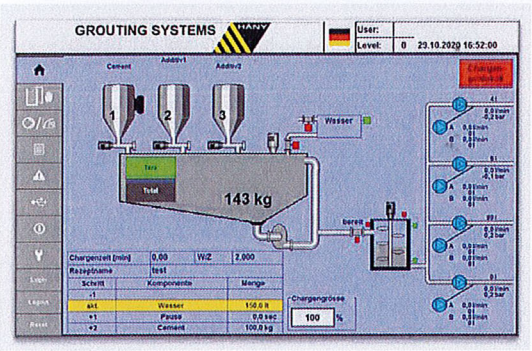

Fig. 8: Real-time view of the mixing process and batch settings
Source: Häny and Groundfynk

Pressure and flow rate are recorded and displayed on the control panel. The pressure in the cement line (P) and the flow rate of the hybrid grout (Q), as well as the cumulative amount (Menge) and injection time (Dauer) are displayed for one pump (**Fig. 7 left**) or for up to 4 pumps (**Fig. 7 right**). The flow rates of each component of the hybrid grout are shown in a single view only (flow rate cement grout QP, flow rate component A, flow rate component B).

The consistent and repeatable production of grout mixes can be ensured through automatic control and recording systems, as shown in **Fig. 8**. The mixing components can be entered and stored in different recipes through the touch screen. In addition, the control automatically optimizes the dosing procedure and achieves optimum accuracy after three mixing cycles. The mixing process is shown in real time on the panels' display, and a batch record of each component of every mixing cycle is stored and available for further documentation.

The data is available for further documentation on a USB memory stick or via a wifi/cellular transfer on an FTP server.

6 Conclusions

Recent developments in grouting technology allow cement-based or organic grouting on a single mobile grouting platform. The new technology offers significant advantages resulting from the simplified change between injection components during the construction process. This contributes to solutions which are technically optimal and reduce costs.

7 References

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