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Pore water pressure effects in clay due to unloading - long-term measurements, change of soil fabric and application

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1 Introduction

The loading process of low permeable soil such as clay is often described in terms of the principle of effective stress (Terzaghi 1925), leading to temporarily increased pore water pressures, which dissipate as time elapses. The same principle is commonly applied to unloading processes. Thus unloading can lead to a temporarily decreased pore water pressure which may recover with time toward the original state. To predict pore pressure development with time, consolidation theory is applied. A one-dimensional solution was presented by Terzaghi (1925, 1943).

Additionally volume change effects of soil (solid) and water (fluid) compressibility according to the Theory of Porous Media, or poromechanics (porous solid with fluid filled interconnected voids), may be considered. A three-dimensional solution, also known as theory of dynamic poroelasticity, has been presented by Biot (1941), modelling soil behaviour as a continuum. Based on such concepts time-dependent behaviour of clay has been analyzed, for example at tunnels (e. g. Giraud et al. 1993) or cut slopes (e. g. Vaughan et al. 2004). Although progress has been made (e. g. Cooper et al. 1998), the precise timing of delayed collapse of cut slopes in clay remains to be described adequately.

Beyond unloading (Blümling et al. 2007, Bernier et al. 2007), quite a number of geotechnical problems still exist, which are not (yet) sufficiently understood (Gudehus 2011).

In this paper in-situ pore pressure measurements are presented. The results indicate, that continuum models may not be sufficient to describe transient pore water pressure distributions in the process of unloading: Structural changes in the soil material may occur, leading to sudden changes of soil properties and thus soil behaviour. Such effects are known (Lanyon 2011) as Excavation Damaged Zone (EDZ), occurring in soil (and rock).

2 Case history (Klingenberg underground clay mine)

In-situ pore water pressure measurements have been carried out in the underground clay mine of Klingenberg/Main (Germany). The project started in 2003. Originally the intention was to examine effects of pore pressure propagation[1] in submerged clay under natural conditions. Since the clay needs to be viewed as nearly-saturated, the increased compressibility of pore water due to microscopic gas inclusions (bubbles) has to be considered in the evaluation of the pressure data. To account for the increased compressibility of the pore water, a three-phase model (solid-fluid-gas, see also: Schwab et al. 2004) was to be applied.

The test site in the underground mine of Klingenberg had been selected because a homogeneous clay deposit allowed in-situ experiments shielded from climatic influences like precipitation and changes of temperature. The time-dependent development of pore water pressures has been observed for over six years.

2.1 Geology and geotechnical properties of Klingenberg Clay

The test site is located in an underground clay mine at Klingenberg. Underground mining is utilized in Klingenberg since 1742, at least two centuries earlier exploitation began in open pits to take advantage of local Ball Clay resources. Pollen analysis cited by Heine (2004) identifies the tertiary clay as a freshwater deposit from the Oligocene period (according to other sources Klingenberg clay seems to be mistakenly attributed to Pliocene). The highly plastic Kaolin clay is grey in appearance. It is a preferred pencil clay for its superb mixing properties with graphite. According to Dobner (1984) the clay consists of 61 % kaolinite, 4 % montmorillonite, 10 % mica and 25 % feldspar und quartz.

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[1] In low permeable soils pore pressure propagation had been verified via in-situ measurements to be a factor in triggering slope movements. In unstable slopes even falling barometric pressure may act as a trigger (Köhler et al. 1999).

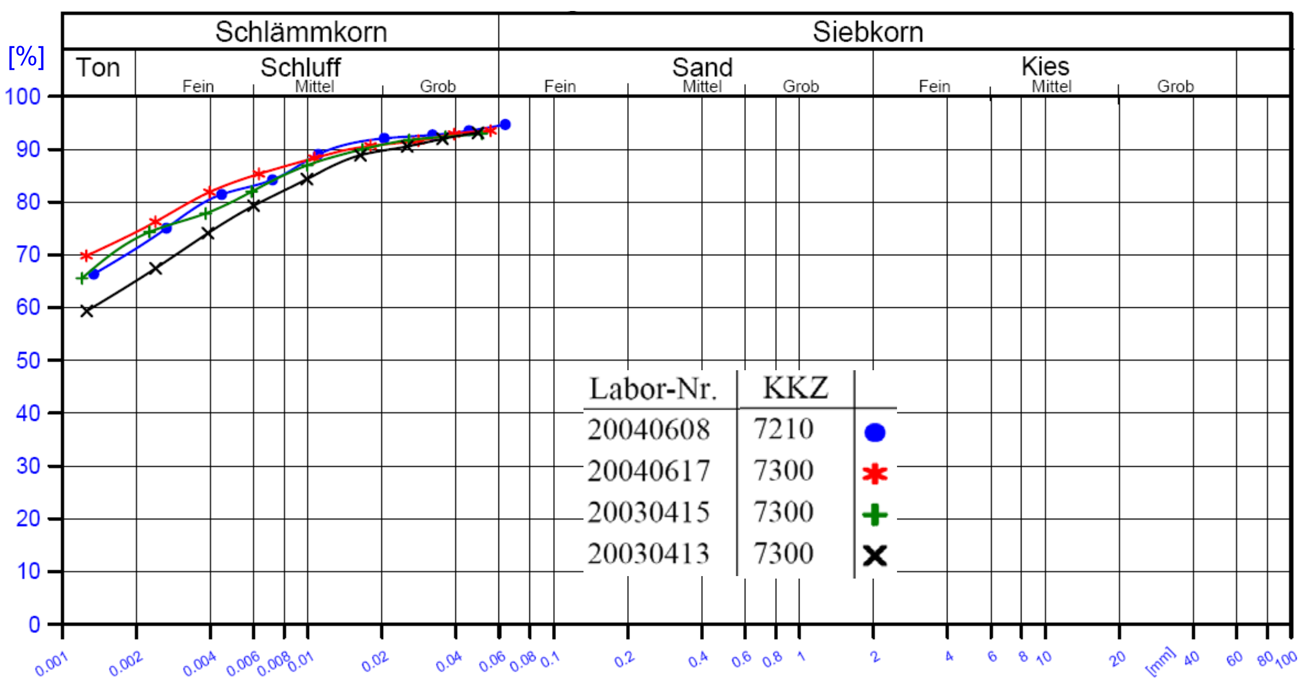


Figure 1: Particle size distribution of Klingenberg Clay

Table 1: Parameters related to Atterberg limits

soil sample #	LL liquid limit w_L [-]	PL plastic limit w_P [-]	PI plasticity index I_P [-]	LI liquidity index I_L [-]	CI consistency index I_C [-]	w water content w [-]	A clay activity I_A [-]
19883322	0.78	0.26	0.52				
20030082	0.93	0.35	0.58	-0.09	1.09	0.30	
20030415	0.82	0.25	0.57	-0.09	1.09	0.20	0.78
20040606	0.74	0.28	0.47				0.66
20040615	0.87	0.33	0.54	-0.06	1.06	0.29	0.73
average	0.83	0.29	0.54	-0.11	1.11	0.23*)	0.72

*) The average value of the water content w is based on a larger number of measurements than listed here.

The particle size distribution is illustrated in Figure 1, showing a very high clay content. According to ISO 14688-2 : 2004 the clay is classified as a very stiff clay of very high plasticity (or: "fat clay" CH according to USCS ASTM-D2487). Parameters related to Atterberg limits are presented in Table 1. The average values were determined by the arithmetic mean characterising Klingenberg Clay. The water content w at the shrinking limit is about 0.16. The clay activity I_A[2] has been determined to be inactive at $I_A = 0.72$, which is close to the limit value (0.75) of inactive to normal clay.

The overall hydraulic permeability k can be expected to be very low and has been determined in the laboratory according to DIN 18130-1 (type TX-DE-ST-UO) to $k = 2$ to 7×10^{-12} m/s. According to DIN 18132 water absorption w_A is 114 % (high).

The undrained shear strength c_u is very high to extremely high (according to ISO 14688-2). Measurements yield $c_u = 245$, 390 and 463 kPa (from laboratory penetrometer tests). The sensitivity is low (< 8), roughly estimated 2 to 3.

Additionally drained direct shear tests (reverse shear tests), a triaxial shear test and oedometer tests have been carried out. A detailed description of the results is beyond the scope of this paper. The geotechnical parameters listed below are derived from those laboratory tests characterizing Klingenberg Clay:

Strength:	friction angle $\Phi'_p = 13°$, cohesion $c_p' = 65$ to 150 kPa (drained, peak)
	friction angle $\Phi'_{res} = 10°$, cohesion $c_{res}' = 0$ (drained, residual)
Stiffness:	Young's modulus E = 30 to 80 MPa (at effective stress 400 to 1600 kPa)

2.2 Layout of the pore pressure measurement system

Location of test site

The test site where pore water pressure measurements have been undertaken is located in a short tunnel (about 7 m long), especially excavated for the project. The tunnel lies 70 m beneath ground level (Fig. 2). The location had been selected under the condition that no preceding mining activity can be assumed at the site where the pressure sensors are installed. Nevertheless the original pore pressure state has been influenced by the main gallery which has been excavated decades earlier.

