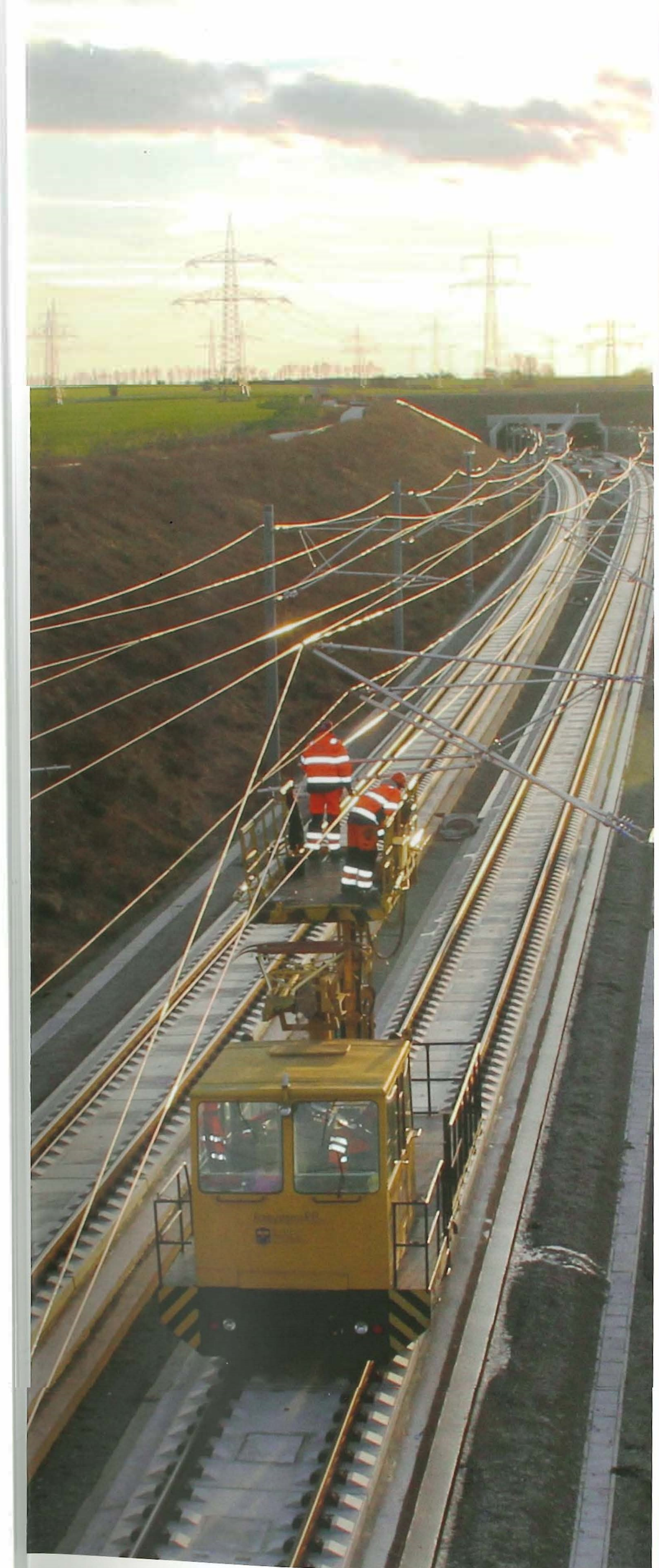

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Sustainable foundations without concrete

Ground screws as a modern option for low-emission and dismantle-able foundations - a description of the applications in the KIB

Graphic 1: ground screws *Source: T. Molter*

TRISTAN MOLTER | IAN KRUKOW | JOHANNES DILLIG

Foundations so far are known almost exclusively as concrete. Ground screws, however, are rising in importance by the day because they are so much quicker to install. They are also easy to uninstall without any problems which makes them quite sustainable. As of right now, ground screws are used for dynamic loads, such as noise barriers.

The beginnings

Foundations have been known to be made from concrete traditionally. No matter if its a small shed or a big house everyone thinks of strip footings or surface foundations made out of concrete. In the past years there has been an uprising of alternatives in fortifications and footings (e.g. garden sheds). Those footings have a steel shell with sheet metal welded onto because of which the shell can drilled into the ground flawlessly. This system is quite similar to drywall screws which also has a kind of shell, as shown in Graphic 1. This construction has been developed step-by-step. The core principle originated a thousand years ago called "pile foundation" and has been developed to the point to which ground screws have become a safe solution for foundations. They can withstand heavy loads as much as traditional concrete foundations could.

