Measuring methods and the automatic recording of boring data for the investigation of the ground

Procédé de mesure et l'engregistrement automatique des données forages de l'investigation du sol

M. KANY, Prof. Dr.-Ing., Head, Institute of Foundation Engineering and Soil Mechanics, Landesgewerbeanstalt Bayern (LGA), Nuremberg, FRG
R. HERRMANN, Dipl.-Ing., Research Engineer, LGA Bayern, FRG

SYNOPSIS First bases for the automatic recording of important boring parameters were worked out for deposit investigations in the Fed.Rep. of Germany. The introduction of these recording systems for the ground investigation was mainly effected by the new edition of the standard DIN 4022 part 2 to 3. The special aim was to improve quality of the boring results and to obtain additional information by the process of the boring procedure. In the report presently existing systems are described and the limits of applicability as well as the aim of the respective data processing systems are presented. By the automatic recording of the boring data additional information about the quality of the samples to be taken is obtained. Moreover information about recovery ration, boring process, savenge pressure and other essential parameters can be obtained.
The data obtained can be transmitted to computer systems by different data storage equipment (discs, recorder) in order to obtain a central recording, storage and processing of the boring results. It is shown examples, how additional measuring values beside the boring records can be described (e.g. relative strength properties of the soil or rock). Thus, carefully directed laboratory investigations for the determination of the soil or rock properties resp. can be executed in a better way than before.

INTRODUCTION

By introduction of the standard DIN 4022 part 2 and 3 the recording of boring data has mandatorily been prescribed in a technical standard. The aim of this standard is both to get further parameters from the boring procedure and to record this additional information about the drilled soil or rock. While there are in total 7 parameters to be recorded for the classification and description of rock according to standard DIN 4022 part 2, there are only 2 parameters to be recorded for the investigation of soil (loose rock) according to standard DIN 4022 part 3.

According to the standard DIN 4022 part 2, they are:
- depth
- boring progress or -velocity resp.
- r.p.m. of the drilling tool
- mud pressure
- stage of mud or mud pressure
- mud loss

According to the standard DIN 4022 part 3 they are:
- depth
- boring progress or -velocity resp.

Beside these informations which are mainly concerning the boring procedure, informations for the classification of the bored soil and rock are necessary as to DIN 4022. It deals with the classification and desciption of the soil- and rock types.

In account of these standard-prescriptions many informations have to be collected. They can partly be registered by automatic processing. Further informations can be obtained by visual and manual classification according to DIN 4022 part 1. These boundary conditions make high demands on data processing systems or partly allow only two way processing of the data which were obtained automatically and manually.

TECHNICAL REQUIREMENTS ON BORING DATA PROCESSING SYSTEMS

For the use of boring data processing systems simplified following aspects should be considered from the view of both soil experts and boring companies:
- easy connection of the system to present drilling devices without extensive conversions.
- Utilization of new technology like liquid crystal indication and highly integrated electronic moduls.
- Easy operation of the system also by persons which are not acquainted to measurement technics and computers after a short instruction.
- As far as possible automatical and permanent running of data processing. Manipulations like rod-annex or rod-reset are compensated and do not cause any falsification of the data.
- Generous interpretation of the boundary parameters in order to guarantee optimum processing of the measurement values also under extreme conditions (high boring velocities).
- Protection of the system against action of unauthorized persons.
- Output of the results for checking insitu by peripheral units like screen, printer or plotter.
- Conversion from vertical to manual boring by negligible system manipulation.

Beside the mentioned requirements the devices have to be qualified for the rough operation in the field. The devices have to be absolutely waterproof or to be placed in a water-proof shelter (casing, driver's cab for drilling devices installed on a truck). Design of these systems has to proceed from a possible alternation of outside temperatures between + 45°C and -20°C.