The cross-section A-A (indicated in Figure 2) is shown in Figure 3, as well as other details. After the tunnel was excavated in 2004 and the tunnel lining was installed, in a first step steel tubes d = 56 mm (see Fig. 4) were put into position as a preparation to install the pressure sensors.

[2] clay activity $I_A = PI/(m_{clay}/m_{total})$ m_{clay}/m_{total} …. clay fraction of weight (≤ 0,002 mm)

The pressure sensors and the data acquisition system went into operation on April 7th, 2005. Because of space limitations inside the tunnel (inner tunnel diameter $d_i = 2 \cdot r_i = 2.00$ m, outer (excavated) diameter $d_o = 2 \cdot r_o \sim 2.25$ m) and specific requirements due to underground mining conditions the installation was quite challenging.

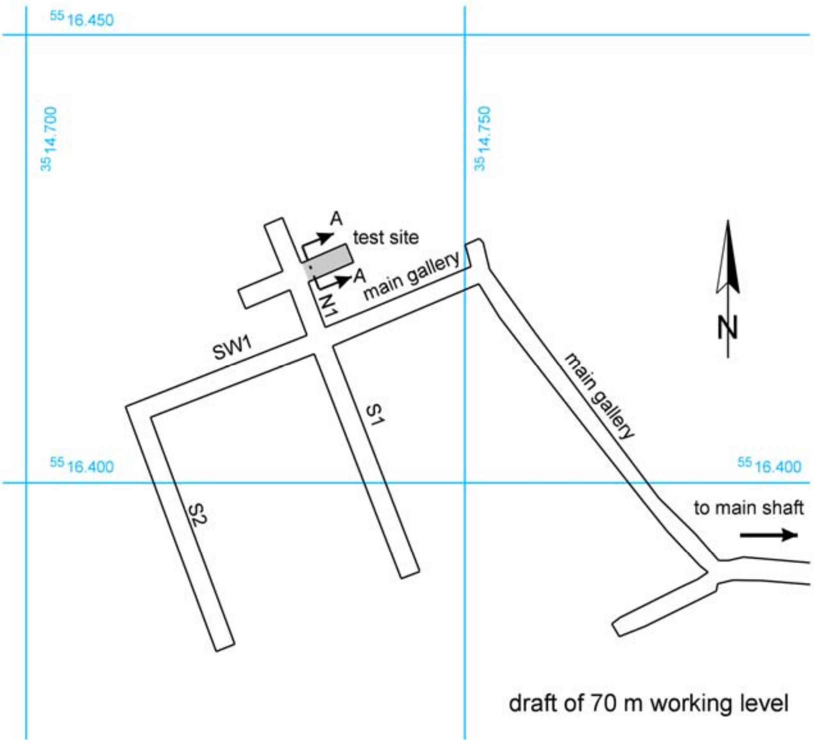


Figure 2: Site plan

Six pressure sensors were placed at a distance b = 1.0 m, 2.0 m and 5.0 m from the outer perimeter of the tunnel lining. In each of the three indicated depths, two sensor equipped steel tubes were installed to increase redundancy. The geometrical position of the sensors is shown in Figure 3.

Tunnel lining

The tunnel lining consists of circular profiles GI-120, steel 1.0520 (31Mn4U, hot rolled), $d_i = 2.00$ m. Three segments, connected by screwed steel plates, are assembled in-situ to a complete circular profile. The spacing of the circular profiles is a = 0.5 m. Between the profiles lagging sheets are installed (corrugated sheet metal plates St 37.2, 4x200x1300 mm) to provide an outer tunnel lining as depicted in Figure 3. Construction details of the tunnel lining are very similar to those of the existing access galleries leading through the underground mine.

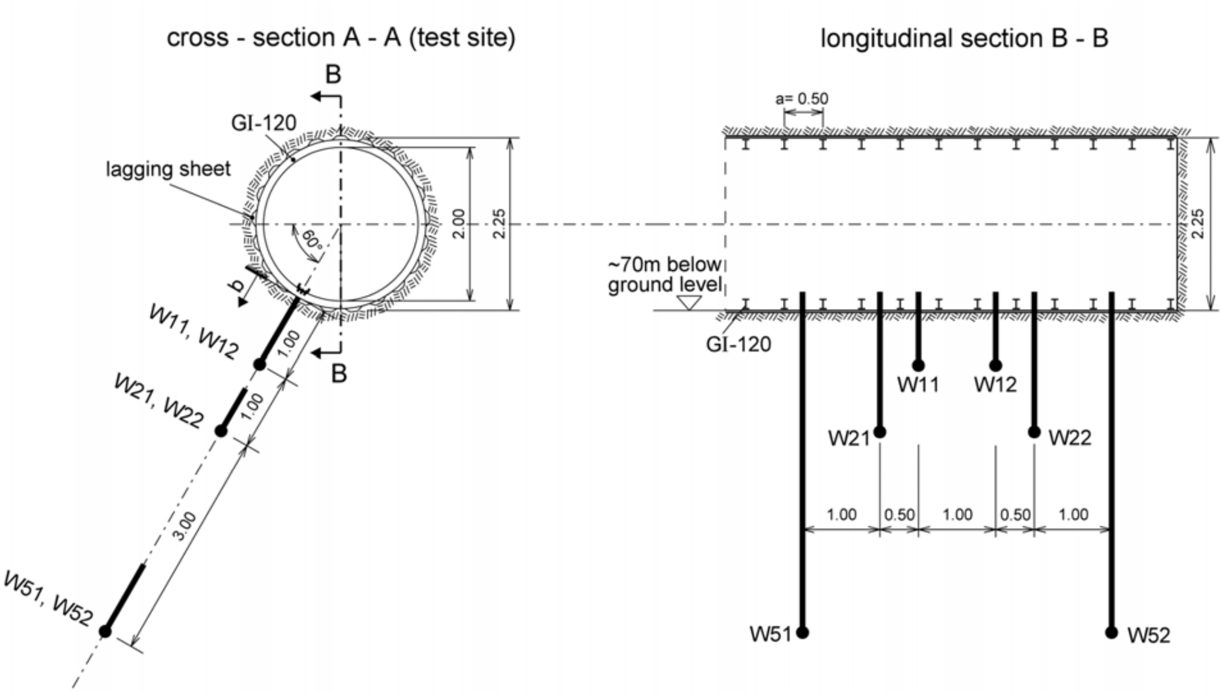


Figure 3: Geometrical layout of measuring system

As indicated above the tunnel lining consists of circular profiles and intermittent corrugated sheet metal which is very soft in comparison to the stiffness of the circular steel profiles. Due to those irregular deformation characteristics of the tunnel lining no convergence measurements have been undertaken.

Especially the profiles located in the vicinity of the junction with one of the main galleries (at the tunnel entrance) suffered from overloading and were deformed massively with time. During the measurement campaign a few of those profiles had to be replaced. Nevertheless no simultaneous influence of those remediation works on the measured pore pressures was detectable.

Applied measuring system

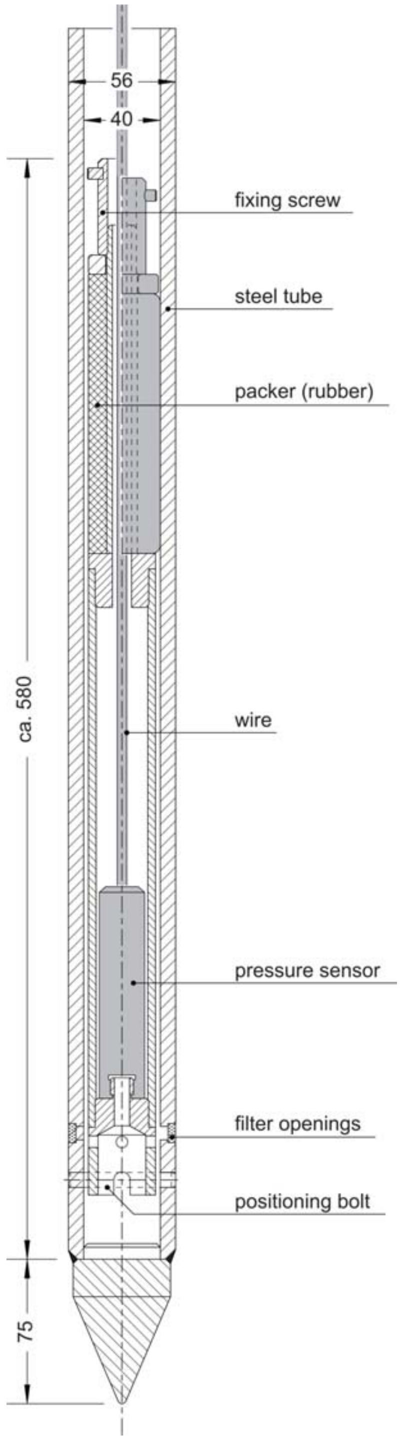
Pressures are measured in relation to reference pressures. The reference pressure may be either constant or variable. At constant reference pressure (absolute pressure datum) an arbitrary but known constant pressure (often: "vacuum") is used. If a variable reference pressure is chosen (open gauge pressure datum) measurements will be in relation to atmospheric air pressure.

