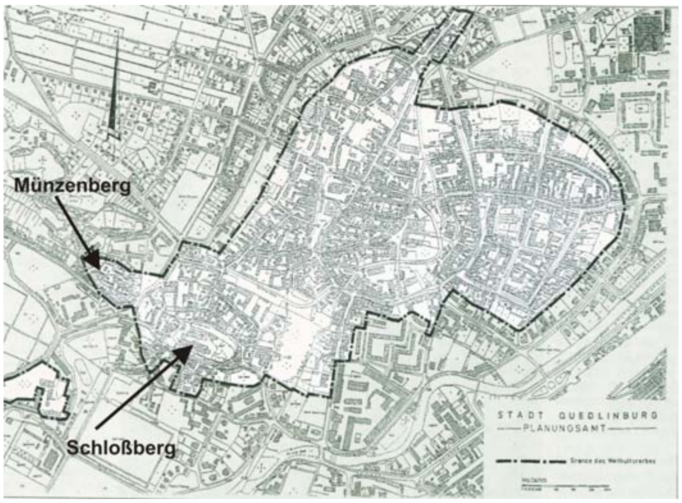
Schrobenhausen 2006

The use of micopiles to strengthen old walls and stabilise steep slopes in Quedlinburg, Germany

Brief description of the current position

Quedlinburg – town of UNESCO World Cultural Heritage with around 1200 halftimbered houses of all styles and epochs, with the Romanesque Collegiate Church (Stiftskirche) of St Servatius on the massive sandstone mound of Castle Hill (Schloßberg) and the Münzenberg above the town. On both hills we have old supporting walls and steep slopes where the town's inhabitants (during earlier centuries) dumped their houshold rubbish and building rubble, the so-called "cultural layer" ("Kulturschutt"), and also discharged their waste water.



World Cultural Heritage area

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, therefore, paramount 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 and of the steepness of the slopes.



Photograph of same location (Axis 9) *Steep slop*

The deterioration / 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 isolated, surface water seeped / diffused through the wall section resulting in “flushing out“ / “washing out“ of the binding agent, which in turn caused the internal bond of the walls to approach zero.


(photograph of deteriorated / decayed wall)

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 supervision.

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

The geologist 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").

Why did we employ micropiles?

The deployment of micropiles was considered for the following reasons:
- You 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 certificate.
- Any necessary design changes due to unforeseen circumstances can easily be accommodated.
- Subsequent tests are not required.

As the soils consultant was unable, inspite 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 continuously ongoing checks being carried out during drilling. 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.

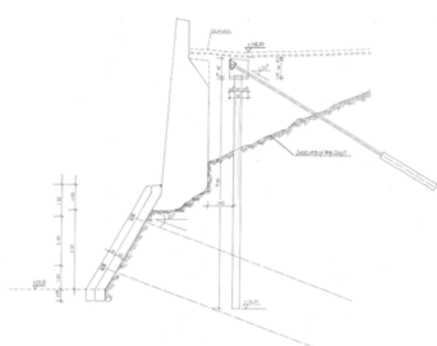
It goes without saying that we carried out static load tests (tension and compression) on each site in advance of the main works.


Static load test

Case histories

1. Stabilisation of an old retaining wall (piles/anchor)

This roughly 6.0 m high wall stands about 3.50 m above datum on the dipping layers of the sandstone formation.


Cross-section


Old situation

The joints of the wall contained only very small amounts of binding agent.
The sandstone beneath the foot or base of the wall was also leached or washed out and, therefore, quite weakened.

The retained road surface behind the wall was now used by heavy goods vehicles which didn’t even exist at the time the wall was built.
We adopted the following working sequence:
- Stabilisation of the foot / base of the wall. To that end we used prestressed anchors (the only time at the Münzenberg) because of the limitations on deformation.
- Injection of binder in the sandstone.
- Strengthening of the brick wall (grouting, dowelling).
- Installation of a piled wall with micropile tie-back anchors.
- Excavation of the space between the old brick wall and the newly installed piled wall.
- Waterproofing back of old wall and installation of drainage system.
- Backfilling space between walls, whereby the lower section was backfilled with single-sized aggregate concrete to such a level that enabled the brick wall to resist the silo wall pressure resulting from the soil backfill.

