BEAM

Real-time Ahead Monitoring While TBM-Boring

2016/2017

BEAM® - Geoelectrical Ahead Monitoring For TBM Drives

The Bore-tunnelling Electrical Ahead Monitoring - BEAM ® - is a non-intrusive focused-electrical induced polarisation ground prediction technique especially designed for the underground construction industry.

BEAM is most suitable for modern high mechanized TBM headings which work under high time and cost pressure. The geophysical BEAM prediction survey is minimizing the geological risk (de-risking tool) as well as increasing the safety level for workers, boring machine and tunnel construction.

It can be used in any hardrock and soft ground geo-logy, under or below the ground water table and thus in any type of boring machine like EPB, Slurry, Gripper, Single or Double shielded TBMs, independent from the manufacturer.

Data acquisition and evaluation are performed fully automatic by connection of the BEAM measuring device (Fig.1) to the TBM guidance system and/or PLC for instance.
Any prediction results are displayed in real time on the integrated BEAM screen placed in the operator cabin or simultaneously on any accredited computer outside the tunnel. Thus enabling fast on-site decisions, in case a critical section is predicted or just intact ground is indicated.

In 2015 BEAM ahead monitoring system works concurrent in 24 TBM projects in Europe and Middle East. Supplied on a rental basis by GET, it is currently used in several tunnel projects at Metro Doha, Metro Riyadh, Metro Athens and Metro Paris among others.

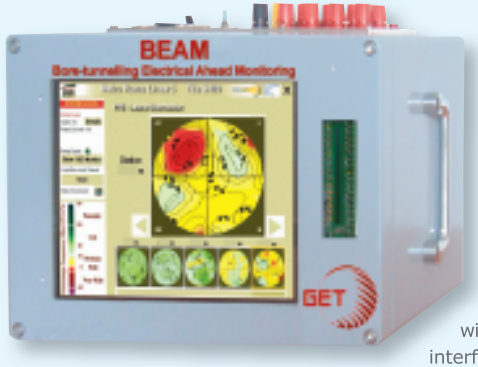


Fig.1 BEAM Multi Channel Unit with SCAN mode interface;
Screen indicates the lateral PFE distribution - a degree of rock mass porosity - within a forefield cross-section ahead of the face; Results represent a cavity zone within pyroclastics on the left top side of an EPB-TBM in Rome.

Ref.: Publication of results with the kind permission of METRO C

BEAM® System

The TBM based BEAM system allows a permanent driving accompanying probing of ground conditions about 3 times the tunnel diameter ahead of the face.

In general a 3-electode configuration is necessary consisting of the whole cutter head or specific electrode plates nearby the excavation tools or the cutters itself (A0) as well as using the shield or safety constructional components (A1) as electrodes, which are automatically electrical coupled to the ground by the TBM itself. At the portal or inside the tunnel the return electode (B) is connected to the ground.

Because of using voltages lower than 42V a continuous operation is possible without any danger for staff and machine.

Based on the measuring data the percentage frequency effect PFE and the resistivity R, an advanced evaluation software is established for geoelectrical-geological/hydro-geological classification and interpretation in real-time while TBM boring.