$$u = p_w - p_{atm}$$

p_w absolute pore water pressure ($p_w = 0$ at "vacuum")

u relative pore water pressure ($u = 0$ at $p_w = p_{atm}$)

p_{atm} atmospheric pressure (fluctuating[3])



Note: $p_w < p_{atm}$ (or: $u < 0$) is referred to "suction"

← Figure 4: Schematic view of pore pressure measuring system

The applied measuring system has been successfully used for over two decades. This is especially valid in low permeable clay. The measuring system has been described in several papers (e. g. Köhler & Heibaum 1990, Köhler & Feddersen 1991). A slightly modified system is still in use (Figure 4). The system is capable of measuring suction. Under field conditions suction may be measured in a range of ~ 0.1 bar < p_w < p_{atm} (abs) or resp. ~ -0.9 bar < u < 0 (rel). Each measuring unit consists of a steel tube (d = 56 mm) with radial filter openings (filter material: porous sintered glassfilter) and a separate packer system containing the pressure sensor. The packer system is installed after the steel tubing has been driven into the ground. The steel tube was driven in pre-drilled holes using a pneumatic hammer. To ensure sufficient sealing the diameter of the holes must not be larger than the diameter of the steel tube. After the steel tubes were brought to depth, the packer systems which contain the pressure sensor had been installed inside the steel tube. The installation process requires the steel tube to be filled with de-aired water to ensure a proper coupling with the pore water in

[3] mean value at sea level: 1 atm
1 atm = 101.325 kPa = 1,013.25 hPa or mbar = 10.332 mH_2O (m water column)
at temperature T: 5°C < T < 25°C

the soil. While positioning the packer system inside the steel tube it is required that the pressure port of the sensor is immersed in de-aired water at all times. The measuring range is between about u = 0.9 bar below barometric pressure ("suction") and up to 2 bar above barometric pressure. Depending on the selected type of sensor the measuring range above atmospheric pressure may be much higher than 2 bar.

With a preceding in-situ test (located in tunnel S1, installation of the sensor on June 22nd, 2004), it was verified that a pressure of less than u = 2 bar, (respectively less than p_w = 3 bar) could have been anticipated in the vicinity of the tunnel, thus an adequate selection of pressure sensors concerning the measurement range was ensured. The following types of piezo-resistive sensors were selected: PAA-36W/80748.02-3 of Keller AG, Winterthur (W11, W12, W21, W22 and W51) and DMP 331i (Code 111-3001-1-1-T-J-1-503) of BD Sensors Gmbh, Thierstein (W52), all pressure sensors: 2-wire system, 4-20 mA, nominal pressure $p_w \leq 3$ bar.

In the tunnel high air humidity (approaching 100 %) and lack of continuous electric supply pose a demanding environment for the data acquisition system (rated IP65) installed in a control box (rated IP66, consisting of V2A stainless steel 1.4301 (AISI 304, X5CrNi18-10)). Electricity was provided by batteries which needed to be recharged periodically outside the underground mine.

Soil temperature is almost constant as well as the temperature in the tunnel (about 11°C).

2.3 Data of time-dependent pore pressure development

Originally readings were taken at a rate of at least once per hour (starting April 7th, 2005). For technical reasons (high humidity, supply of electricity via batteries) the period of continuous data acquisition was shorter than anticipated: No readings are available from June 24th to November 27th, 2006 and November 11th, 2007 to January 26th, 2009. Starting January 27th, 2009 (at t ~ 33,000 h) data acquisition was resumed by taking manual readings using a handheld device in irregular time intervals (averaging about one reading per month). The data acquired in more than six years until August 3rd, 2011 (at t ~ 55,400 h) is plotted in the diagram of Figure 5. Please note the logarithmic scale of the time axis which has been chosen to improve visualization during early phases of the pore pressure development. The above mentioned manual readings are represented by dotsymbols, continuous readings (taken before January 27th, 2009) are depicted in solid lines. In both cases the chosen colours refer to the particular sensor listed in the legend of the diagram.

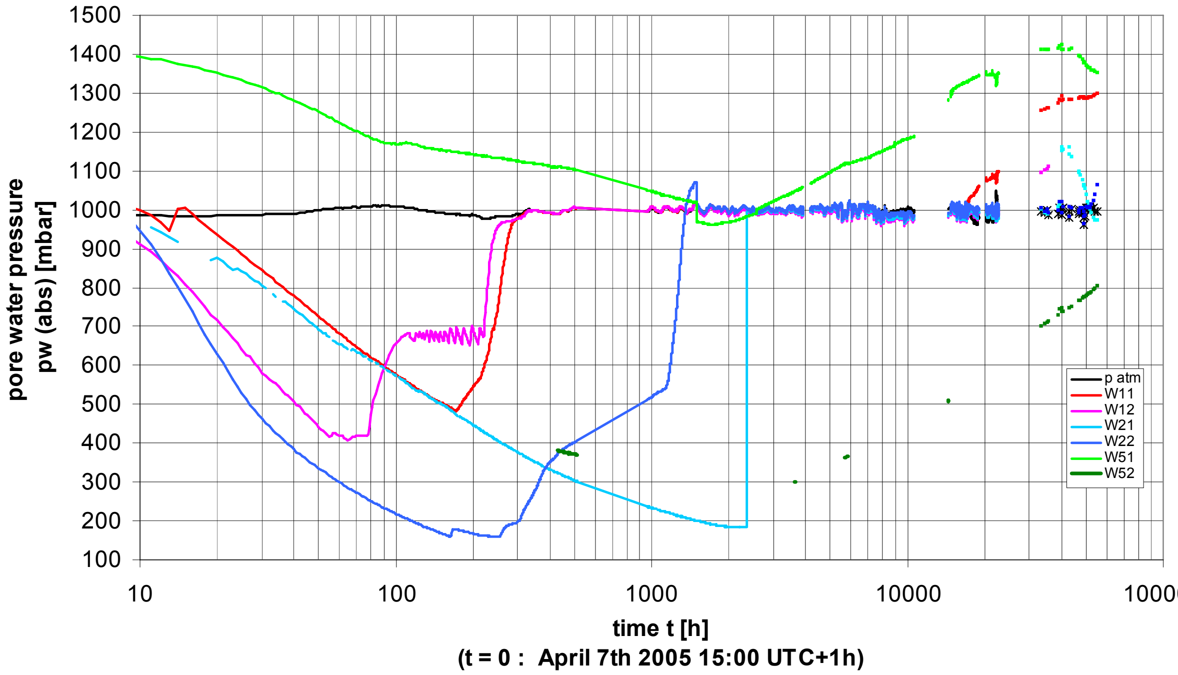


Figure 5: Time-dependent pore pressure development

In November 2009 the electric cable of sensor W12 accidently was sheared off and has not been replaced since. Early in the measuring campaign sensor W21 sporadically produced irregular readings (leading to discontinuities in the plotted line). Since manual readings are taken, the plausibility of W52-readings seems to have improved (while connected to the data acquisition system W52 rarely showed plausible readings).

Interpretation of data

In Figure 6 typical characteristics are illustrated schematically which may be derived from Figure 5. Please note: Phase 0 is indicated by a dotted line because it has no relevance regarding phases 1 to 4 on grounds that (e. g.):

- Original pressures not influenced by tunnelling cannot be measured because installation of the pressure sensors started after tunnel excavation had been finished.
- Installation of the steel tube that houses the packer system changes local pore pressures temporarily.

- After installation of the packer system in low permeable soil it is known that pore pressures need some time to equalize before a representative pore pressure reading can be taken. After that initial phase, the hydrodynamic time lag is very small due to the applied measuring system.