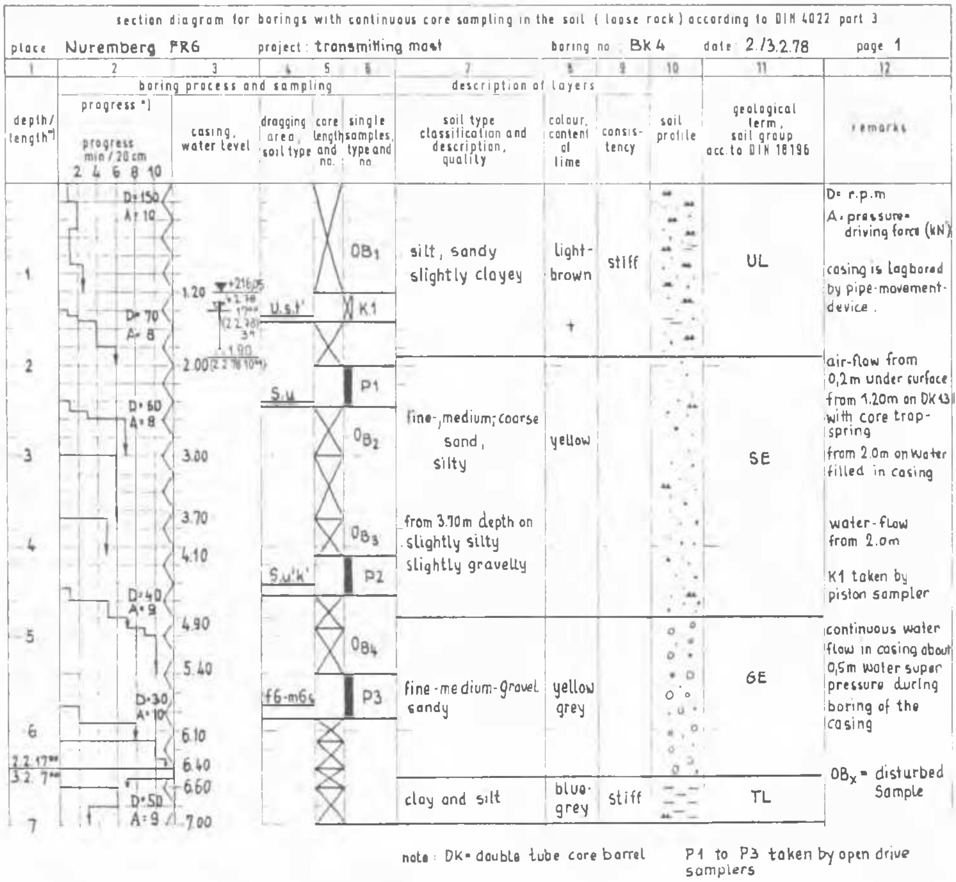


Fig. 1 Example for a filled-in section diagramm of a rotary boring in rock (DIN 4022 part 2)

REGISTRATION OF BORING PARAMETERS

By hydraulic boring devices boring data are usually measured in the following way:
Rate of penetration by angular step dispenser with forward and backward recognition. Dimension (cm).

Boring Progress
by rate time-measurement. Dimension (cm/min).

The boring velocity is determined from the measurement of the time necessary for the boring of one interval (calculation rate/time). After a scale conversion via paper feed the boring progress can directly be read by means of a plotter.

Torsion moment
of the boring tool. Measurement by torsion-moment-measurement hub or pressure-converter resp. at the hydraulic circulation of the power rotary swivel or rotary table. Dimension (Nm).

Revolutions per minute
of the drilling tools via gear grooves in the rotary swivel or rotary table. Dimensions (r.p.m).

Mud flow
by r.p.m. of the pump driving shaft or by flow measurement device. Dimensions (litres per minute).

Mud pressure
by pressure converter with isolating membrane in the mud circulation. Dimension (bar).

Delta flow
by information of differences between mud quantity in the flow pipe (measurement via r.p.m. of the pump driving shaft) and mud quantity in the return (measurement by flow measurement device). Dimensions (litres per minute).