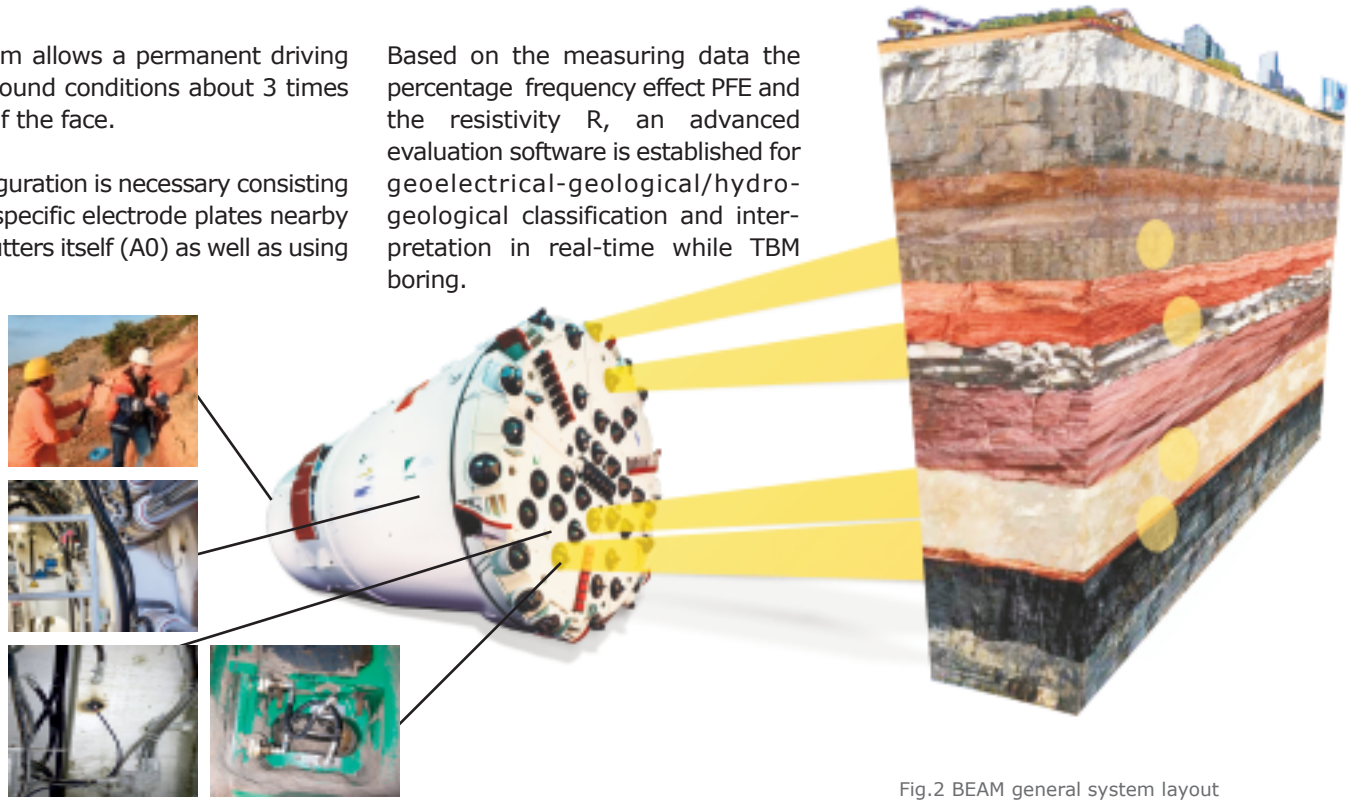


Fig.2 BEAM general system layout

BEAM Measuring Unit
Geoelectrical device located in the TBM operator cabin as a stand alone unit with integrated display or mounted in the display panel;

Measuring electrode(s) A0 (+)
The whole cutter head with all or single excavation tools contacted to the face during boring-rotation;

Guard electrode A1 (+)
The shield or armed lining (anchors);

Return electrode B (-)
A fixed steel/copper rod at the portal or anchor inside the tunnel in a large distance to the face;

Automation
Connection of the BEAM-unit via interface to the TBM guidance system and PLC f.i. enables the fully automatic data acquisition;

Communication
Provision of internet access for transferring any real-time BEAM results from the BEAM-unit in operator cabin to a computer outside the tunnel, e.g. office cabin or other accredited computer;

BEAM® INTEGRAL

The BEAM-INTEGRAL system is the basic system which uses the whole cutter head as one large A0-measuring electrode.

It can be easily and quickly installed in tunnel projects currently under construction without any disturbance or stoppage of TBM excavation.

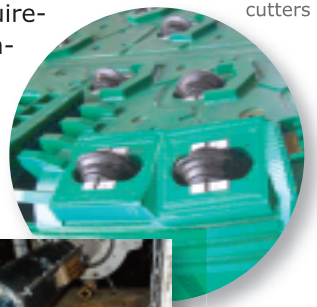
Forefield prediction results are displayed one-dimensional. Critical ground changes like Karst and fault zones are detected and visualized in a distance about 3-times the tunnel diameter (Fig.3).

Fig.3
BEAM INTEGRAL interface; Forecast results represent a water-filled cavity of about 2m width in 4m ahead of the TBM.

BEAM® SCAN

BEAM-SCAN system uses additionally selected A0 electrodes placed nearby the excavation tools or the cutters itselves for an advanced lateral resolution ability, providing more detailed 2D and 3D imaging.