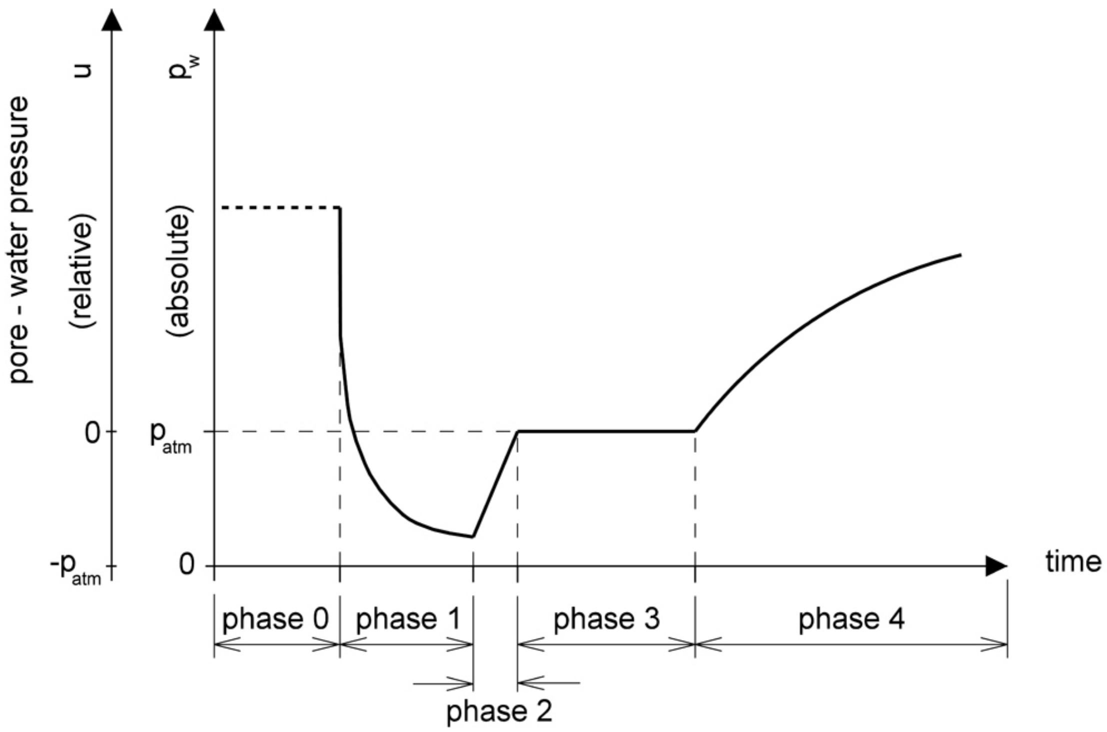


Figure 6: Schematic sketch of the evolution of pore pressure in clay

The effects mentioned above cannot easily be distinguished or quantified in the readings. Thus the readings acquired right in the beginning of the measurement campaign (phase 0) are somewhat arbitrary. A precise timing of the end of phase 0 and the beginning of phase 1 cannot clearly be distinguished, both phases may overlap in a smooth transition.

In phase 1 pore pressure strives asymptotically against steady state conditions ("suction"). Depending on factors like e. g. the distance from the tunnel wall or stiffness of soil and tunnel lining) this phase may last from about a few days to several months. In phase 2 the pore pressure suddenly increases to atmospheric pressure. This increase is quite remarkable. In a first analysis a systematic error in the measuring system may be suspected. But such an explanation seems to be unlikely because the timing of the increase of pressure happens systematically, depending on the distance of the sensor from the tunnel lining (e. g. far away from the tunnel lining = later timing and vice versa).

Additionally the increase of pressure towards atmospheric pressure seems not to be linked to a specific threshold pressure (e. g. outgassing) which may have triggered the process. Phase 3 is defined by atmospheric (barometric) pressure reaching into the soil beyond a certain sensor. This prolonged phase lasted for several months or even years. Finally in phase 4 increasing pore pressure was observed which may be explained by fissures or joints which have been closed again as soon as sufficient time has elapsed. Pore pressures may finally approach steady state conditions.

Sensors located closer to the tunnel lining show those effects earlier than sensors located further away from the tunnel, indicating a systematic and time dependent influence. Vice versa sensors located further away from the tunnel lining show those effects not only later in time, but also the changes may develop at a much slower pace (compare W51 to W11/12/21/22).

3 Discussion

Transition from phase 1 to phase 3 (see Figure 6) may be attributed to changes in the soil fabric: With the excavation of the tunnel deformation processes are induced. Clay is moving toward the artificially created opening. Because of very low permeability, pore water cannot move fast enough from the surrounding soil to respond to pre-failure deformation, falling pore pressure is to be expected (even suction may occur). Corresponding to the falling pore water pressure, gas bubbles expand, which are always present in natural pore fluids, resulting in non-trivial time-dependent deformation processes. Results of calculations carried out with a fully coupled model are presented in Schwab et al. (1D finite element simulation of two unloading processes - excavation and water draw down - as an application of the three-phase model). These time-dependent deformation processes may eventually lead to conditions causing micro-joints or micro-cracks to open (during phase 2). At that point, transition in soil fabric implies significant changes of geotechnical parameters, as permeability, stiffness etc., which is especially valid in phase 2, allowing atmospheric pressure to reach far into the soil (phase 3). In the beginning of phase 4 the soil fabric may change again (closing of micro-joints or micro-cracks).

Similar effects have been observed e. g. in the vicinity of a shaft in Boom clay (RESEAL project, underground research facility HADES in Mol, Belgium)[4].

In literature the term EDZ (Excavation Damaged Zone) is used to identify the zone affected by processes described above. According to Blümling et al. (2007) EDZ *"…is a zone with hydro-mechanical and geochemical modifications inducing significant changes in flow and transport properties."* In the paper presented here EDZ is defined as a zone, where the soil fabric is altered in a way that atmospheric pressure is allowed to reach into the soil mass (this definition forms a subset of the definition of EDZ according to Blümling).

Starting from suction in phase 1 an *in*crease towards atmospheric pressure has been observed in phase 2. If the starting pressure (phase 1) happens to be above atmospheric pressure, a *de*crease towards atmospheric pressure might take place

In Figure 7 the size of EDZ is shown schematically comparing measurements of Klingenberg (green) and Mol (blue). In this graph EDZ is defined as the zone, where the soil fabric is altered in a way that atmospheric pressure is allowed to directly reach into the soil mass, leading to a lower bound estimate if compared to EDZ as defined by Blümling.

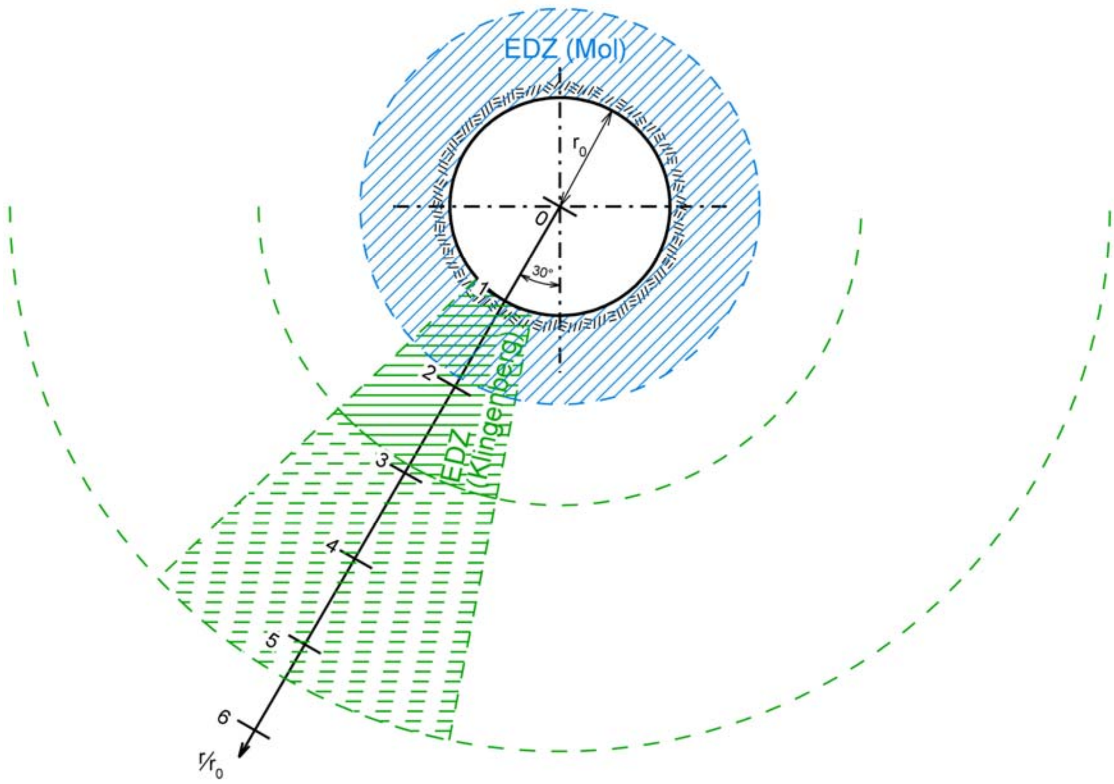


Figure 7: Extend of EDZ in Klingenberg compared to EDZ in Mol

[4] Brief information on the RESEAL project is provided in "Appendix A".

In Klingenberg (r_o = ½ · 2.25 m = 1.125 m) the change of soil fabric (e. g. micro-cracks) reached from the tunnel lining into a distance b from the outer tunnel lining of more than b = 2 m and less than 5 m or expressed dimensionless: $2.78 < r/r_o < 5.44$

The measurements in Mol (r_o = ½ · 2.20 m = 1.10 m) show, that the change of soil fabric reached at least 1 m beyond the outer shaft lining ($r/r_o > 1.91$) which is basically in accordance with the results of Klingenberg. Please note: In Mol the sensors were located max. 1 m off the tunnel lining. Thus effects at distances greater than 1 m are beyond the limits of the measuring system of Mol.

