

The use of micropiles to reinforce old walls and stabilize steep slopes in Quedlinburg, Germany

Presented by Heinz Staudt

Sections:

Brief description of the current position

Why did we employ micropiles?

Case histories

- 1. Stabilisation of an old retaining wall (piles/anchor)**
- 2. Stabilisation of a facing wall / revetment**
- 3. Replacement of a failing wall**
- 4. Stabilisation of an excessively steep slope**

Concluding remarks

Brief description of the current position

The structures I am referring to today are all located in Quedlinburg.

For the benefit of delegates from overseas, Quedlinburg is located in a very central location within today's Germany on the north east side of the Harz region.



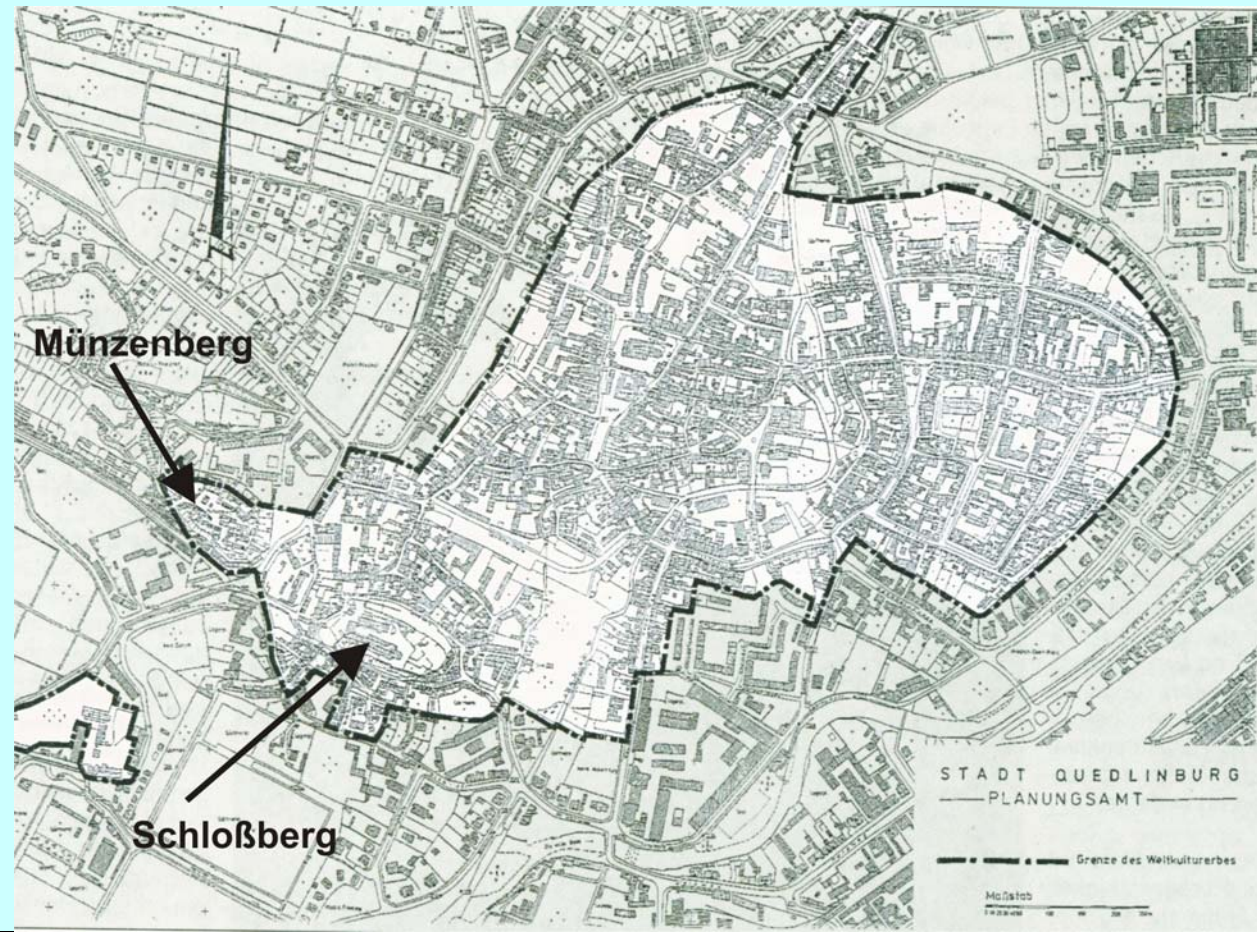


In an imperial document dating back to the 10th century, Quedlinburg is referred to as a metropolis of the empire.