Weight on bit
effective pressure force of the drilling tool on the well bottom - and/or difference measurement. Dimension (N or kN).

The pressure of the drilling tool is recorded for vertical drilling by means of two pressure converters at the pull-down cylinder. By this modifications at the drilling rod (rod annex) the rod load should automatically be measured. Measurement of the drilling pressure is made as to the following formula:

$$F_S = G_{BS} + F_A - F_G \quad (kN)$$

F_S = drilling pressure

G_{BS} = force from dead weight of the drilling rod

F_A = pressure force (can be controlled at the drilling device)

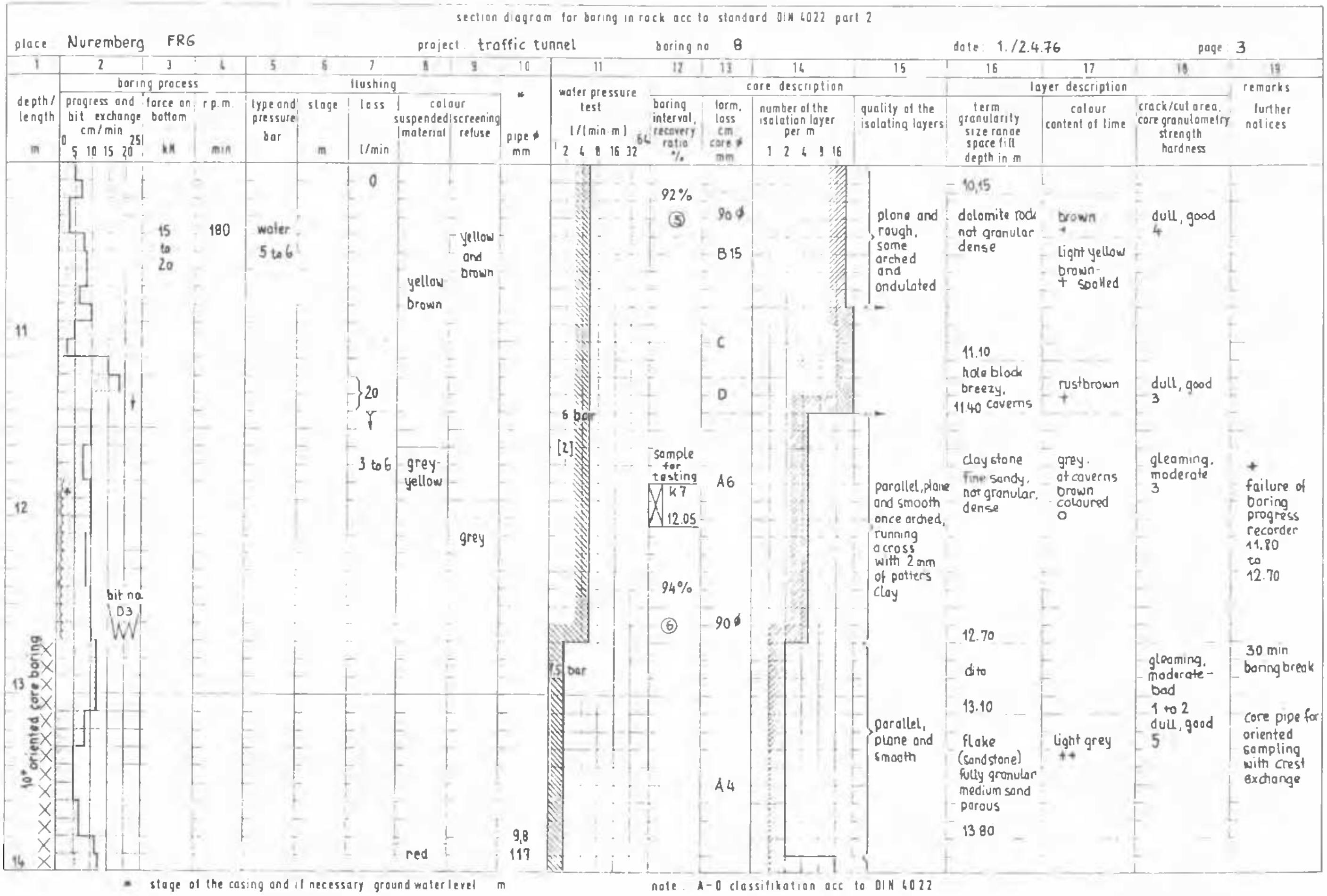


Fig. 2 Example for a filled-in section diagramm of a rotary boring in soil (DIN 4022 part 3)

F_G = back pressure force (to be controlled at the drilling device)

As force-level compensation for the possible elimination or reduction resp. of the force the dead weight of the rod.

BORING DATA PROCESSING SYSTEMS

Three typical boring data processing systems presently used in the FRG are described in the following:

Boring Data Processing System Type A (Heyberger, 1983)

Basic Device:
The device unites electronic evaluation, registration and display in digital form in one casing. The device is weatherproof and is heated when temperature falls below 8°C. The allowed ambient temperature is +45°C -20°C.
The device can also be used as a combination device for the boring data processing and for the flow-pressure-measurement of water pressure tests and injections.

Measurement:
The measurement rate (depth measurement) consists of a defined measurement cylinder for a measurement cable of 3-4 mm thickness made of stainless steel wire.
The cylinder tension ist realized by a spiral spring. The cable length is 15 m. Measurement itself is made inductively by a coding disc,disintegration is 10 mm.

Evaluation:
The electronic system for evaluation counts and adds the measurement impulses and displays the boring depth in digital form. This value is also printed on the registration strip. The boring progress is calculated from the depth and a time basis and printed graphically. The electronic system for evaluation always works in the boring direction, recovery is not registered.

Registration:
The registration consists of a normed paper-printer with 58 mm-writing width. Paper feed is controlled by the depth, time-basis is printing the values, from this results a graphical diagram of the boring process with parallel depth registration. The registration strip evaluates about 100 cm of depth on 1 cm of paper.

Boring Data Processing System Type B (Dockhorn, 1983)

Basic device:
The central unit, a table-computer, is recording automatically all present boring data by an interface/digital-transformer. Corresponding to the installed program the boring-tower- and working-data are worked by the computer-system. The data are presented on the picture as lists, tables and graphics. Programms can be developed and written in BASIC, PASCAL and machine-language.

A Floppy-Disc-Storage unit is used for the data storage, transmission and reading of the computer programs and is controlled by the central unit. Furthermore a printer and an analog-digital-converter for 30 separate channels can be connected.

Measurement:
By the boring-progress-measurement device the rod length and time during boring of the annexed rod is continuously measured.

Evaluation:
Signal to the DVM-display, storage- and registration unit is made by an electronic difference-pressure-recorder. Signal is also made for the moving up and down of the Kelly-rod as well as the beginning and end of boring by the annexed rod. The impulse-signal is adjustable during the boring progress for registration, marking or counting of 10 cm, 50 cm or 100 cm length unit.

Boring Data Recording System Type C (Müller-Pettenpohl, 1983)

Basic Device:
The basic device consists of a basic unit with display, keybord for basic operations and writing of comments and a built-in data recorder.

In the following the essential characteristics are mentioned:
Maximum boring velocity recordable: 500 cm/min
boring rate range-display - 999 999 to 999 999 cm
measurement interval: selectable from 1 to 250 cm
disc recording:
recording velocity: 6000 bits/s.
recording method: REAT after WRITE
data format: ASC II
Data capacity:
per disc: 2 x 1800 data blocks

Measurement:

After starting of the measurement procedure continous measurements of the applied stresses are made. Before display or storage resp. the measurement data are multiplicated with the appropriate factors.

Output of the data is made together with the depth and the calculated boring velocity on the display.