However basic differences exist: The measurements in Mol have been carried out in the vicinity of a shaft, in Klingenberg an area below a tunnel has been observed. Thus for reasons of geometry, stiffness of clay (and support system/tunnel lining) and other reasons both cases cannot be expected to show identical behaviour. Still similar effects have been observed in both cases due to unloading[5]:

- sudden change of soil fabric (e. g. expansion of bubbles supporting micro-cracking) leading to relatively fast changes (increase or decrease) of the pore water pressure towards atmospheric (barometric) pressure (phase 2), compare Fig. 5 to Fig. A.1

- followed by a period of time (phase 3), when atmospheric pressure is reaching some distance into the clay where the pore water pressure is approximately equal to barometric pressure
  In Klingenberg this period lasted approximately 24 months (at $r/r_o = 1.89$), in Mol the period lasted for 41 months (at $r/r_o = 1.82$), see: Fig. 5 and Fig A.2.

- followed by a further change of soil fabric (e. g. cracks are closing again), resulting in increasing pore water pressure (toward steady state, phase 4),

- in Klingenberg the characteristic pore pressure development of Fig. 6 has been observed to reach into the soil from the tunnel lining up to $r/r_o < \sim 3$ (possibly even more than 3, but less than $r/r_o = 5.4$). This figure may be taken as a rough

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[5] Beyond Klingenberg and Mol similar effects have been observed in Opalinus Clay at Mont Terri, where additionally a structural characterization of EDZ is given by Bossart (2004).

approximation (lower bound) of the size of EDZ around an underground opening, where atmospheric pressure is eventually reaching into the soil.

Although substantial knowledge exists on self-sealing processes (see also: Bock et al. 2010), consideration of the effects described above may improve the understanding of geotechnical aspects such as

- the loading of tunnel linings,
- delayed collapse of cut slopes,
- short term stability of slopes and excavations.

4 Conclusion

In-situ pore pressure measurements have been carried out in the underground clay mine of Klingenberg with the original intention to examine effects of pressure propagation (e. g. fluctuating barometric pressure) in the clay. In this context the development of pore water pressures with time has been observed for more than six years. Results are presented and discussed in this paper. In combination with other observations found in literature (e. g. Blümling et al. 2007, Bernier et al. 2007, Van Geet et al. 2009), the interpretation of the measurements leads to the conclusion, that a continuum model may not be sufficient to describe transient pore pressure in the process of unloading. Instead changes of soil fabric or soil structure may occur, leading e. g. to discontinuous time-dependent development of pore pressure. Such effects are not implemented in the vast majority of models existing today. Taking into account such fundamental changes of soil properties could improve the understanding of some geotechnical processes not yet solved satisfactorily. Whether the closed fissures of phase 4 fully restore the original fabric and behaviour of the soil in phase 1 cannot be answered within the framework of the relatively small Klingenberg project. Further research is needed to increase insight into the processes of phases 1 to 4 especially concerning further geotechnical applications e. g. such as time-dependent stability of cut slopes and deep excavations.

The continuous support of Eckhard Ehrt (Tonwerk Klingenberg) is much appreciated, which was essential in this project.

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Appendix A:

Information on pore pressure measurements of the RESEAL project (underground research facility in Boom Clay at Mol)

The case presented in this appendix refers to the RESEAL project of the underground research facility at Mol (Belgium) in a shaft located in Boom Clay. All information listed below is taken from Bernier et al. (2007) [1] and Van Geet et al. (2009) [2] to ease comparison to the measurements of Klingenberg.

Boom Clay is a tertiary clay (rock) from the early Oligocene, geotechnical data from [1]:
saturated permeability k = 2 to 4 x 10^{-12} m/s, Young's modulus E = 300 MPa,
friction angle Φ' = 18°, cohesion c' = 300 kPa,
unconfined compressive strength UCS = ~ 2 MPa

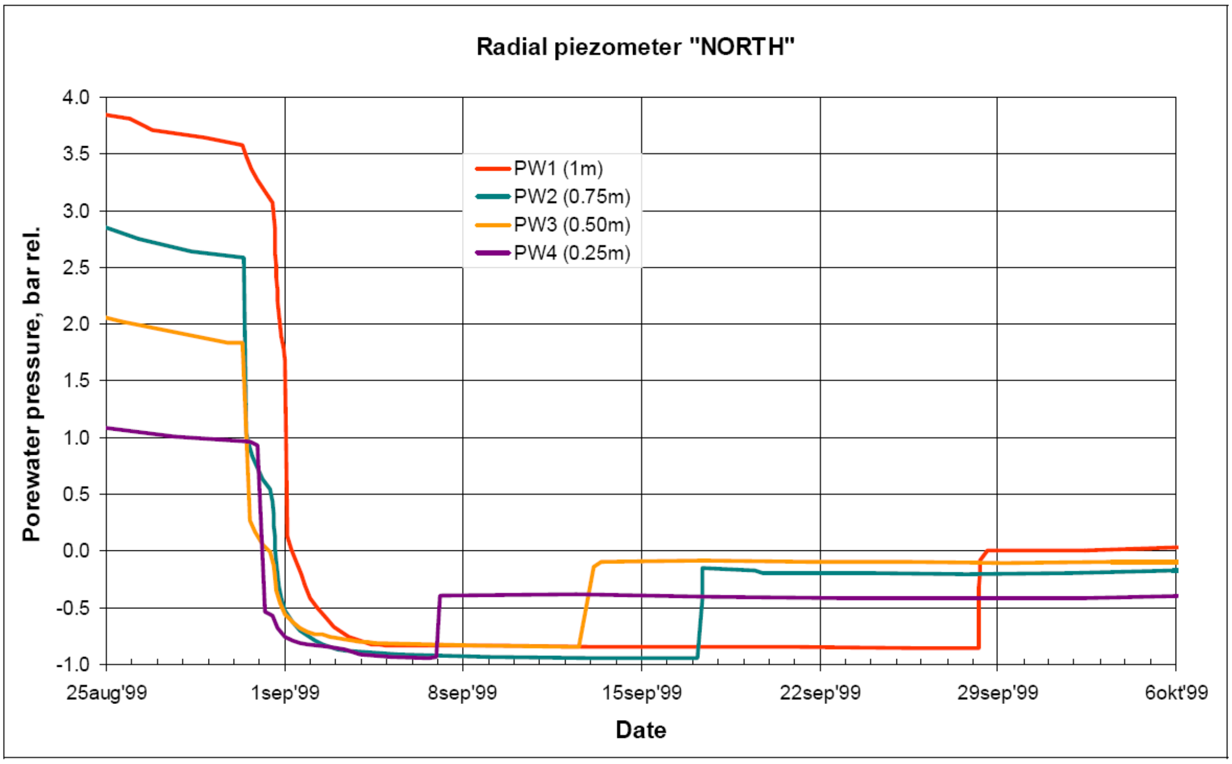

Figure A.1: Piezometer readings (early phase of measurements) in Mol (from: [2] p. 82)

The outer diameter of the shaft [2] is $d_o = 2 \cdot r_o$ = 2.20 m (outer perimeter of the shaft lining).

In a horizontal section (~ 240 m below ground level) pore pressures were measured in three arrays of five sensors ("radial piezometer": PW1 to PW5). In each array five sensors were located at varying distances b from the outer perimeter of the shaft lining, reaching to a maximum of b = 1,0 m into the ground.

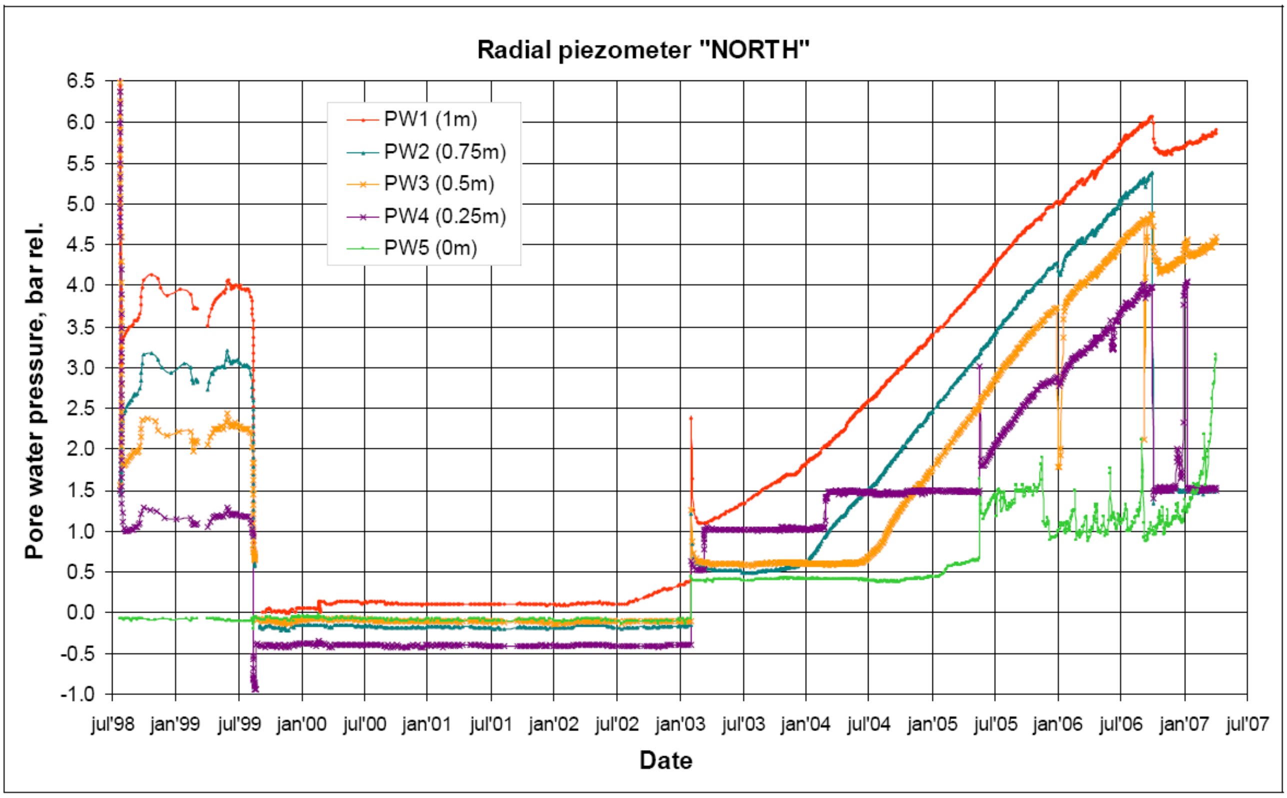

Figure A.2: Piezometer readings (long-term) in Mol (from: [2] p. 264)

