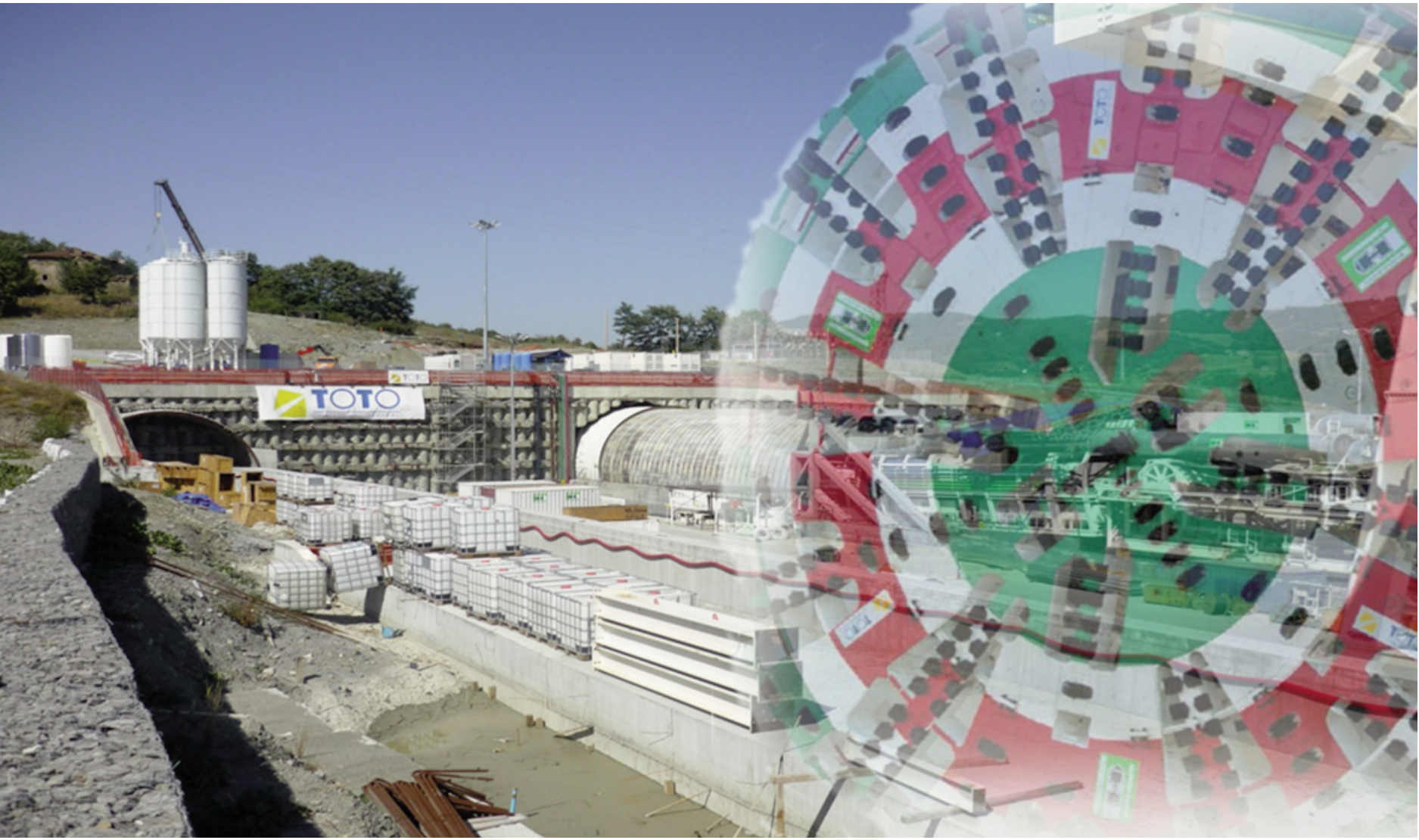
BEAM

Real-Time Ground Prediction While TBM-Boring



2013/2014

BEAM® - Geoelectrical Ahead Monitoring for TBM-Drives

The Bore-Tunnelling Electrical Ahead Monitoring - BEAM -, developed and patented by Kaus, managing director of GET, is a non-intrusive focused-electrical induced polarisation ground prediction technique especially designed for the underground construction industry.

BEAM is qualified for modern high mechanized TBM headings as well as surveying of existing tunnels.
It can be used in any hardrock and soft ground geology and thus in any type of boring machine like EPB-, Slurry-, Gripper, Single or Double shielded TBMs, independent from the manufacturer.

Main components of the survey system are the measuring unit (Fig.1.) placed in the TBM operator cabin and special adapted excavation tools which are used as electrodes.
The unit is connected to the guidance system and PLC for instance to receive the station values and a boring signal which allows fully automatic data acquisition and visualisation in real-time on an integrated monitor.