Example:

depth (cm)	boring velocity (cm/min)	force (N)	torsion moment (Nm)
4532	30,3	2050	97,7

rotary (r.p.m.)	flow rate (l/min)	flow pressure (bar)
280	40,6	9,87

Two kinds of data presentations on the display are selectable.
- The upper line shows the values of the past interval, the lower line shows the value of the presently bored interval.
- The upper line shows the present depth or measurement values resp., the lower line showing the average values of last interval.

Registration:
The measurement values are recorded on the disc or printed on the paper.

Beside the described parameter recording the system allows:
to measure and store the friction value, to indicate the crest depth during placing and removal of the rod, to indicate the actual parameters for levelling purposes, to indicate the

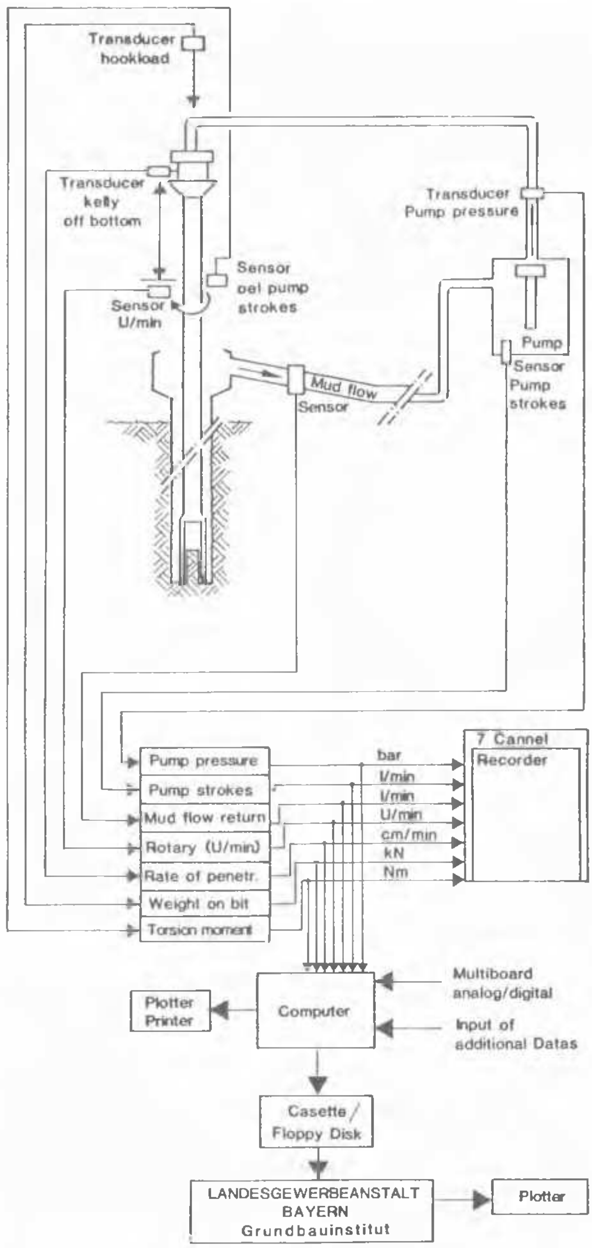
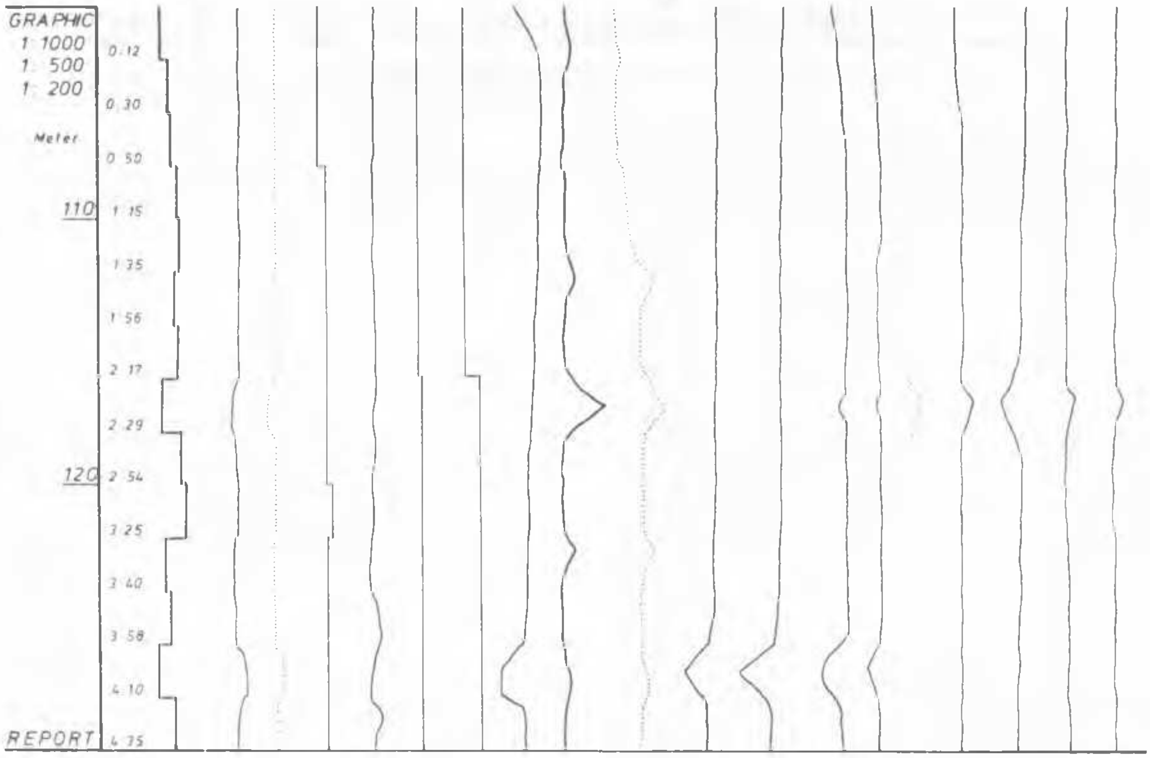