King Heinrich I and his successors, the Saxon dynasty of the Ottonians, turned the town into a centre of German and European politics, education and culture.

There are still more than 1200 half-timbered houses of all styles and epochs, the Romanesque Collegiate Church (Stiftskirche) of St Servatius on the massive sandstone mound of Castle Hill (Schloßberg) and the Münzenberg where in former times an abbey was situated.

These were the main reasons why, in 1994, Quedlinburg became an Unesco World heritage site.

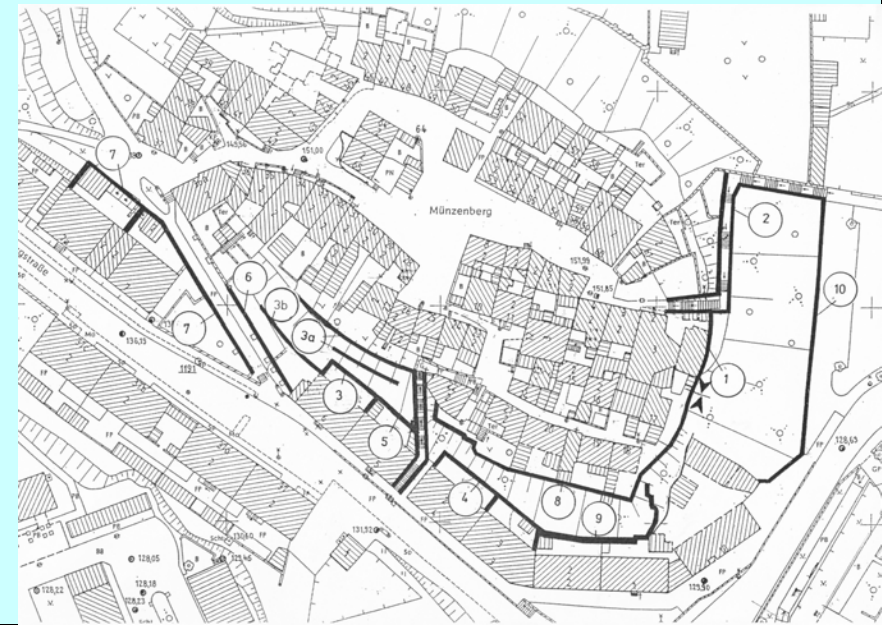


The structures referred to later in this presentation are all situated at the Castle Hill and the Münzenberg



Castle Hill

On both hills we have old supporting walls and steep slopes where the town's residents (during earlier centuries) dumped their household rubbish and building rubble, the so-called "cultural layer" ("Kulturschutt"), and also discharged their waste water.



Münzenberg



It goes without saying that in Germany any construction work in such an environment must be carried out in close co-operation with historical monuments protection agencies.

It was paramount, therefore, to ensure that everything was preserved as far as possible, and thereby contributing to the preservation of the town's unique character.

Building in such an environment means being considerate, considerate of the very restricted conditions, of the residents, of the very limited site setup area

Photograph of same location



and of the steepness of the slopes.



The deterioration and decay of the old walls was basically due to the following reasons:

- Load increase due to increased height of slopes / embankments or new / additional traffic loads.
- As the back of the walls was not waterproofed, surface water seeped or diffused through the wall section resulting in “flushing out“ or “washing out“ the binding agent, which in turn caused the internal bond of the walls to approach zero.



We have been engaged in Quedlinburg since 1993. At first in the form of survey and consultancy work, subsequently in connection with planning, design and technical project management and supervision.

The case histories presented here are all from the period 1997 to 2003.

The geologists provided us with the following data:

- both mounds consist of stratified sandstone, which is dipping to the south-west at approx.

25° - 35°.

- The layers have extremely varying degrees of binding agent, resulting in compressive strengths ranging from a slightly cemented sand to an extremely hard sandstone.

The sandstone is generally overlain by the “cultural layer“ (“Kulturschutt”).

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Why did we employ micropiles?

