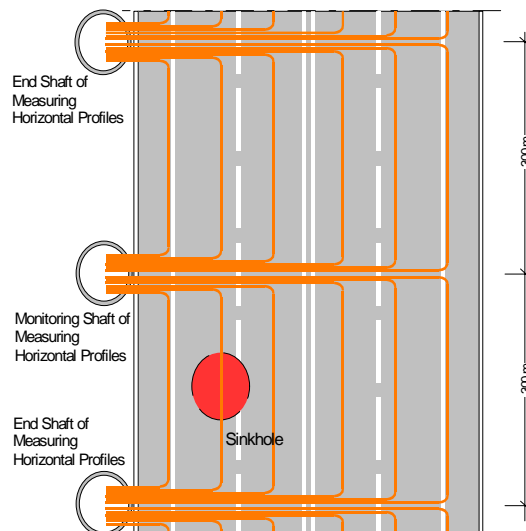


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New Hydrostatic Methods for Measuring Settlements of Constructions under Extreme Geological Boundary Conditions

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Abstract

More and more constructions have to be built in areas with extreme geological conditions. In the offshore areas, sometimes it is necessary to bank on thick and weak silt beds. Routes for the rapid traffic must be led in a straight line. For this reason it often cannot be avoided that constructions will cross areas with sinkholes.

New construction techniques in the underground engineering enable a rapid progress of construction and a short construction period. In this context the measurement engineering is asked for well-adapted measuring methods and a capable Software.

Therefore the engineering company Lhotzky + Partner developed the fully automatic *hydrostatic measurement of horizontal profiles method* to examine all kinds of surface and subsurface horizontal profiles and their variations in time. With an arbitrary high measuring point density, it is also possible to measure non-uniform regional settlements under extreme boundary conditions with a high accuracy. Special advantages of the method are the fast and simple pipe laying (DN20) and the utilisability even under extreme boundary conditions. The biggest advantages over the horizontal inclinometer are the durability against extreme deformations, the high measuring point density and the possibility to lay the test-pipe in alternating directions. Due to the consequential use of the latest data systems technology and permanently updated special software, it is possible to analyse and evaluate the data already on site. The possibilities of this new method will be shown at the example of the EADS-Extension Area "Mühlenberger Loch" (Hamburg, Germany).

For sinkhole area monitoring of geotextile secured traffic routes, another multifunctional hydrostatic measuring system based on the *hydrostatic measurement of horizontal profiles method* was developed. In addition to the automatic building control and a radio alarm status signal of sinkhole events, it is possible to measure the incurred settlements in a close measuring grid and display them three-dimensional. Also after the completion of the reconstruction, the hydrostatic sinkhole monitoring system remains fully operative. The effective and cost-saving method and its geotechnical possibilities will be exemplified by the sinkhole area monitoring of an embankment carried freeway section.

1 Horizontal Profiles Measurement (System Lhotzky) – Hydrostatic Settlement Measurement under Extreme Boundary Conditions

More and more constructions have to be built in areas with extreme geological boundary conditions. In the offshore areas, sometimes it is necessary to bank on thick and weak silt strata. Routes for rapid traffic must be led in a straight line and for this reason, sometimes it often cannot be avoided that constructions will cross areas with sinkholes. New construction techniques in the underground engineering enable a fast construction progress and a short construction time even under extreme geological boundary conditions.

In this context, well-adapted measuring methods that can measure the required subsoil measurement categories with a high temporal- and local resolution, are also demanded from the measurement engineering. Furthermore, a capable software is also required for a fast processing and representation of the measurement results.

Therefore, the engineering company Lhotzky + Partner developed the hydrostatic measurement of horizontal profiles, which enables the automatic measurement of the current elevation of profiles with an arbitrary interval and also along of the inaccessible measurement profiles, so that the non-uniform regional settlements can be measured with a high accuracy. Special advantages of the method are the fast and simple pipe laying (DN 20), as well as the utilisability even under extreme boundary conditions. The biggest advantages compared to the horizontal inclinometer are the durability against

extreme deformations, the high measuring point density, and the possibility to lay the test-pipe in alternating directions.