Fig. 3 Outline of a drilling data processing system (Kany/Herrmann, 1982)



DEPTH	TIME	ROP	HOOK LOAD	WOB	RPM	TORQ	ST.P PRES	PUMP RATE	PIT LEVEL	GAS 1	GAS 2	MUD-WT IN	MUD-WT OUT	TEMP OUT	DELTA TEMP.	H2S	PH	VISC	MUD-FLOW	RES
Mtr.	HR:MI	MIN/M	TONS	TONS	r/MIN	AMP	BAR	L/MIN	M^3	PPM	PPM	KG/L	KG/L	°C	°C	PPM			1/MIN	MS
9999,9	23:15	240	999	999	200	100	350	3500	999	1000	1000	2,00	2,00	99,99	99,99	99	14	150	4000	999
										500000	500000									
0000,0	00,00	000	000	000	000	000	000	0000	000	000000	000000	0,00	0,00	00,0	00,0	00	00	000	0000	000
10 cm		1 MIN	1 T.	1 T.	1r/	1 A	1BAR	10 L	1 M	10 ppm	10 ppm	10 g	10 g	0,001	0,01	1	0 1	1	10 L	1 MS
		/min			min					1000ppm	1000ppm									

Fig. 4 Presentation of the boring data (Dockhorn, 1983)

parameters of 32 past intervals.

The systems is largely self-controlled during a measurement and stops the measurement procedure when unfortunate defects are arising. The cause of the interruption is indicated on the display.

For the conversion to horizontal borings usually a pressure-converter is fixed, which records the pressure on the difference surface of the pull-down-cylinder. This is directly indicated.