Another benefit of ground screws is that no digging is necessary and by extension no transport of spoil is required. (Un-)Installation does not require any form of Terra-forming. For those reasons ground screws are very eco-friendly and sustainable. And despite all that, the installation time is also much shorter compared to traditional foundations. It can even be as short as several minutes.

Ground screws role in *Deutsche Bahn*'s constructive engineering

Deutsche Bahn AG (DB) wanted to take advantage of the benefits of ground screws as well. But for that to happen an admission by the Federal Train Authority (EBA) is need. First efforts have been made to get an admission for static purposes with the intention to implement the ground screws in projects of constructive engineering (KIB) such as train platforms or railings. Those efforts have been initiated by a company called CTS Composite Technologie System GmbH in Geesthacht because they intended to install their products easier and faster. After passing all the tests with flying colors EBA gave out an admission for field-tests. From that point forward a number of project were able to be finished successfully (Graphic 2 and 3).

The further development to dynamic load transfers

The experience with purely statically loaded ground screws lead to dynamic loadings as the self-explanatory next step. In order to deliver proof of the dynamic load transfer capabilities of ground screws, exceptions and assumptions were necessary. To measure the ground screws a standard case of inner city noise barriers was chosen. This covers a vast majority of fields in which the usage of ground screws is applied. As noise protecting element a mix of aluminum cassettes and concrete was used. The standard case and test is taken with current technology. In the beginning the ground screws are treated like a pile driver pipe. To which extend this procedure is accurate remains to be seen until planned tests for train plateaus have taken place in the future. In order for construction companies to remain familiar and comfortable with ground screws without getting used to them first, thoughts went into coming up similarities between ground screws and noise barrier posts. Those posts are usually placed into pile driver pipe with the help of concrete. During the development of ground screws for noise barriers, the top part of the ground screws has been designed like a pile driver pipe so that the conventional method mentioned can still be applied. Alternatively, a second variant has been developed which envisages an adapter that can easily be screwed onto the noise barrier posts.

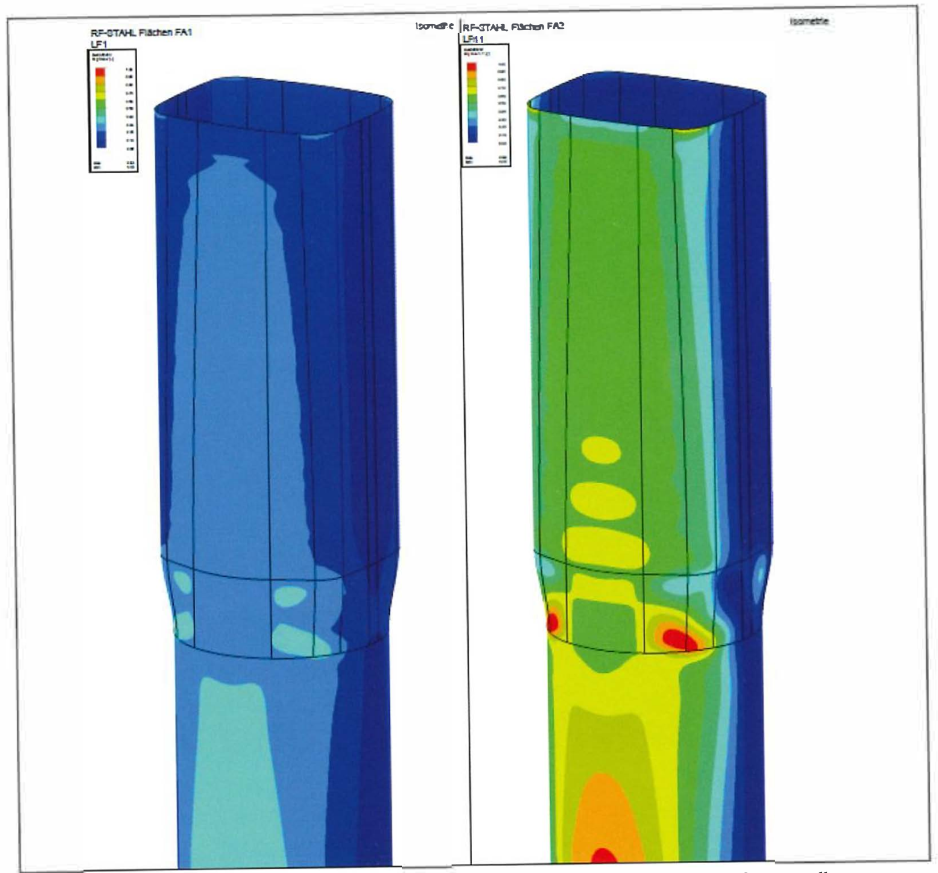
Graphic 2: embankment stairs resting on ground screws *Source: CTS*