The deployment of micropiles was considered for the following reasons:

- One can bring them to the site in relatively short lengths and, if necessary, without mechanical means.
- They can be used as temporary and permanent solutions.
- Compression and tension members can be constructed from the same system and have the necessary building approval certificates.
- Any necessary design changes due to unforeseen circumstances can easily be accommodated.
- Subsequent tests are not required.

As the soils consultant was unable, in spite of extensive site investigation, to provide us with precise details of the highly variable elevations of individual sandstone layers, the use of micropiles was almost imperative. This meant that, although we were able to determine anchor lengths during the planning and design stage, the actual lengths had to be verified and changed as a result of checks being performed continuously throughout the drilling operations. In this context, the relatively simple and cost-effective lengthening of micropiles with the use of couplers was a definite advantage.

The micropiles used consisted of GEWI monobar piles (and anchors) with diameters ranging from 32 to 63.5 mm.

The boreholes had a diameter of 140 mm and were drilled through the overburden material as fully cased boreholes with the use of a continuous flight auger.

A down-the-hole hammer was used in the sandstone.

All micropiles were grouted.

It goes without saying that we carried out static load tests (in both tension and compression) on each site in advance of the main works.



Static load tests

Tension + compression



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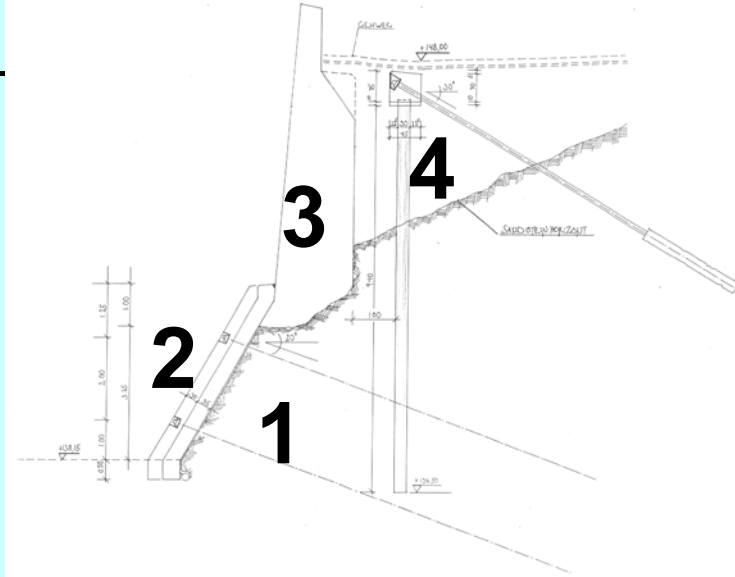
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We adopted the following working sequence:

- 1 Injection of binder in the sandstone.
- 2 Stabilisation of the base of the wall. To that end we used prestressed anchors (the only time at the Münzenberg) because of the limitations on deformation.
- 3 Strengthening of the brick wall (grouting, dowelling).
- 4 Installation of a piled wall with micropile tie-back anchors.



2. Stabilisation of a facing wall

1 The original brick facing wall (rear part of cross-section) initially extended a little above the original ground level (as facing wall).

2 Over the years, the terrain was gradually built up with the "cultural layer" ("Kulturschutt").

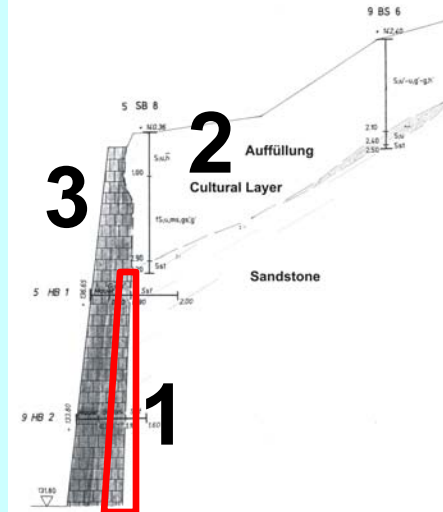
3 One has increased the height of the initial facing wall and then constructed a further facing wall (with bricks) in front of the existing wall with its extension.



Aspect from above



Front view



Site investigation

This enlarged cross-section of the wall was, however, totally unable to carry the earth pressure resulting from the fill.

On the basis of the available results of the soil investigation, the entire bank had become unstable.