Through the consequential use of the modern data-technology and permanently updated special software, the measurements can be evaluated already on location and can be represented in practical form as graphics and tables. In shortest time, the measurement results can be made available on the internet by all decision makers of the construction project.



Figure 1-1: Mobile device of horizontal profiles measurement

For the safety of the DASA-Extension Area “Mühlenberger Loch“, an embankment enclosure from geotextile coated sand pillars (System Möbius) was built steady at the extreme settlement sensitive silt beds. Moreover several settlement measuring horizontal profiles with lengths up to 120 m were installed diagonally to the embankment axis on the geo-grid over the pillars heads for monitoring the settlement behaviour of the embankment fill.

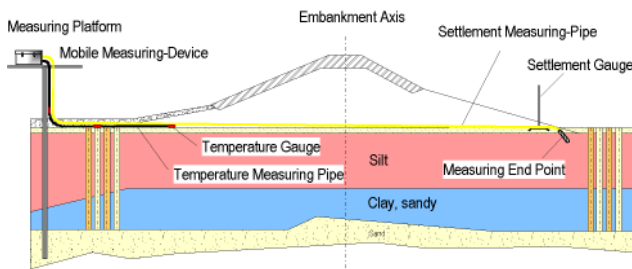


Figure 1-2: Typical measurement setup

The laying succeeded in a short-term open ditch on the sand that was closed again immediately after the laying of the measuring pipe. The second end point of the horizontal pipe (Turn-around point) was overwhelmed on the polder side. The installation and deinstallation of the measuring device succeeded at low water, whereas the measurements took place fully automatic at high water phase. The measurement results show that the high-precision settlement measurements can be conducted also under extreme boundary conditions.

2 Sinkhole Monitoring of Traffic Routes

An innovative possibility to the efficiency and cost-saving sinkhole monitoring of geotextile secured traffic routes is established by a new variant of the hydrostatic measurement of horizontal profiles.

The hydrostatic measuring horizontal profiles, which each of them has 4 measuring internal tubes, are mislaid parallel at intervals of 3 m at the base of the traffic embankment under the geotextile. Two adjoining measuring internal tubes filled with fluid are connected respectively on a differential pressure sensor. If a sinkhole event (e.g. $d \sim 4$ m) occurs, then a signal is registered at the sensor based on the deformation of the tube. Through an overlapping wiring of the sensors with the measuring internal tubes, the adjoining transducer indicates also a signal, but with reversed sign. In this case, a status signal of the event succeeds per radio alarm to the control center.

The multifunctional possibilities for the sinkhole monitoring are exemplary represented for a 600 m long freeway section. In addition to the automatic monitoring, the storage of the sensor data in a data logger and the status signal of sinkhole event per radio alarm, the incurred settlements can be measured by the hydrostatic measurement of horizontal profiles at the second tube pair of the measuring horizontal profiles with a close increment and displayed in three-dimensional. Additionally saving works can be monitored and the lift-

ings/heaves (e.g. by hydraulic injections) can be traced. Also after the completion of the reconstruction works, the hydrostatic sinkhole monitoring system remains fully operative through the deformation ability of the synthetic horizontal profiles. With only 12 measuring horizontal profiles, an area of 12.000 m² can be monitored efficiently and cost-saving.

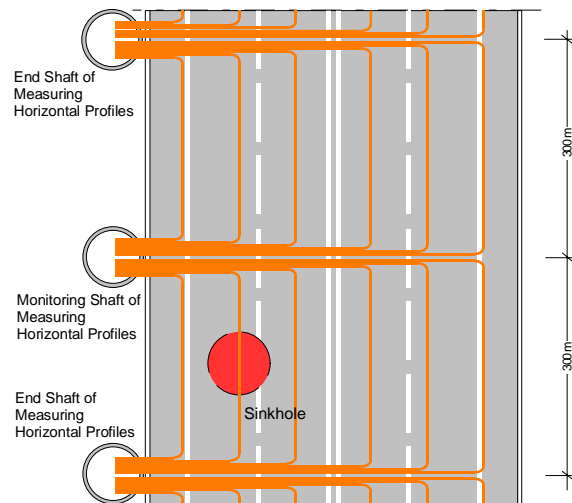


Figure 2-1: Exemplary measuring horizontal profiles setup of a sinkhole monitoring of a 600 m long freeway section

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