Recording of Additional Boring Parameters

Beside the mentioned boring data recording systems the boring operators can partly supply measurement devices for gaz-measurements (by gaz-detectors), as well as temperature, density- and viscosity-measurements of the mud flow.

SUMMARY

In the report the actual state of boring data recording is presented. The report does not claim completeness. It is intended to give a general survey about the actual possibilities for recording of boring parameters.

From the view of the soil expert the systems have to allow possible boundary conditions as well as measurement of very large and small values concerning the range of measurement. In the field of soil investigations (socalled shallow borings) an essentially higher degree of accuracy is necessary than for deep borings.

If measurements are made in rate- and time-intervals which are too large, important ground properties can remain unknown. This means that, e.g. in hard formations, thin cohesive or not cohesive layers are not recognized as a result of flow in the core. These layers then do not appear representative in the boring-progress survey program in account of the formation of an average value by the electronic system for evaluation. Furthermore there should be the possibility to come as near as possible up to the boundary area of the maximum boring velocity (free fall of the boring rod, e.g. for cavernous rock. Under certain conditions this also allows to find distinct cavernous properties of the rock and the beginning of large caverns in the soil.

A high degree of accuracy of the mud pressure measurement provides possibilities of recognition of artesian ground water with low pressure, which can oftenly not be detected by the usual boring procedures and flood measuring. By the recognition of flow losses additional informations about the found caverns can be obtained. The extent of

Depth TEUFE CM	Rate of penetr. BOHRG. CM/M	Weight on bit ANDR KP	Torsion moment DRHM KPM	Rotary (U/min) DRHZ U/M	Pump pressure SPDR BAR	Mud flow return SPLR L/M
1000	4.3	3010	176	234	21.4	85.1
1010	5.1	3010	180	236	21.4	85.2
1020	6.5	3480	185	245	21.5	85.1
1030	4.9	3200	170	230	21.3	85.3
1040	5.5	3350	185	250	21.0	85.0
1050	5.8	3560	195	253	21.0	85.0
1060	7.3	3820	203	251	21.4	85.4
1070	5.4	3280	198	255	21.6	85.1
1080	6.3	3760	208	258	21.8	85.6
1090	7.5	3880	225	260	21.7	85.5
1100	7.5	4010	231	261	21.6	85.4
1110	5.8	4000	218	256	21.5	85.3
1120	4.4	3820	194	246	21.5	85.4
1130	5.3	3760	205	246	21.0	85.3
1140	5.8	3790	208	248	22.0	85.1
1150	6.5	4120	218	251	21.3	85.0
1160	7.2	4280	225	255	21.5	85.0
1170	5.5	3350	185	250	21.0	85.0
1180	5.8	3560	195	253	21.0	85.0
1190	7.2	4280	225	255	21.5	85.0
1200	5.1	3010	180	236	21.4	85.2
1210	6.5	4120	218	251	21.3	85.0
1220	6.3	3760	208	258	21.8	85.6
1230	5.8	3790	208	248	22.0	85.1
1240	6.5	3480	185	245	21.5	85.1
1250	7.5	3880	225	260	21.7	85.5
1260	7.3	3820	203	251	21.4	85.4
1270	5.3	3760	205	246	21.0	85.3
1280	4.9	3200	170	230	21.3	85.3
1290	4.4	3820	194	246	21.5	85.4
1300	5.4	3280	198	255	21.6	85.1
1310	4.3	3010	176	234	21.4	85.1
1320	5.8	4000	218	256	21.5	85.3
1330	7.5	4010	231	261	21.6	85.4
1340	6.5	3480	185	245	21.5	85.1
1350	5.5	3350	185	250	21.0	85.0
1360	4.4	3820	194	246	21.5	85.4
1370	5.4	3280	198	255	21.6	85.1
1380	4.3	3010	176	234	21.4	85.1
1390	4.9	3200	170	230	21.3	85.3
1400	5.8	3560	195	253	21.0	85.0
1410	5.3	3760	205	246	21.0	85.3
1420	7.5	4010	231	261	21.6	85.4
1430	7.3	3820	203	251	21.4	85.4
1440	6.5	4120	218	251	21.3	85.0
1450	7.5	3880	225	260	21.7	85.5
1460	6.3	3760	208	258	21.8	85.6
1470	5.8	3790	208	248	22.0	85.1
1480	5.8	4000	218	256	21.5	85.3
1490	7.2	4280	225	255	21.5	85.0
1500	5.1	3010	180	236	21.4	85.2

