MICROPILES -SUSTAINABLE AND RESILIENT

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ABSTRACT

Two terms - at least in Europe present in every discussion and every day. What do they mean? What does it mean for foundation engineering? Can we assume, that Micropiles fulfil the criteria to be called sustainable and resilient?

Analysing the design, material, execution – from theory to practice – it will be discussed and shown in exemplary projects, that this is not a question but is fact.

Micropiles are sustainable and resilient!

1. SUSTAINABILITY AND RESILIENCE

In June 1992 – almost 20 years ago - the United Nations Conference on Environment and Development took place in Rio de Janeiro and in the "Agenda 21" of the Rio Summit the aims were declared for the implementation of a sustainable development. The term "sustainable development" was first proposed by the World Commission on Environment and Development (WCED) in its 1987 re-port Our Common Future (also known as the Brundtland Commission report). WCED, which included 23 members from 22 countries, was formed by the United Nations in 1984, and for three years studied the conflicts between growing global environmental problems and the needs of less-developed nations.

WCED's widely used definition of sustainable development is:

"Meeting the needs of the present without compromising the ability of future generations to meet their own needs."

Since 1987, there have been many efforts to explain and amplify what is meant by sustainable development.

In general, for an engineer, a sustainable system is the one that is either in equilibrium, or changes slowly at a tolerable rate. This concept of sustainability is best illustrated by natural ecosystems, which consist of nearly closed loops that change slowly. For example, in the food cycle of plants and animals, plants grow in the presence of sunlight, moisture and nutrients and are then consumed by insects and herbivores which, in turn, are eaten by successively larger animals. The resulting natural waste products replenish the nutrients, which allows plants to grow and the cycle to begin again.

Sustainability has often been defined as how biological systems endure and remain diverse and productive. But, the 21st-century definition of sustainability goes far beyond these narrow parameters. Today, it refers to the need to develop the sustainable models necessary for both the human race and planet Earth to survive.

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- The concept continues to expand in scope. In 2000, the Earth Charter broadened the definition of sustainability to include the idea of a global society "founded on respect for nature, universal human rights, economic justice, and a culture of peace." Old models of consumption and industrialization will not support the world's growing population. If humans wish to have the water, materials and natural resources needed to thrive, a new approach to living is called for. It's no secret that economic growth and energy have come at the cost of environmental degradation. In answer to this challenge, sustainability experts are looking at ways in which we can slow or prevent pollution, conserve natural resources and protect remaining environments.
- A sustainable society is founded on equal access to health care, nutrition, clean water, shelter, education, energy, economic opportunities and employment. In this ideal society, humans live in harmony with their natural environment, conserving resources not only for their own generation, but also for their children's children. Each citizen enjoys a high quality of life and there is social justice for all.
- Businesses are facing a new paradigm. They're being asked to create long-term practices that do more to respect the environment, the well-being of employees and the prospects of future generations. Meanwhile, these same businesses are also expected to improve profitability, fund innovation and increase market share for current stakeholders.
- Amid all the gloom surrounding the future, the promise of science shines brightly. Optimists hope that new technologies and urban infrastructures, built with environmentally sound practices, can support a sustainable, healthy and happy population.

But what does it mean to technology in general and geotechnical engineering in particular?

Resilience is often used and seems to have several differing meanings depending on topics.

Ecological Resilience is the capacity of an ecosystem to recover from perturbations

- Climate resilience - the ability of systems to recover from climate change.
- Soil resistance - the ability of soil to maintain a healthy stat in response to destabilising influences.

Resilience in social sciences

- Resilience – the ability of a system to withstand changes in its environment and remain functional.
- Psychological resistance – an individual's ability to adapt in the face of adverse conditions.

Resilience in technology and engineering

- resilience in material science - the ability of a material to absorb energy when deformed, and release that energy upon unloading
- resilience in engineering and construction - the ability of buildings, parts of buildings and infrastructure to absorb assaults without suffering complete failure.

So, which issues are important for us as engineers when we try to assign these definitions to Micropiles?