The diameter of the ground screw is smaller than the usual pile driver pipe. To make sure that a high enough margin for the positioning of the post inside of the pipe is provided, the head area of the ground screw is approximating into a rectangular cross section. This leads to a transition from a circular to a rectangular cross section with spikes that will prove crucial for measuring processes.

A three-dimensional CAD-model of the ngnc-head is transitioned to a area-model with finite elements that provides the tensions necessary. As a result of trains passing by, pressure-suction-waves with a high amount of load changes are created. Those are taken into account as quasi-statical loads at the limit state of loading capacity. Additionally, proof of the longevity are required to rule out long-term failure of the constructions. Graphic 4 shows the distribution of tension spikes for both cases with which the capacity limit of the transformed pipe can be determined.

As an alternative to clamping the post inrm the pile driver ngnc* a screw terminal with a base is provided. The design is carried out through a standard procedure. A cleat is taking care of the thrust transmission which will also be put into concrete. Nevertheless, the total amount of concrete used is significantly lower compared to the first method because only the cleat will be clamped and not the entire post. Additionally, the work hardening of the pipe will not be necessary for the process due to accurate positioning made possible by slotted holes in the base. However, because the base has to be screwed on the outside of the pipes diameter, it is quite large. That's why additional rips are

Graphic 3: platform system and temporary train platform *Source: CTS*



Graphic 4: FEM-Model of the ground screws' adapter *Source: Dillig Ingenieure*

mandatory in order to be able to take the bending momentum.
To test the theory out in practice, ground screws have been tested on a railway and proving grounds with matching soils. Table 1 shows the concept of the experiment. At the railway in Laufach tests have been made with trains as well as proof loads for pressure and horizontal stress (Graphic 5). At the proving grounds, cyclic tests alongside statically combined proof loads (traction and pressure) have been taken on different soils.

Construction noise and vibrations

The construction of noise barrier posts at railway facilities is so far done through rammed tubular steel posts. These are installed with the help of high-frequency vibrating pile drivers mounted onto an excavator. This results in a lot of noise and vibrations for the residents leading to a lower acceptance by them. That could become the cause of delays when trying to realize a project due to construction freezes.
During the test installation of the ground screws (Graphic 5) sound levels as well as vibration levels have been measured and compared to rammed tubular steel posts.
The temporary results show that the installation of a ground screw is significantly more quiet than the ramming of a steel post. The created sound level during the installation of a ground screw is around 9 dB(A) lower than the steel post rammed into the same location. A realistic combination of excavators with equipment and mounted tools needed for each method have been used during the test. The test installation took place in non-cohesive soils. A temporary comparison of the two sound levels in accordance with AVV Baulärm leads to a reduction of the minimum of required distance for construction from around 64 m (rammed posts) to only 24 m (ground screws). As a result, the acceptance by residents for noise barrier constructions will rise and construction freezes will be reduced.
The vibrations created during the installation of ground screws can be lowered by a multiple (compared to rammed posts). Damage risks in towns, cities or other construction sites with many adjacent buildings can be reduced as well. According to the temporary results, the vibrations emitted by installing ground screws are way below the threshold necessary to be damaging to adjacent structures (2,50 [mm/s] at the base) - whereas the rammed alternative would have exceeded these thresholds and limits by DIN 4150-2 by a landslide. Graphic 6 shows this in an exemplary way for a distance of 30 m to the installation point.