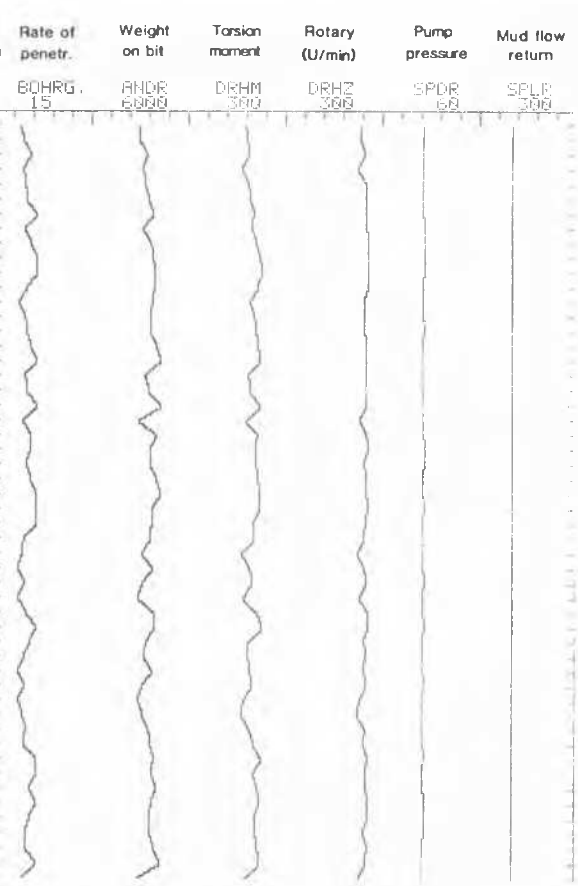


Fig. 5 Presentation of the boring data (Müller-Pettenpohl, 1983)

small-scale caverns can be determined by the deviation of the medium flow loss over the time. If certain parameters are kept constant (boring pressure, r.p.m., flow pressure, boring tools) results about the relative stability of the soil can be obtained. From these results the soil- and rock expert can make more exact selection of samples for tests on the basis of the boring data. By measurement of the actual depth by data processing, caving areas and overbored areas can be recognized. The comparison of the core length determined according to standard DIN 4022 "soil- und rock determination" with the measured boring rate allows statements about the recovery ratio and by this about the quality of the sampler. From the boringness of the rock result further informations concerning the structure strength of the bored rock.

The authors will largely examine the above-mentioned perspectives also with respect to their activities in national and international working groups or DIN-committees resp. Summarizing we can say that by the recording of boring data an essential concentration of informations about the bored soil or rock can be reached. By continous minuting of the total boring procedure the boring process is netted by data with the boring profile. This results in an important amelioration of the standards in the field of soil investigation and leads to a better security of soil mechanical prediction and of the structures built on these informations.

REFERENCES

DIN 4022 part 2 and part 3

Dockhorn, W. (1983). Technical documents - Electronic Construction Service - measurement technics - Engineering Nordhorn

Heyberger, W. (1983). Technical documents, measurement technics, Comdrill Heilbronn

Kany/Herrmann (1982). Pilot project "boring data recording" of the Landesgewerbeanstalt Bayern, Grundbauinstitut, Nürnberg (unpublished documents)

Müller-Pettenpohl (1983). Technical documents, measurement technics GmbH, Müller Petterpohl, Wächersbach