2. DESIGN AND MATERIAL, EXECUTION

Assigning the above quoted definition sustainability can mean to give attention to the ecologic and economic effects when starting a design process. That means reduction of resource consumption during production, erection and maintenance and even recycling – e.g. for foundations, deep foundation systems instead of large shallow concrete foundations. It also means to use soil as part of the load-bearing system instead of replacing it. It also means to design for a longer lifespan period of the built construction. Long-lasting materials lead to enhancement of life-span and reduction of maintenance and renewing costs. It also means avoiding hard to separate composites as well as simple recycling without a lot of nonrecyclable waste. As most of the running cost of a building are for energy consumption – electricity, heating and cooling – a demand for intelligent products is evitable.

In order to assess sustainability, the carbon footprint is used today, among other things. The carbon footprint is historically defined as the total emissions caused by an individual, event, organization, or product, action, expressed as carbon dioxide equivalent. In most cases, the total carbon footprint cannot be exactly calculated because of inadequate knowledge of and data about the complex interactions between contributing processes, including the influence of natural processes that store or release carbon dioxide. For this reason, *Wright, Kemp, and Williams*, have suggested to define the carbon footprint as:

A measure of the total amount of carbon dioxide and methane emissions of a defined population, system or activity, considering all relevant sources, sinks and storage within the spatial and temporal boundary of the population, system or activity of interest. Calculated as carbon dioxide equivalent using the relevant 100-year global warming potential = GWP100. To reduce the carbon footprint optimization of design is one of the main issues to meet sustainability.

Obeyance of the demands of sustainability leads us further to resilience – as buildings life span should be enhanced it is important to look for a design that provides the ability to withstand or absorb assaults without complete failure. This can be achieved by use of material, that can absorb energy when deformed and release that energy upon unloading or remain viable.

When we widen our focus on the erection process, we find out that the use of lightweight machinery contributes to the reduction of resources – not only energy consumption, but also resource reduction in the fabrication of that machinery used in the erection process of Micropiles.

3. EXAMPLES OF SUSTAINABILITY AND RESILIENCE USING MICROPILES

Some examples will how Micropiles can tribute to the demands of sustainability and resilience.

4.1 Ropeway tower foundation

Ropeway towers are usually erected with a shallow gravity foundation. As ropeway systems get bigger and loads increase foundations grow not only linear to the weight of the gondolas.

According to foundation design of the ropeway company a gravity foundation 8 m deep, 6 m wide and 1,2 m thick with a base of 1,8*1,8 m 3 m high should be the foundation for the tower shown in the picture. As the slope had an angle of inclination of nearly 38 degrees the pit would have been to be secured by pit lining and a problem of excavation deposit – more than 380 m³ of soil - would have occurred, despite of concrete transport to the tower sites. The design was changed to a split combined-micropile-slab foundation reducing the concrete volume of the foundation to 20% of the original volume adding 6 Micropiles GEWI 50 6-8 m long to each foundation.

Concerning sustainability, the carbon footprint of concrete used was reduced to 20%, the carbon footprint of earthworks was also reduced by 60%.

As the deep foundation with Micropiles added to the slope stability as well the client got a resilient foundation, the cost of which could also be reduced in total by 60% paying for the design 10% of the cost for the tower foundation.