Communication facilities at site transfer the forecast results to every accredited computer outside the tunnel simultaneously.

Supplied on a rental basis by GET, it is increasingly ordered since the year 2000 to serve at international TBM projects with a total tunnel prediction length of more than 120km.

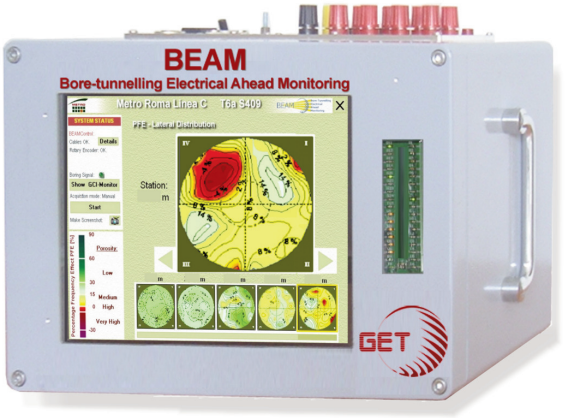


Fig.1 BEAM Multi Channel Unit with BEAM SCAN interface; Screen indicates the lateral PFE distribution (rock mass porosity) within a cross-section in a distance of 3 times the tunnel diameter ahead of the face;
Forecast results represent a cavity zone within pyroclastics on the left top side of an EPB-TBM in Rome.

ref.: Publication of results with a kind permission of our client 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. Data acquisition and evaluation is performed automatically and prediction results are displayed in real time enabling fast on-site decisions.

An advantageous feature of the system is the utilization of excavation tools and safety constructional components as electrodes, which are automatically electrical coupled to the ground by the TBM itself.

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/hydrogeological classification and interpretation.

General System Layout (Fig.2)

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

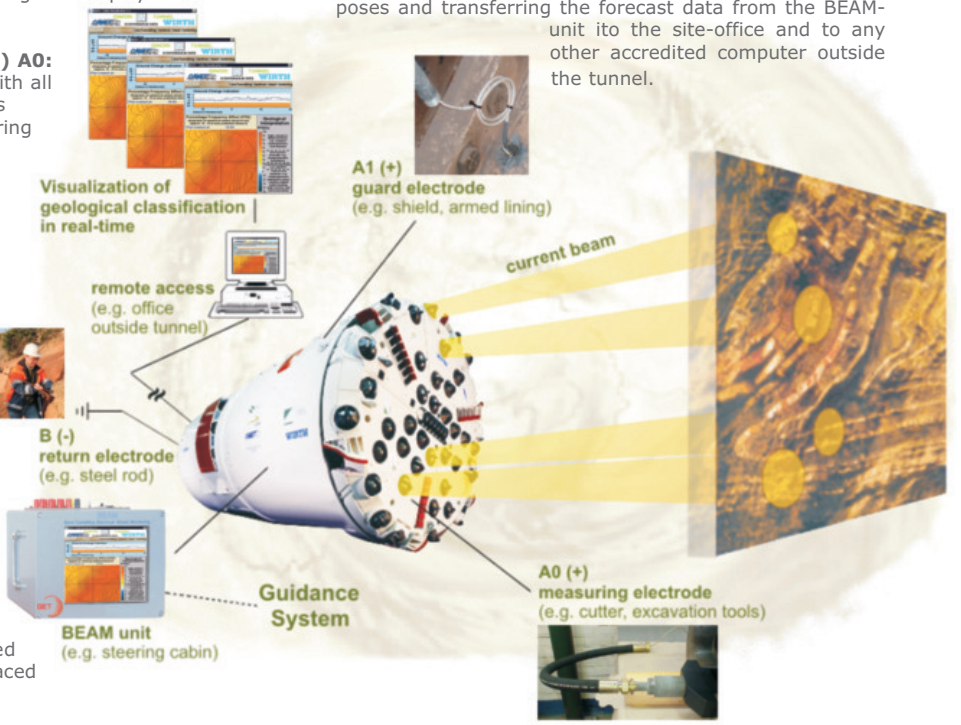
Measuring electrode(s) A0:
The whole cutter head with all or single excavation tools contacted to the face during boring-rotation;

Guard electrode A1:
The shield or armed lining/ anchors;

Return electrode B:
A fixed stake or anchor inside or outside the tunnel in a large distance (> 300m) to the face.

Automation:
Connection of the BEAM-unit via interface to the TBM guidance system enables the fully automatically data acquisition and thus, yields increased resolution by narrow-spaced survey-points;

Communication:
Internet access, telefon line or data cable and the remote access utilities at jobsite are needed for maintenance purposes and transferring the forecast data from the BEAM-unit ito the site-office and to any other accredited computer outside the tunnel.