Fig. 4 Selected cutters



Additional installations and requirements like an electrical rotor, information about rotational position of cutter head via rotary encoder are necessary.

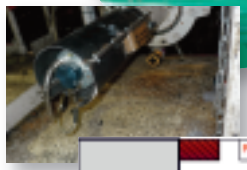


Fig. 5
Electrical rotor with integrated encoder

The Lateral PFE Distribution View (Fig.1) is a feature available by using BEAM-SCAN system only.
The forefield ground is imaged by cross-sections indicating detailed distribution of PFE inhomogeneities, which are related to rock mass porosity.

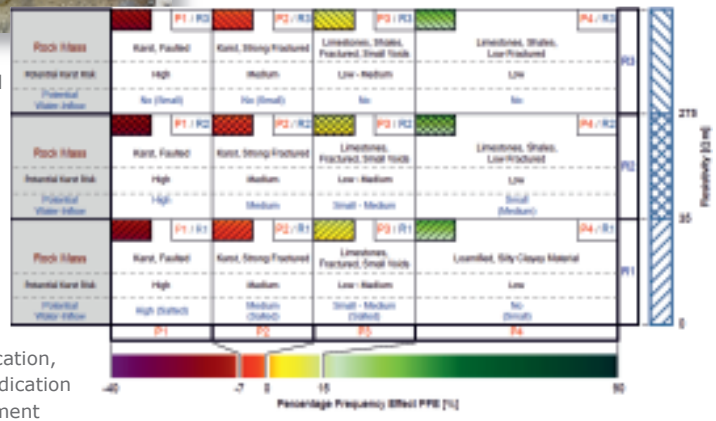


Fig.6
Customized matrix for ground classification, water-inflow indication and risk assesment

Petrophysical Classification

BEAM is based on an advanced inhouse developed processing, evaluation and visualisation software which shows the measuring data and distribution of percentage frequency effect PFE and resistivity R for geological classification and hydrogeological characterisation (Fig.3).

The PFE characterizes the ability of the ground to store electrical energy. Thus, it is reciprocally correlated to the effective porosity (permeability). The Resistivity provides additional information about the fracture/cavity infillings (e.g. water, gas/air).

The diversity of softground and hard rock are characterized by typical combined PFE/Resistivity-classes, which define different geological/hydrogeological ground situations (rock mass types and water-inflow potential).

Based on correlation of geoelectrical PFE-data and R-data to documented geological and hydrogeological conditions at different tunnel projects guided by BEAM surveys, a petrophysical classification was developed for hard rock and softground, each with 12 types (Fig. 6).

Application at GALLERIA SPARVO - Italy

For the improvement of the highway A1 from Milano to Napoli in Italy, the worldwide largest EPB machine with a diameter of 15,55m at this time has been operated during the SPARVO project in Italy under the assignment of TOTO Costruzioni Generali and the owner Spea Ingegneria Europea - Gruppo Autostrade per l'Italia.

Such a major project though complex conditions, like as in the Appenines with frequently present squeezing clay sections, methane and fault zone are requiring a deep and precise knowledge of the geological scenarios to be face with the TBM.
Most of the problematic geotechnical situations are related to the sudden occurrence of unexpected high porosity ground like cavities, karst rocks, fault/fractured zones and coarse material.

Thus the main task of the permanent BEAM operation is a reliable early detection of such critical rock sections. Furthermore the system should also be able to indicate ground "without problems" hence enabling fast boring and construction activities.

Along the 2500m long TBM-drivage there have been several successfully early warning forecasts of critical rock sections which have been confirmed and safely cleared up by using different geotechnical tunnelling measures.

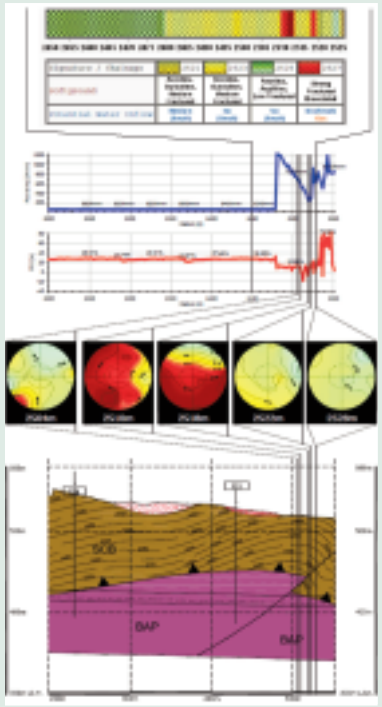


Fig.7 A comparison between the BEAM data and the tunnel-geological profile. The indicated transection zone of a nappe structure and a thrust fault correlates quite well with the obtained anomaly results of the BEAM survey.