Figure 1 – Ropeway tower 35 m high in steep terrain

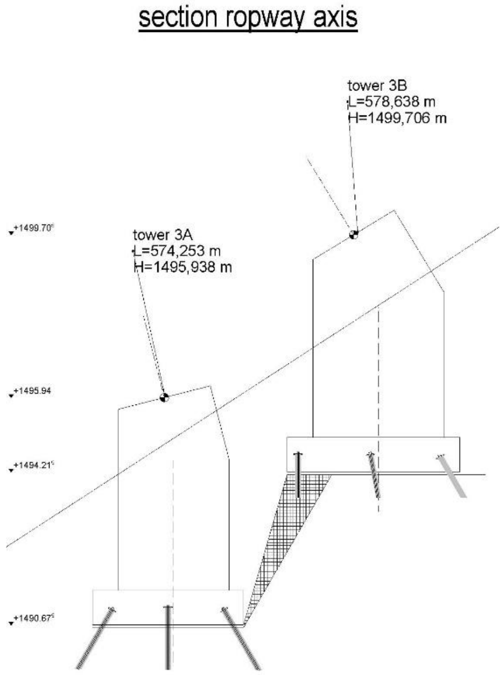

Figure 2 – section of micropile-slab-foundation

4.2 Pile foundation and slope Stabilization

In 1990 a difficult foundation of a ropeway station was erected on a steep slope in a famous Austrian ski resort. Vertical column loads of more than 4500 kN, avalanche loads in horizontal direction of about 10 kPa and information of supposed creeping – although no survey proved this – were a big challenge. Within 3 weeks nearly 2300 m of Micropiles GEWI 50 at single lengths of up to 15 m were drilled. Results of several pile testing led to a working load of 550 kN per pile. After finishing the project survey proved that the structure was stable, and no movements could be identified. With the micropile foundations of the columns and the rest of the building big shallow gravity foundations could be avoided. Due to lacking data, the creeping of the slope was not detected at that time, but the decision for the Micropiles was a step to sustainability, although this was not an issue at that time.

10 years later after a winter with lots of snow and heavy rain during the melting period, water caused a shallow slope slide adjacent to the foundation of the building. Permanent survey showed that the slope was creeping since then at a speed of approximately 30 mm per year. As the movement of the structure was parallel to the ropeway axis this caused no technical problems.

Another seven years passed, and flooding rain caused severe slope slide reaching from 100 m down the building, where a torrent washed its banks leading to this slide. A permanent survey of the slope and level control in the building was installed and reviewed daily. Due to low temperatures and lack of water in the ground creeping velocity decreased during winter to 5 mm per week. Starting spring movements increased again to 10 mm/week. Beginning of July 2007 - after snow has gone - stabilization works started. Due to inaccessible and steep terrain a solution using Micropiles was chosen, in order to reach each installation point. Project consisted of two main items – securing bank line of the torrent and stabilizing the slope by using micropile walls and drainage systems to extract water from the ground.

Drilling cores from time of erection of the station in 1990 showed rock surface – grey schist - in a depth of 5-7 m below surface as well as water on that level. Soil was a moraine – silty clay with stones up to 500 mm dia. – due to slipping loose packed.
Starting with stability analysis soil parameters were varied till safety proved to be around 1,00. Based on that stabilizing measures and drainage systems were induced to lift stability to at least 1,40. This led to the final solution using 5 micropile walls – GEWI 50 – head connected with a concrete slab, drainage system and gulley to bring surface water down to the torrent including bank line stabilisation and river bed stabilization.

Figure 3 - site view from top of station down to the torrent

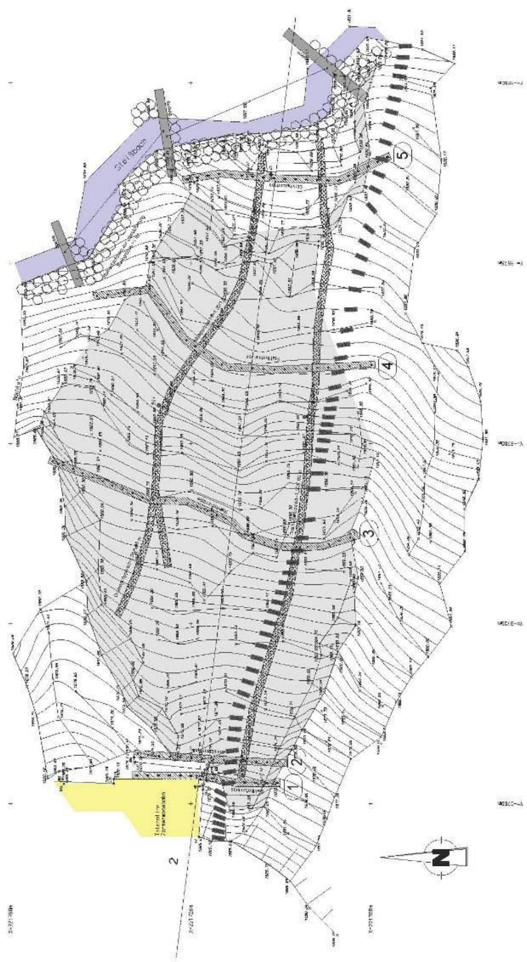

Figure 4 - top view of site – 5 MP-walls, drainage and gulley

Hollow bar MAI R51-800 single length 15 m were used to reduce drilling time. After site installation and preparing access for drilling equipment more than 5000 m of Micropiles were drilled within a period of 2,5 months. Concrete slabs on top were finished by end of October, when works had to be stopped due to early winter on site.