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3. Bulletin & Final Program

August 2011

FMGM 2011 BERLIN

8th International Symposium on

Field Measurements in GeoMechanics

Berlin, Germany, September 12-16, 2011

www.FMGM2011.org

FMGM 2011 BERLIN

Workshops 1 -3 ,Monday, September 12, 2011

Workshop 1 - Offshore instrumentation
9:00 a.m. - 12:00 noon room Audimax

Chairman: Rolf Balthes

Validation of design concepts by instrumented offshore pile foundations during installation and operation
KIRSCH, Fabian

Instrumented Pile Monitoring for Baltic Sea Offshore Wind Foundations in the light of the latest requirements of the German
WEIHRAUCH, Stefan

Concept and Results of the Pile Instrumentation at FINO 3 (Research for the german wind Industry No. 3 in the german bight)
FRITSCH, Maik

Prospects for Dynamic Piletesting on Offshore-Foundations
ZAHLMANN, Jörn

Geotechnical and structural Instrumentation of offshore structure in the international Oil- and Gas-Industry
DOUGAN, Alan

Workshop 2 - Instrumentation in underground laboratories and geological repositories
9:00 a.m. - 12:00 noon room Kinosaal

Chairman: Klaus Wieczorek

Instrumentation in Underground Laboratories and Geological Repositories – Overview and Special Challenges
WIECZOREK, Klaus

Geomechanical experiments at the Meuse Haute-Marne Underground Research Laboratory
ARMAND, Gilles; NOIRET, Aurélien

Challenges in geotechnical measurement techniques: case studies in the Mt. Terri rock laboratory, Switzerland
TRICK, Thomas

Geophysical Measurements and Monitoring in Underground Laboratories and Geological Repositories – Rock Characterization
SCHUSTER, Kristof

Long-term reliability/accuracy/power supply
JAEGGI, David

Workshop 3 - Standardization and product data sheets
9:00 a.m. - 12:00 noon room 2002

Chairman: Martin Beth

Field measurements in the fundamental geotechnical Eurocode EC 7 (EN 1997-1 and -2)
SCOTT, Jonathan

A comprehensive initiative towards more user-friendly standards
NUßBAUMER, Manfred

Standards and Eurocodes – some issues for authors to consider
DUNNICLIFF, John

Instrumentation standards in the United States
MARR, Allen

Geotechnical monitoring standards in Germany: DIN 4107, Parts 1 to 4
BOCK, Helmut

Geotechnical monitoring standards in Switzerland: Swiss Standard SN 670305
The European Task Group No. 2 of CEN TC341/WG1 on geotechnical monitoring by field instrumentation
STEINER, Walter

Engineering geodesy standards in Germany with particular reference to DIN 18710 – 4 “Deformation measurements”
HEUNECKE, Otto; KLEIN, Karl-Heinz

Do we need regulations for product data sheets of geotechnical instrumentation?
PEZZETTI, Giorgio

For the most up-to-date workshops information and to register, visit
www.FMGM2011.org

FMGM 2011 BERLIN

Monday, September 12, 2011

9:00 a.m. - 12:00 noon Workshops

W1: Offshore Instrumentation (Room Audimax)
W2: Instrumentation in Geological Repositories (Room Kinosaal)
W3: Standardization and Product Data Sheets (Room 2002)

12:00 noon - 1:00 p.m. Lunch in the Exhibit Hall

1:00 - 6:20 p.m. Forum for Young FMGM Engineers (Room Audimax)

1:00 - 2:00 p.m. Session 1

Temporal prediction of landslides failure by continuous TInSAR monitoring
Mazzanti, P.; Bozzano, F.; Cipriani, I.; Esposito, F. (Italy)

Parameterization of a dry-stone retaining wall on a terraced slope in Valtellina (northern Italy) and subsequent stability analysis
Camera, C.; Apuani, T.; Masetti, M. (Italy)

Monitoring of a secant piled wall using fibre optic sensors
Schwamb, T.; Fuentes, R.; Elshafie, M.; Ouyang, Y.; Janmonta, K; Soga, K.; Ferreira, P.; Swain, A. (United Kingdom)

Load test on bored pile embedded in soft soil: Field measurement vs. finite element analysis
Apoji, D. (Indonesia)

Compression device for CDZ Experimentation – Mechanical containment test in gallery: control and monitoring
Morel, J.; Noiret, A.; Bourdon, M. (France)

Discussion

2:00 - 2:20 p.m. Refreshment Break in the Exhibit Hall

2:20 - 3:20 p.m. Session 2

Modernization of rockfall hazard management systems: Using LiDAR technologies to improve identification and monitoring of potentially unstable
Lato, M. (Norway)

Soil measuring on a full-scale model of a gravity base foundation for offshore wind turbines
Sommer, J. (Germany)

Application of observational method in conventional tunnelling projects in urban areas- the case of Niayesh road tunnel project, Tehran, Iran
Ghorbani, M.; Sharifzadeh, M.; Daiyan, M. (Iran)

High resolution monitoring of temperature in diaphragm wall concrete
Doornenbal, P. J.; Hopman, V.; Spruit, R. (Netherlands)

Suitability evaluation of the differential radar interferometry method for detection and deformation monitoring of landslides
Plank, S.; Singer, J.; Minet, C.; Thuro, K. (Germany)

Discussion

3:20 - 3:40 p.m. Refreshment Break in the Exhibit Hall

3:40 - 4:40 p.m. Session 3

Geomechanical surveys and geostatistic elaborations in Valchiavenna (Italian central Alps)
Ferrari, F.; Apuani, T.; Giani, G. (Italy)

Abu Dhabi, Qasr Al Hosn Rehabilitation Project: Automatic site monitoring in extreme temperature conditions
Mananjara, H.-P. (France)

Geotechnical monitoring system of an highway viaduct in Northern Italy
Tombolato, S.; Matteo, P.; Lucia, S.; Luigi, M. (Italy)

Application of terrestrial laser scanning an photogrammetry to a deep excavation
Fuentes, R.; Backes, D.; Robson, S.; Ferreira, P.; Swain, A. (United Kingdom)

Multivariate analysis of the measured data from monitoring system
Jung, S.J.; Kim, T.H.; Park, D. K.; Kim, H.S. (Korea)

Discussion

4:40 - 5:00 p.m. Refreshment Break in the Exhibit Hall

5:00 - 6:00 p.m. Session 4

A study on the behaviors of concrete lining and rock mass during shaft sinking by means of the short step method
Sakai, K.; Koike, M.; Aoki, T.; Inagaki, D. (Japan)

Influence of grout on earth pressure measurements taken by inclinodeformometer
Schwager, M. V. ; Fischli, F.; Puzrin, A. M. (Switzerland)

Automatic response capability in geodetic sensor networks
Horst, S.; Alkhatib, H.; Kutterer, H. (Germany)

Cost effective groundwater monitoring system during the construction of the 3rd E.ON power plant, Maasvlakte, Rotterdam, The Netherlands
Hogeweg, N.; Van der Salm, R.; Ochtman, D. (Netherlands)

Stabilization of soft ground under embankment load using deep cement mixing columns
Thang, N. N.; Kawamura, M. (Japan)

Discussion

7:00 p.m. FMGM2011-Welcome-Reception at the Senators Hall
8:00 p.m. Announcement of the first prize winner of *Forum for Young FMGM Engineers*

FMGM 2011 BERLIN

Tuesday September 13, 2011

9:00 a.m. - 12:00 noon Opening Session (Room Audimax)

Welcome - Jörg Gattermann, Chairman of the Organisation Committee
Greeting adresses
Keynote Lecture 1: N.N. - The History of Berlin
A moment of honour for the chairmen of the past FMGM Symposia
Awarding the prizes for the Forum for Young FMGM Engineers
Keynote Lecture 2: First Prize Winner of the Forum of Young FMGM Engineers