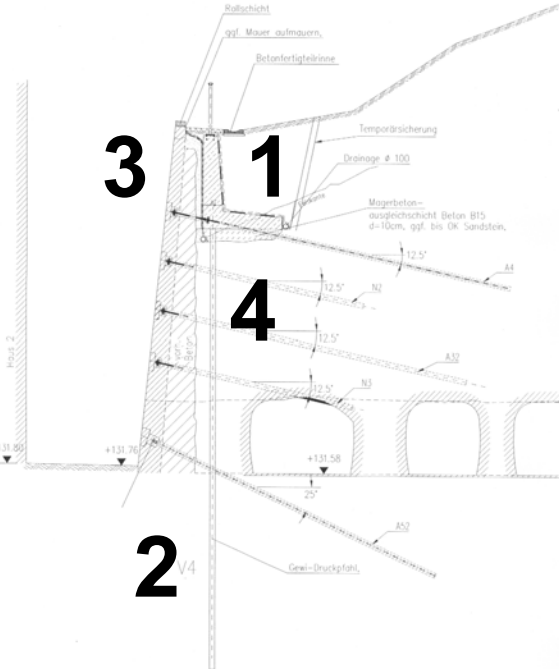
Between the back of the wall and the sandstone, water flowing down on top of the "hard" sandstone layers had washed out or cut out large cavities.

The external appearance of the brick wall had to be preserved .

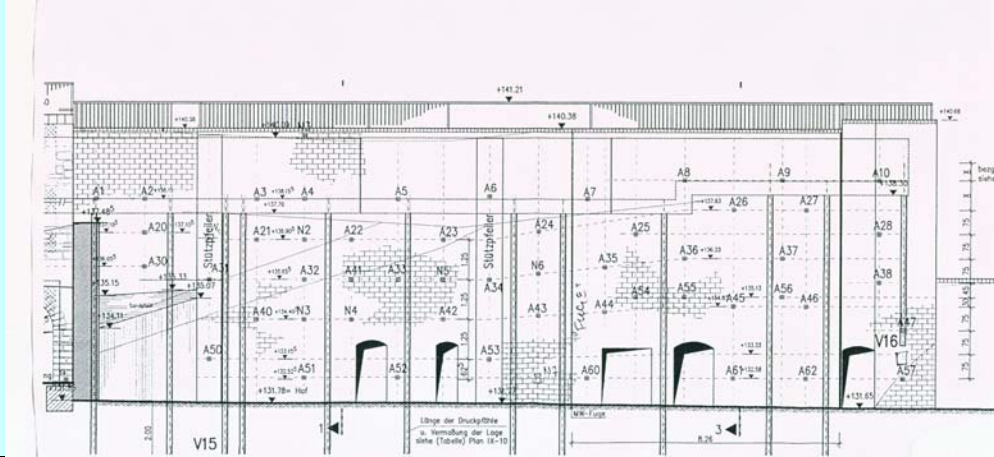


We adopted the following working sequence:

- 1 Construction of an excavation pit to top of "bedrock" at the top of the wall under the protection of a tied-back cover of shotcrete.
- 2 Installation of compression piles to carry the vertical loads from a concrete cantilever wall (as the sandstone was unable to sustain the foundation pressure applied at the front edge of the cantilever wall).
- 3 Installation of the top anchors to carry the horizontal loads from the concrete cantilever wall.
- 4 Construction of the cantilever, followed by backfilling
- 5 Stabilisation of the bank and wall with micropiles as tendons. The micropile heads were fitted with concrete pads to facilitate load distribution. These were faces with bricks.



Temporary retention system, Pile drill, vertical
 Vertical GEWI pile test



Former owners of the hillside had dug out caves as a substitute for cellars, the precise dimensions of which were not known. As a result, caves were drilled into, which had to be taken into account in the anchor design.

We bricked the caves up and bulk-filled them with grout.