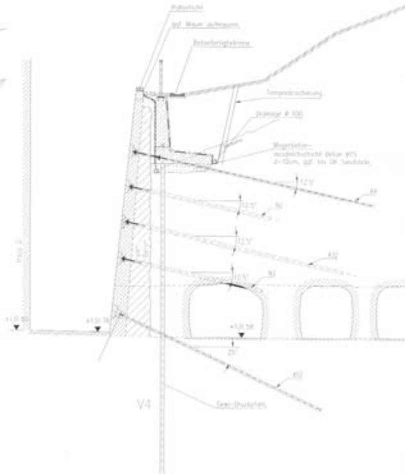

General view after finish

2. Stabilisation of a facing wall / revetment

The original brick facing wall / revetment (rear part of cross-section) initially extended a little above the original ground level. (Section see earlier)
Over the years, the terrain was gradually built up with the “cultural layer“ (“Kulturschutt“).
One has increased the height of the initial facing wall and then constructed a further facing wall (with brickstones) in front of the existing wall with its extension.
This increased 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 that flowed down on top of the "hard" sandstone layers had washed out / cut out large cavities.
The external appearance of the brick wall had to be preserved.

We adopted the following working sequence:
- 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.
- 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).
- Construction of the cantilever, followed by backfilling.
- 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.

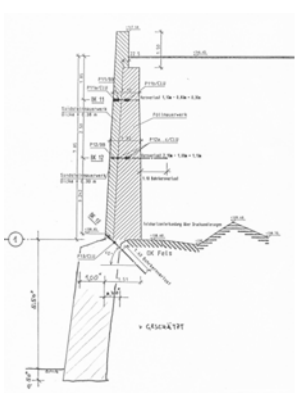


Site investigation *Design* *View after finish*

3. Replacement of a failing wall

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.

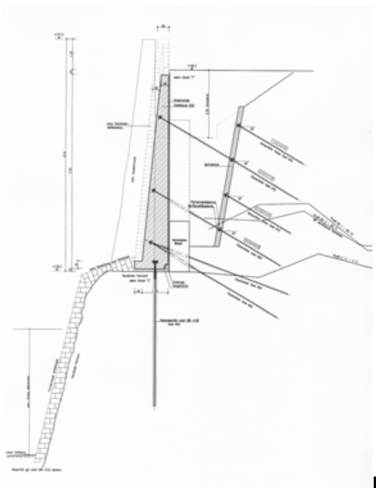
In addition, the sandstone blocks of the outer wall were very severely damaged.
We were provided with the following soil investigation data based on both horizontal and vertical boreholes:



Cross section

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 are 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.

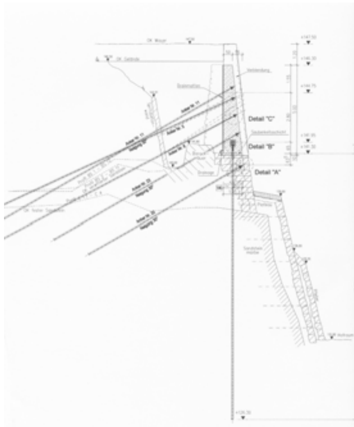
Due to the poor overall state of the brickwork we decided to dismantle the wall under the protection of a tied-back shotecrete cover.
The design envisaged a reinforced concrete retaining wall with sandstone block facing founded on compression piles and tied back by tension piles.


First design

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.


View on apsis

Neither of them had been recorded in any of the documents.
The consequence was a redesign with the following result:



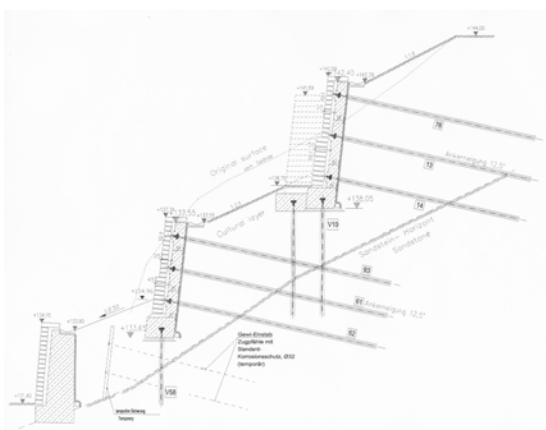
(Smaller replacement structure, longer piles, considerably longer anchors)

(Cross section)

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 over many decades been built up with the “cultural layer“ ("Kulturschutt") and building rubble to such an extent, that they have become ultracritical. In some isolated cases this has already resulted in retaining structure and slope stability failures.



Cross section

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 onto compression piles.

Anchor drilling

Anchors in slope

Wall panels from above

Finished construction

Concluding remarks

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.

Heinz Staudt