As we were aware, that creeping would not stop immediately to the securing measures, we looked for a solution, which allowed some deformation of the piles but still providing the necessary bearing capacity. Instead of prestressed anchors, which were an alternative possibility to stabilize the slope, we chose the micropile solution, which was more resilient due to mild behaviour of the steel used. With the anchor creeping leads to an increase of stresses in the anchors, which have to be released from time to time. Handling the anchors brings the possibility of damaging of the corrosion protection at the anchor head, making this solution a critical one. Mild steel quality of Micropiles is far less dangerous and therefore more sustainable and resilient.

The continuing of the survey after completion of securing works showed a permanent reduction of creeping speed to the value before the second event.

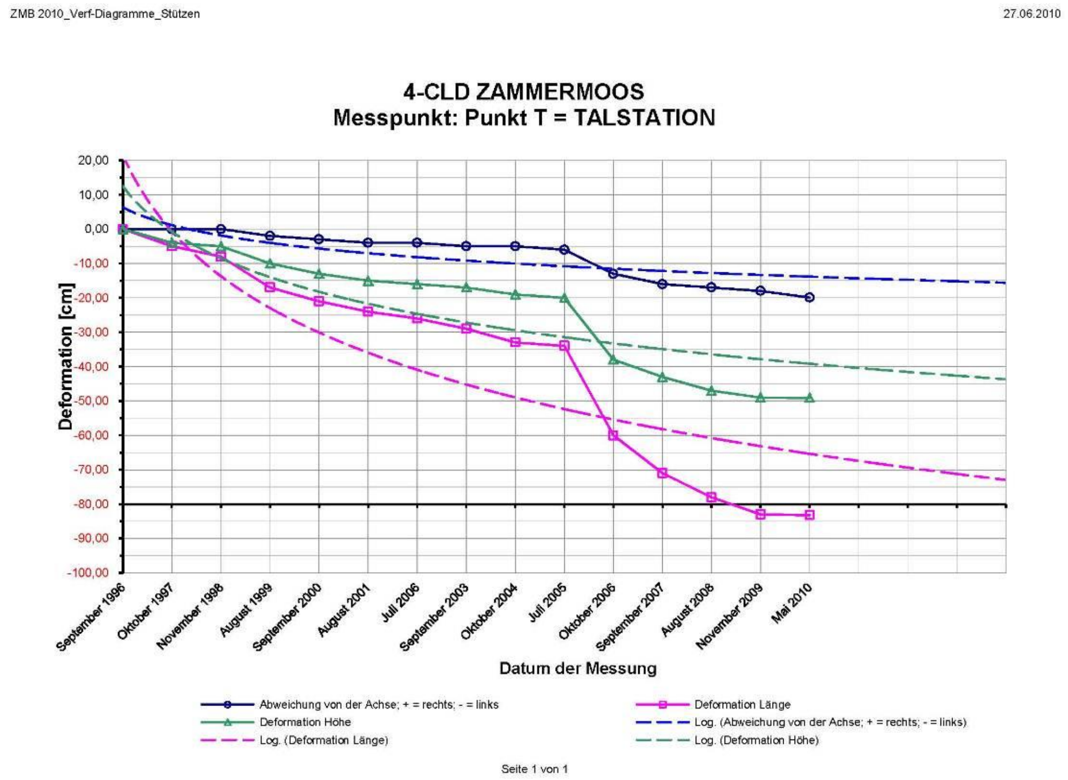

Figure 5 - decrease of creeping velocity to a value < before flooding

The metered movements could be reduced to an acceptable value with this sustainable and resilient solution.

4. SUMMARY

The two examples show clearly that with the use of Micropiles we can design sustainable foundations, reducing the carbon footprint of foundations. If the development of Micropiles does not lead to higher steel qualities, which show a less mild behavior, Micropiles lead to resilient solutions under all kinds of loading – creeping, impact loading, earthquakes.

Looking back to the origin of Micropiles as we know them today, Fernando Lizzy was a pioneer and probably without knowing he followed the rules of sustainability and resilience – he invented a resource saving way of foundation and stabilization in soil, which is robust and long-lasting.

Micropiles are sustainable and resilient! - That is a fact.

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