10:55 - 11:15 a.m. Coffee Service in the Exhibit Hall

Keynote Lecture 3: Major Problems in the Design and Construction of the Gotthard Base Tunnel
Kalman Kovári, Consulting Engineer and Heinz Ehrbar, Chief Construction Officer Gotthard Base Tunnel

12:00 noon - 1:00 p.m. Lunch in the Exihibit Hall

1:00 - 3:00 p.m. Concurrent Technical Sessions

	Room Audimax	Room Kinosaal
1:00 p.m.	Security is measurable – GeoMonitoring on a slope on Ruegen Becker, D.; Hermsmyer, D.; Rietdorf, A.; Krömer, T.	Emerging technologies of field instrumentation, data collection and reporting Gujral, A.; Rastogi, V. K.
1:20 p.m.	Long term measurement and analysis of a deep mass movement Müller, M.; Brunner, F. K.	New web based software for efficient geotechnical monitoring and data management Rackwitz, F.; Savidis, S.A. ; Rickriem, J.
1:40 p.m.	Steering supporting measures for urban tunnelling Thurlow, P.; Knitsch, H.	Demanding real time deformation monitoring and web data management Krangnes, L.
2:00 p.m.	Metro induced vibration measurements in bored tunnels and subsoil, Rotterdam, the Netherlands Berkelaar, R.; Zandbergen, D.; Dalmeijer, R.	Spatial database and web-GIS for managing and validating river embankment monitoring data Simeoni, L.; Floretta, C.; Zatelli, P.
2:20 p.m.	Toulon Tunnel: Where instrumentation pilotes everyday the tunnel works Bourgine, A.; Dupriez, N.; Perraud, V.	Real time, on-line monitoring for every Project Thorarinsson, A.; Simmonds, T.
2:40 p.m.	Frejus Security Tunnel: Instrumentation of a rock tunnel under large convergences Prusak, A.; de Lorenzi, D.; Beth, M.	A micro Geo-Electric Signals measurement for the rock slope observation Shishido, M.; Kusakabe, Y.; Ito, Y.; Murayama, H.; Niwa, H.

3:00 - 3:30 p.m. Refreshment Break in the Exhibit Hall

3:30 - 4:30 p.m. Poster Slam - Two Minutes of Fame (Room Audimax)

Every poster will be presented in two minutes by its authors. Floor Voting!

4:30 - 5:00 p.m. Refreshment Break in the Exhibit Hall

5:00 - 6:20 p.m. Concurrent Technical Sessions

	Room Audimax	Room Kinosaal
5:00 p.m.	Summary and lessons learned from New York City tunneling instrumentation Roy, D.	Realistic design of big base slabs by combining geotechnical measurements and FEA to model the soil-structure-interaction Vittinghoff, T.; Schneider, H.
5:20 p.m.	A network of robotic total stations to monitor the construction of Linea 9 of Metro Barcelona: The case of double tunnel of Sagrera Valdemarin, F.; Tamagnan, D.; Schwarz, H.	Dynamic response analysis of an embedded retaining wall: full-scale Instrumentation, monitoring and data interpretation Rainieri, C.; Laorenza, C.; Dey, A.; Santucci de Magistris, F.;
5:40 p.m.	-swissMon – An Approach to 4D Monitoring of Tunnels in Urban Environments Meyer, C.	Measurements and investigations on the efficiency of geothermal storage of solar energy Mock, S.; Herrmann, R. A.; Höfer, H.
6:00 p.m.	Development of new MPBX design for the New York City No. 7 Line Extension Project Jensen, N.; Gouvin, P.; Dasta, R.	Standards and Eurocodes - some issues for authors to consider Dunnicliff, J.

7:00 p.m. City Bus Tour Berlin

FMGM 2011 BERLIN

Poster Session, Tuesday September 13, 2011

3:30 - 4:30 p.m. Poster Slam - Two Minutes of Fame

Room Audimax

Underground wireless communication system using low-frequency magnetic field signals: development, merit and potential application areas
Choo, J.; Kim, Y. S.; Oh, Y.-S.; Lim, S.; Jung, Y.-H.

Digital photogrammetry based real-time pile penetration measurement system
Kim, Y. S.; Choo, J.; Eom, I. S.

Foundation reinforcements on highway bridges in soft grounds due to seismic retrofit
Nam, M. S.; Jeong, J.-H.

Development of Discontinuity Analysis Program using Reverse Engineering and Its Application
Cheon, D.-S.; Park, E.-S.; Jung, Y.-B.; Song, W.-K.; Choi, Y.

Field Measurement of Prestress Force of Tension-Type Ground Anchor using FBG Sensor Embedded 7-Wire Strand
Kim, Y.S.; Sung, H.J.; Kim, J.M.; Lee, C.J.

Development of the state of stress in the closer surrounding of the pile toe regarding to driven offshore foundations
Fischer, J.

Geomechanical investigation of coastal cliffs by terrestrial remote sensing techniques
Mazzanti, P.; Bretschneider, A.; Brunetti, A.

Earth pressure measurement on buried corrugated steel pipe culvert
Hong-Jong, K.; Nam, M. S.; Jeong, J.-H.

Using TDR system for continuous moisture monitoring of swellable Rock in MiS powerhouse Cavern
Daiyan, M.; Sheibani, H.

The early warning system of the 'Grande Frana' in Ancona
Cardellini, S.; Osimani, P.

In situ stress monitoring: Investigations of pressure pad coupling conditions
Friedrich, C.; Krause, M.; Paeghe, W.; Eilers, G.

Fibre optics strain sensing for geotechnical structures
Schwamb, T.

Case study of detecting a massive hard rock for tunnel excavation in serpentinite area by geotecnichal property data of
Okazaki, K.; Shishido, M.; Takahashi, Y.; Inoue, T.; Ito, Y.

Systematic inspection method for slope using digital photogrammetry
Ito, Y.; Shishido, M.; Kusakabe, Y.; Anan, S.

Automatic Metro of Torino - Line 1 - Porta Nuova St. - Lingotto St. Tract
"Example of risk management with continuous monitoring during TBM excavation in some critical zones"
Morino, A.; Mitrugno, D.; Fornari, E.; Colleoni, G.

Wednesday, September 14, 2011

FMGM 2011 BERLIN

8:30 - 10:00 a.m. Keynote Lectures

Room Audimax

Measurement and Monitoring: What they expect from?
Pezzetti, G.

Impact And Benefit of GEO Sensor network technology For Monitoring TASKS
Heunecke, O.

Installation monitoring – Real-time key for operational success
Sparrevik, P.

10:00 - 10:30 a.m. Refreshment Break in the Exhibit Hall

10:30 a.m. - 12:30 p.m. Concurrent Technical Sessions

	Room Audimax	Room Kinosaal
10:30 a.m.	Integrated onshore / offshore site investigation for Izmit Bay Suspension Bridge crossing the north Anatolian Fault zone, Turkey Balthes, R.; Chacko, J.	Filling the gaps between drillhole data with high resolution geophysics Bazin, S.; Pfaffhuber, A. A.
10:50 a.m.	Extenso-Piezometer developed for femern large scale tests Sparrevik, P.; Løvholt, J.; Hayes, S.; Kvistedal, Y.	Detection of imperfections in diaphragm walls with geophysical measurements Spruit, R.; van Tol, F.; Hopman, V.
11:10 a.m.	In-situ measurements regarding soil plugging behavior inside tubular piles Henke, S.; Fischer, J.	Development and application of the shallow seismic reflection survey ahead of tunnel face using tunnel excavation blast as the seismic source Murayama, H.; Niwa, H.; Kuroda, T.; Noda, K.
11:30 a.m.	Mitigation of underwater piling noise using new hydro sound dampers (HSD) Elmer, K.-H.; Gattermann, J.; Bruns, B.; Kuhn, C.; Stahlmann, J.	The acousto-elastic stress measurement-a new procedure for the geotechnical on-line monitoring Jäger, F.-M.
11:50 a.m.	Geotechnical monitoring on a ship: The stability of cargo in a hold Burton, P.; Ransley, C.	Monitoring dams and reservoir slopes with interferometric SAR Vöge, M.; Larsen, Y.; Frauenfelder, R.
12:10 p.m.	Dynamic load testing of large scale piles - offshore and onshore Schallert, M.; Klingmüller, O.	Positioning system for the fixed link across Fehmarnbelt Hermsmeyer, D.; Huck, B.; Rüffer, J.