Ref.: Publication of results with the kind permission of TOTO

BEAM® - Conclusion

Successful commercial application is realized since 2000. BEAM systems has accompagnied more than 60 TBM projects boring in hardrock, soft ground as well as in mixed ground.

BEAM is a robust and reliable long-term operating geophysical probing technique fulfilling the practical demands under the rough conditions of tunnelling work.

Thus BEAM system enables tunnel excavation to achieve particularly high advance rates, either due to improved confidence when it shows consistent ground conditions ahead of the face, and enable appropriate action to be taken when responses suggest more difficult ground conditions ahead of the face.

Summary of BEAM´s features:

- Permanent automatic high resolution and non-destructive forward prediction while tunnelling;
- Early detection and warning of changes in geotechnical-geological and hydrogeological ground conditions like fault/karst zones, cavities or permeable water-/gas-bearing zones;
- Geoelectrical-geological/hydrogeological classification of prefield ground changes in real time visualised on the BEAM unit in the operator cabin and also on every other accredited computer in the world;
- Optimum planning of safety and lining measures in advance and with it in time to shelter staff, tunnel and boring machine;
- Realisation of high advancement rates without disturbance and stoppages of tunnelling work add to time reduction and cost savings;
- Detection distance ahead of the face amounts about 3 times of the tunnel diameter;
- No percussion or core drilling is needed to use BEAM;
- Evaluation software comprising geological interpretation is self-instructional for tunnel engineers and miners jobsite;
- Applicable in any geology as well as above and below the ground water table;
- Implementation in any type of TBM independent from the manufacturer;
- Effective contribution to lowering geological risks and increasing the safety level.

GET

GEO EXPLORATION TECHNOLOGIES

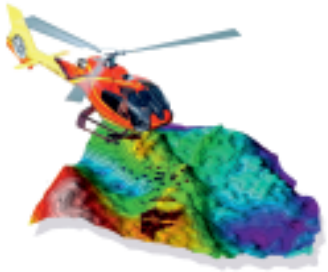
GEO EXPLORATION TECHNOLOGIES - GET - is a German geophysical service company experienced in exploration of subsurface structure and ground characteristics across the world since 1986.

GET performs state-of-the-art ground-based geophysics for geotechnical projects in the application fields groundwater, rock and soil engineering, environment as well as UXO-detection and maintains a modern portfolio of geophysical equipment.

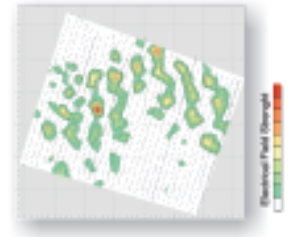
Furthermore it conducts some unique and innovative techniques; like the TBM-based BEAM® ground prediction system for the tunnelling industry as well as the new helicopter-borne seismo-electro-magnetic methods HYDROSCAN® for exploration and 3D imaging of oil&gas reservoirs as well as ORESCAN® for ore mineral prospecting.

In total 10 highly qualified geophysicists, geologists, oil field engineers as well as trained freelancer are available for reliable performance of customized projects across the world.

HYDROSCAN
Airborne Oil & Gas Exploration



ORESCAN
Airborne Ore Mineral Prospecting



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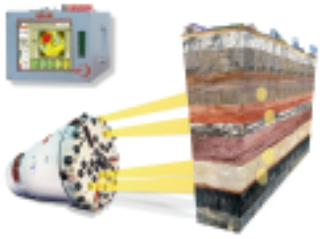
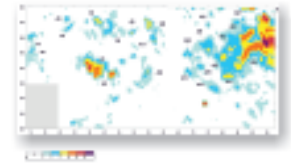


TDEM
Metal Objects & Uxo Detection



Geo Exploration Technologies GmbH
Körnerstrasse 2
55120 Mainz, Germany

phone +49 6131 69 04 99
info@geo-exploration-technologies.com
www.geo-exploration-technologies.com

Geophysics
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