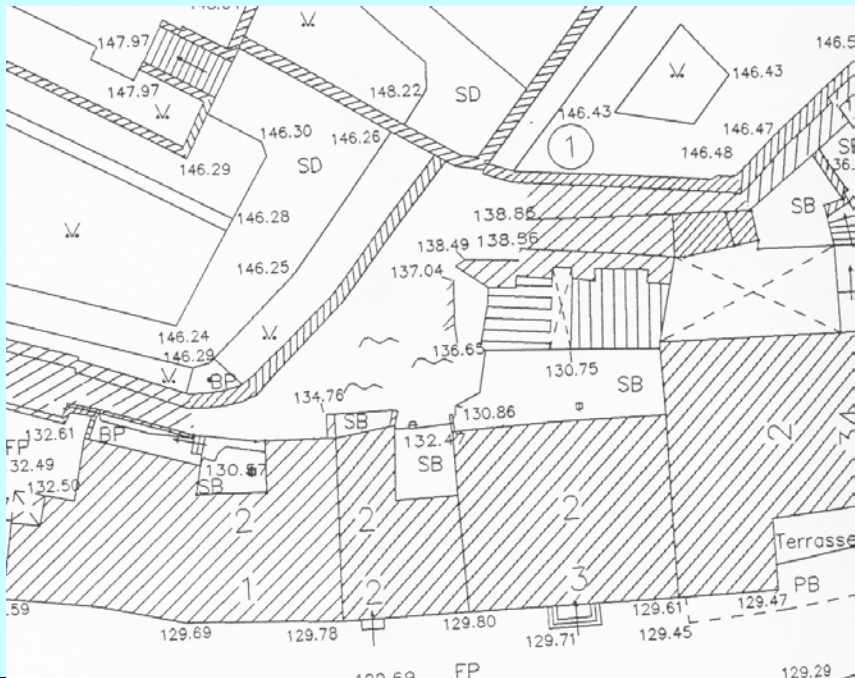


General view of the strengthened wall



3.Replacement of a failing wall

At the eastern end of the Castle Hill we encountered another problem.



This roughly 9.6 m high wall stepped at 7.7 m had developed a very severe bulge which had been hidden for many years behind the houses along this stretch of the road.

In addition, the sandstone blocks of the outer wall were very severely damaged.

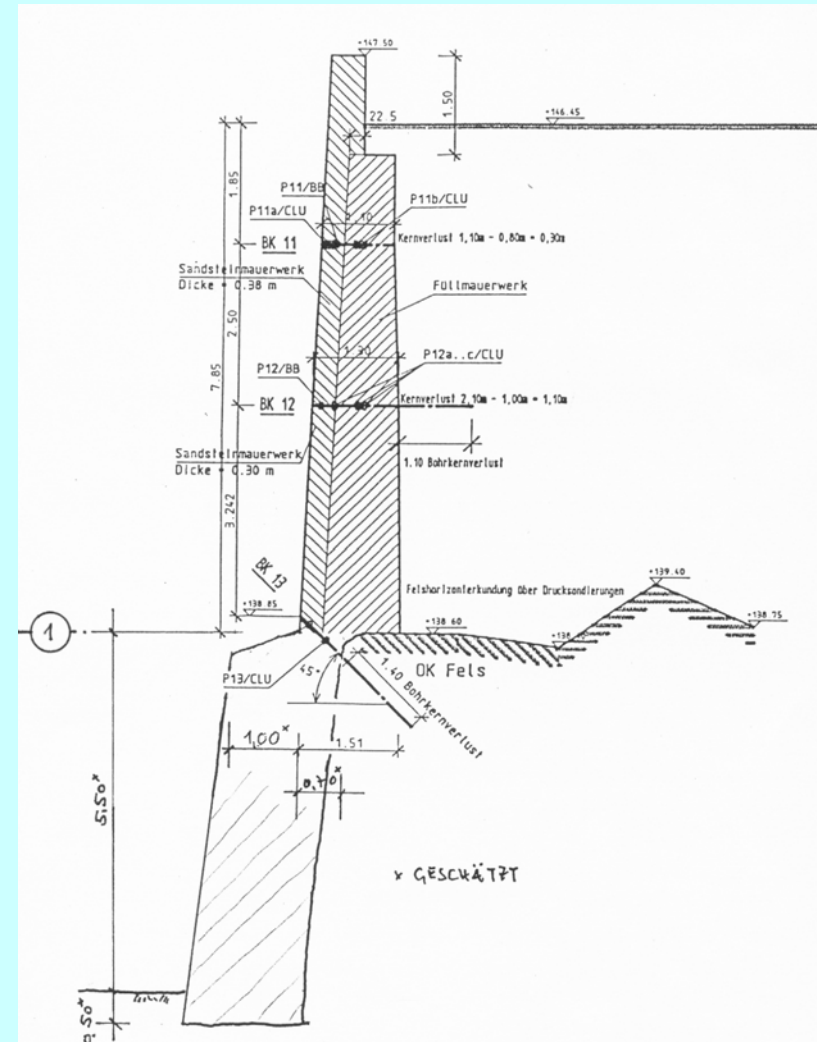


We were provided with the following soil investigation data based on both horizontal and vertical boreholes:

It is self-evident, that an adequate stability could not be verified for this wall.