BEAM® INTEGRAL

The BEAM-INTEGRAL is the basic system which uses the whole cutter head resp. cutting wheel 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, cavities, obstacles or water-bearing zones etc. are visualized timely (Fig.3).

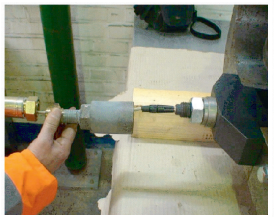
Fig.3 BEAM INTEGRAL interface;
Forecast results represent a water-filled cavity of about 2m width in 4m ahead of the TBM

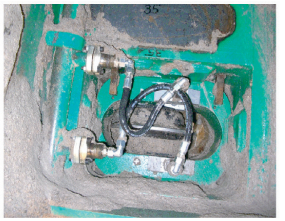
BEAM® SCAN

BEAM-SCAN system uses additional selected A0 electrodes for an advanced lateral resolution ability, providing more detailed imaging of 2D and 3D targets.

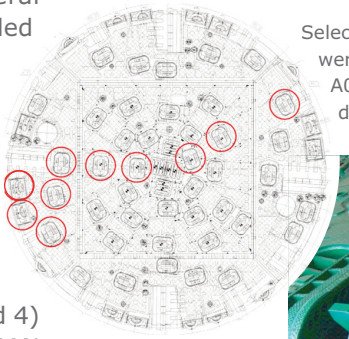
Additional installations and requirements like an electrical rotor, information about rotational position of cutterhead via rotary encoder and specially adapted excavation tools (OEM) are necessary.

The Lateral PFE Distribution View (Fig.1 and 4) 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.

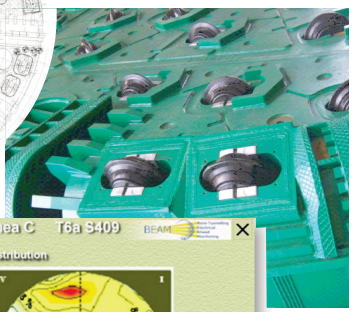




e.g. Connection and protection of isolated A0-contacts ("measuring electrodes")



Selected excavation tools were isolated and act as A0-measuring electrodes



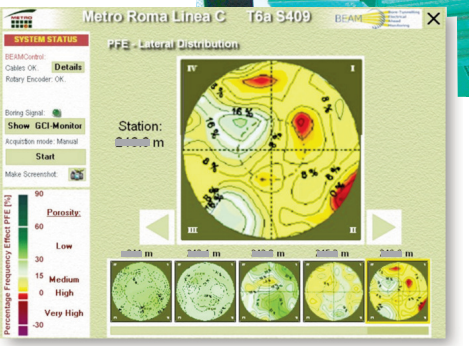


Fig.4 Lateral PFE Distribution View (SCAN mode);
Forecast results of a high fracture porosity zone with small cavities (<0.5m ø), high-medium water-inflow

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).

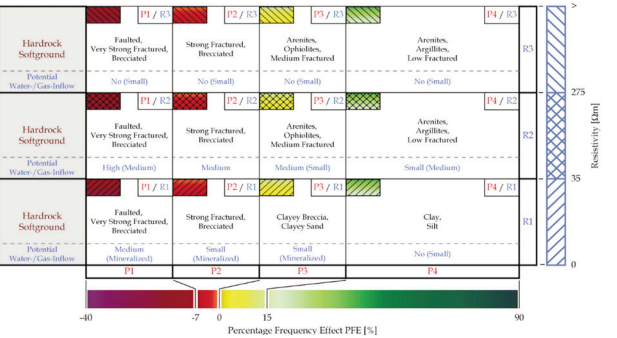


Fig.5. BEAM PFE-R-correlation matrix yields an advanced tool for customized geological and hydrogeological hard rock and soft ground characterisation

Ground changes or obstacles are characterized by typical combined PFE/Resistivity-anomalies, 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 soft ground (Fig. 5), each with 12 types.

Conclusion

Successful commercial application is realized since 2000. BEAM systems has accompagnied more than 33 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 could enable 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 hydro-geological 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 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 job site;
- Applicable in hardrock and soft ground as well as above and below the ground water table;
- Implementation in any type of TBM independent from the manufacturer;
- Contribution to lowering risks and increased demands to occupational safety.

Company Profile

GET - GEO EXPLORATION TECHNOLOGIES - 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 metal object and UXO-detection.
It maintains a modern portfolio of geophysical equipment.

Furthermore it conducts some unique and innovative techniques; like BEAM® ground prediction system for the tunneling industry as well as the new helicopter-borne seismo-electromagnetic methods HYDROSCAN®, ORESCAN® and AQUASCAN® for exploration and 3D imaging of oil & gas reservoirs, ore deposits and groundwater resources.

The company is led by the geologist and geophysicist Dr. Arnim Kaus and the economist Dipl.-Econ. Wolf Boening.

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.

GET

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