12:30 - 1:30 p.m. Lunch in the Exhibit Hall

1:30 p.m. - 3:30 p.m. Concurrent Technical Sessions

	Room Audimax	Room Kinosaal
1:30 p.m.	6 years earthworks monitoring with a fiber optics geotextile enabled sensor Artieres, O.; Dortland, G.	An automated approach for near surface soil site profiling by sasw technique Mukherjee, M.; Prashant, A.
1:50 p.m.	Testing a large fibre optic strain-rosette, embedded in a landslide area Wöllner, J.; Woschitz, H.; Brunner, F. K.	Ground-Based Radar Interferometry (GBInSAR) for the monitoring of a deep-seated landslide (Aosta Valley, NW Italian Alps) Barla, G.; Antolini, F.; Barla, M.; Mensi, E.; Piovano, G.
2:10 p.m.	An all-digital implementation of the Brillouin optical frequency domain analysis for long-range distributed strain Nöther, N.; Krebber, K.; Schneider-Glötzl, J.	A comparative trial of robotic total stations and terrestrial radar interferometry Thomas, A.; Vogelaar, J.
2:30 p.m.	The use of optical fibre sensors for the development of an alerting system for flowslides Damiano, E.; Minardo, A.; Avolio, B.; Bernini, R.; Olivares, L.; Zeni,	Surface movements derived from Space: Valuable information for underground geomechanical processes! Petrat, L.; Zschocke, A.; Petrat, K.
2:50 p.m.	Truly distributed optical fiber extensometers for geomechanical structure monitoring (dikes and underground repository) : influence of sensor external coating Blairon, S.; Delepine-Lesoille, S.; Vinceslas, G.	Advances in the application of Time Domain Reflectometry (TDR) as a monitoring system for subsurface deformations Singer, J.; Thuro, K.; Festl, J.
3:10 p.m.	Smart CFRP systems for structural monitoring and retrofitting Käseberg, S.; Schaller, M.-B.	From planning to reporting of airborne laser scanning Bannehr, L.; Jany, S.

3:30 - 4:00 p.m. Refreshment Break in the Exhibit Hall

4:00 p.m. - 5:40 p.m. Concurrent Technical Sessions

	Room Audimax	Room Kinosaal
4:00 p.m.	Use of electrolevels for measuring slab deflection of concrete faced rockfill dams Rocha-Filho, P.	The forward ground prediction based on the axial displacement behavior of three dimensional convergence measurements Takemura, I.; Tatsuhiko,O.; Koji,I.; Tatsunori, C.; Masato, S.
4:20 p.m.	The RASNIK opto-electronic alignment system: a high-precision, zero-drift deformation and displacement monitoring system van der Salm, R.; van der Graaf, H.; Dorresteijn, W.	Employing LiDAR during construction of underground facilities: The development of a custom workflow and automated tools Lato, M.; Vöge, M.
4:40 p.m.	The effect of cement slag's amount on the measuring results of vibrating wire strain gages in concrete Ahangari, K.; Noorbakhsh S. M.	Combined observations of surface displacements using differential interferometry SAR (DInSAR), GPS and traditional monitoring techniques Di Martire, D.; Iodice, A.; Ramondini, M.; Ruello, G.; Calcaterra, D.
5:00 p.m.	Buoyancy effect on slightly sloped horizontal in-place inclinometer George, C.; Jensen, N.	The capabilities and limitations of satellite InSAR and terrestrial radar interferometry Thomas, A.; Solomon, I.
5:20 p.m.	GeoBeads, multi-parameter sensor network for soil stability monitoring Peters, E.; van der Vliet, P.	Failure mechanisms in rock slopes imaged with a portable radar interferometer (GPRI) Kos, A.; Strozzi; T.; Wiesmann, A.

5:45 - 6:30 p.m. Special Session (Room Audimax)

Awarding the prizes for the Poster Slam

FMGM - The Future

The bid for FMGM 2015

7:30 p.m. FMGM Banquet (Restaurant 'Umspannwerk Ost')

Thursday, September 15, 2011

FMGM 2011 BERLIN

9:00 a.m. - 10:30 a.m. Keynote Lectures

Room Audimax

Urban Tunnelling Instrumentation: Analysis and reflexions
Beth, M.; Pezzetti, G.; Schmuck, C.

Sensortechnology for Smart Levee Monitoring
Hopman, V.; Kruiver, P.; Koelewijn, A.; Peters, T.

On Site Visualization as a new scheme for risk visualization and safety management for geomechanics applications
Akutagawa, S.; Nomura, M.; Yamada, H.; Abe, R.; Izumi, C.; Kusui, A.

10:30 - 11:00 a.m. Refreshment Break in the Exhibit Hall

11:00 a.m. - 1:00 p.m. Concurrent Technical Sessions

Room Audimax

11:00 a.m. Practical aspects of the fully-grouted method for piezometer installation
Contreras, I. A.; Grosser, A. T.; Ver Strate, R.

11:20 a.m. The length measuring probe for deformation measurements in axial and lateral direction - accuracy, compensation of temperature effects and measurement-experience
Szczyrba, S.; Kudla, W.

11:40 a.m. Field Performance of fully grouted piezometers
Simeoni, L.; de Polo, F.; Caloni, G.; Pezzetti, G.

12:00 p.m. Use of piezometers to monitor the stability of river embankments
Pozzato, A.; Simeoni, L.; Tarantino, A.

12:20 p.m. Instrumentation and monitoring of a proto-type scale test on pile foundations for over head bridge cranes
Mühl, A.; de Carvalho Thá, P.; Glockner, A.; Röder, K.

12:40 p.m. Analysis of the behaviour of an artificial clay-calcium mixture as a construction material of an embankment for landslide risk
Lollino, P.; Cotecchia, F.; Monterisi, L.

Room Kinosaal

New construction and extension of hydropower plants; site investigations with hydraulic and geotechnical in-situ testing
Hayer, J.; Reinhardt, S.; Kern, A.

Permanent construction and geo monitoring programs for quality assurance of the construction and operation of the Danube Harbour Straubing
Lauber, T.; Herrmann, R. A.

Settlement historical buildings compensated
de Nijs, R.; Kaalberg, F.

Case studies on design of vibration mitigation measures based on field measurements and numerical methods
Schepers, W.; Achilles, S.; Savidis, S.

Geotechnical measurements during construction and operation of Sülfeld lock
Stelzer, O.; Schwab, R.; Neumann, S.

Long-term geotechnical response of Venice coastal defences detected by Persistent Scatterer Interferometry
Bincoletto, L.; Simonini, P.; Strozzi, T.; Teatini, P.; Tosi, L.

1:00 - 2:00 p.m. Lunch in the Exhibit Hall

2:00 p.m. - 3:40 p.m. Concurrent Technical Sessions

Room Audimax

2:00 p.m. Distributed sensor techniques in geotechnics
Glötzl, R.; Krebber, K.; Wosniok, A.; Schneider-Glötzl, J.

2:20 p.m. Foundation for proposed Al Mada Towers in Jeddah, Saudi Arabia
Chua Tong Seng; Choo, S.; Chiew, L. K.

2:40 p.m. Deep heat mining by HDR/EGS technology
Rummel, F.

3:00 p.m. Data sheets and catalogues: a tool to select instruments?
Pezzetti, G.

3:20 p.m. On-line sources of information about geotechnical Instrumentation
Dunnicliff, J.

Room Kinosaal

Comparison of wireless signal transmission and seismic tomography for monitoring radioactive waste repositories
Spillmann, T.; Rösli, U.; Parsons, S.; Blechschmidt, I.; Marelli, S.; Maurer, H.; Manukyan, E.; Breen, B.; León, V. M.; Bárcena, I.

Preceding instrumentation for testing installation and handling of extensometers in real conditions
Fischle, W.; Kuropka, F.; Eilers, G.

Mine by experiments in order to study the hydromechanical behavior of the Callovo-oxfordien clay stone at the Meuse Haute-Marne underground research laboratory (France)
Noiret, A.; Armand, G.; Cruchaudet, M.; Conil, N.

Results of stress and strain measurements in a barrier made of salt concrete
Manthee, F.; Fischle, W.; Paehge, W.; Rathke, C.; Mauke, R.

Innovative TDR-techniques for capturing the water saturation process of the engineered barriers and host rocks in the framework of nuclear waste repository design experiments
Wörsching, H.; Trick, T.; Gaus, I.; Rüedi, J.; Schlaeger, S.

3:40 - 4:10 p.m. Lunch in the Exhibit Hall

4:10 p.m. - 5:30 p.m. Concurrent Technical Sessions

Room Audimax

4:10 p.m. From site instrumentation to reversed stability analysis
Záleský, J.; Kos, J.; Kozel, M.; Záleský, M.

4:30 p.m. Interpretation of subsurface monitoring results near three deep excavations for North-South line in Amsterdam
Korff, M.; de Nijs, R.; Kaalberg, F.; van Tol, F.

4:50 p.m. MEMS Digital inclinometer probe interchangeability
Tigani, B.; Rongo, R.

5:10 p.m. On the influence of casing and backfilling materials on inclinometer tests
Alber, M.; Plinninger, R.; Düllmann, J.

Room Kinosaal

In-situ rock stress measurement using downward compact conical-ended borehole overcoring technique in a vertical HQ-size borehole
Sakaguchi, K.; Kizaki, A.; Matsuki, K.

Pore water pressure effects in clay due to unloading - long-term measurements, change of soil fabric application
Schulze, R.;

Monitoring challenges and opportunities associated with major construction programme slippages
Cook, D. K.; Kleinlugtenbelt, R.; Baaten, R.

5:40 p.m. Closing Ceremony (Room Audimax)

7:00 p.m. City Boat Cruise