However, walls like this can collapse suddenly without warning – at least that is what I have already experienced.

Nevertheless, we were unable to imagine that this cross-section could have survived so many decades and we were sure that something had to assist the wall to survive.





During the process of dismantling the wall we discovered (as a partial explanation for the stability of the old wall) a Baroque wall and the apsis of the oldest chapel of Quedlinburg. Neither of them had been recorded in any of the documents.



This example also shows how important it is to work with material (in this case micropiles) that can be adapted quickly to changing circumstances.



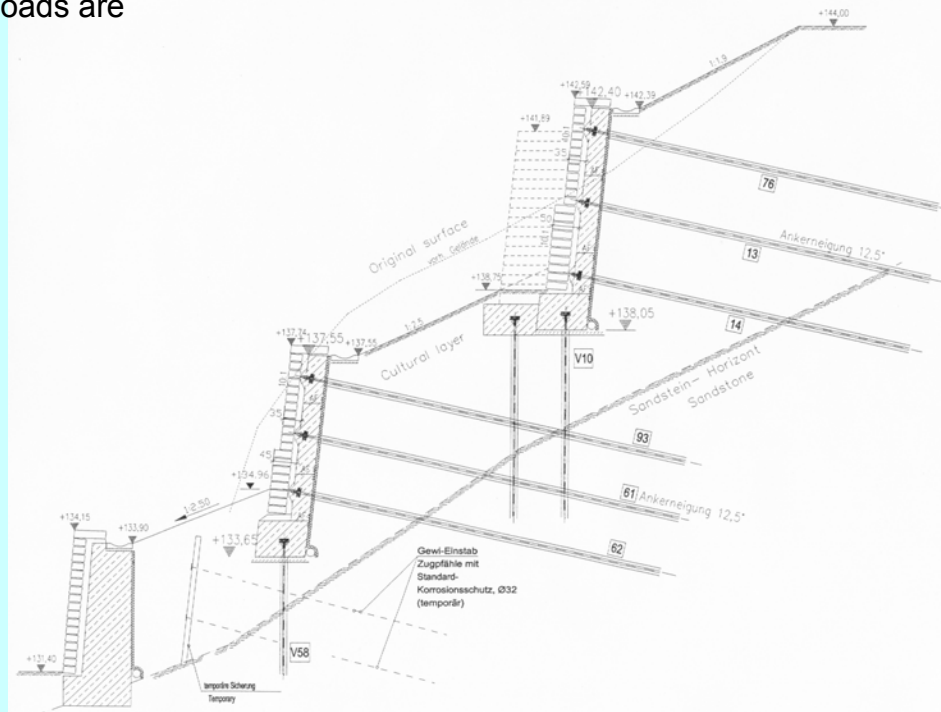
4. Stabilisation of an excessively steep slope

Various slopes have been built up over many decades with the "cultural layer" ("Kulturschutt") and building rubble to such an extent, that they have become ultra critical.

In some isolated cases this has already resulted in retaining structure and slope stability failures.

We have improved these slopes by a phased construction of wall panels built into the slope similar to the soil nailing technique. The wall panels are tied back with tension anchors, the vertical loads are either carried directly by the sandstone or transferred to compression piles.

Here one example





Installation of anchors from a light scaffolding platform



Anchor in the slope



Installation of strips of drainage blanket and a thin layer of shotcrete to secure the partially cut away soil.





Installation of reinforcement and anchor heads

Spraying of wall



Anchor head detail



Wall sections from above



Front view of completed fully faced wall section



On the 2nd of December 2005 we were then able to hand the completed structures of the Münzenberg back to the town of Quedlinburg in the presence of Minister Dähre.



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Micropiles are structural members that can be used in many different ways and for many different reasons in the restoration and redevelopment of old retaining walls and steep slopes.

The case histories presented above can only provide an extract of the numerous and different possibilities.

I hope, however, I have succeeded in demonstrating that micropiles are a valuable tool in restoration work.

Thank you for your attention!

Heinz Staudt