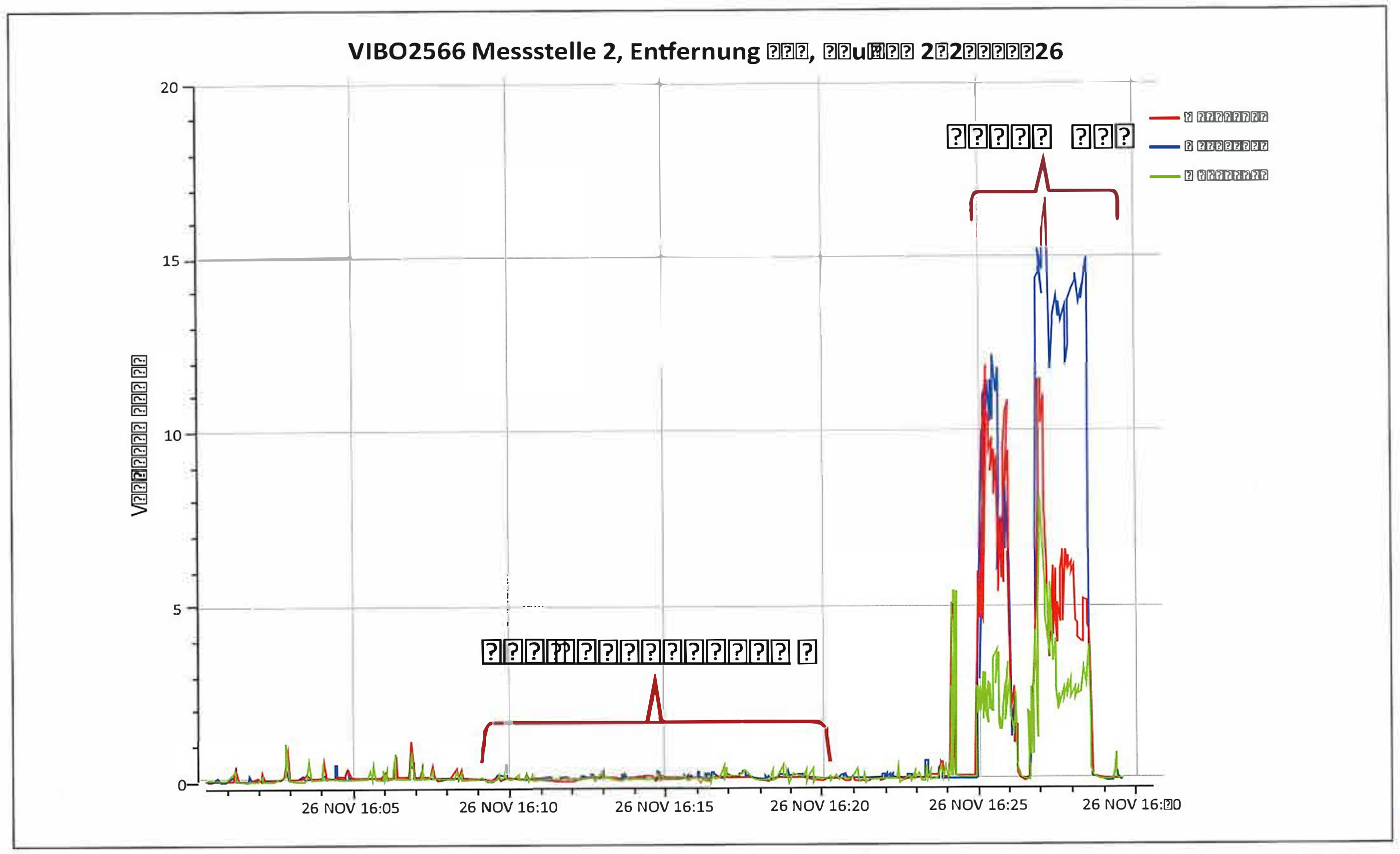
Graphic 5: test installation of ground screws *Source: Krinner*

Conclusion

Ground screws are becoming more and more important. The benefits are the independence from the weather, that no drying or hardening rests are needed as well as being able to cut the excavation work - which by extension also cuts the transport of dug up soil. Additionally, ground screws are precisely predictable under static and also dynamic circumstances. Construction noise and vibrations are reduced significantly compared to traditional methods. Minimal de-installation costs support the longevity and sustainability of projects using ground screws as a base and they are also more eco-friendly due to the lack of excavation and soil destruction needed. The last point on its own would already more than enough to show the improvement ground screws provide in this field.
A lot more possible fields of usage for ground screws will be experimented with in the near future leading to an even higher acceptance in the industry, further underlining the long-term potential of ground screws.

soil type		non-cohesive soil	cohesive soil
testing location		Laufach No. 5 (KRB 523)	Laufach No. 4 (KRB 521)
static PB combined	pressure (axial to post axis)	1x	1x
	horizontal (transverse to post axis)	1x	1x
static PB extra	traction (axial to post axis) - pile driver pipe	–	1x
	traction (axial to post axis) - KRINNER ground screw	–	1x
testing location / testing grounds (e.g. Straßkirchen or similar)		testing grounds?	testing grounds KRINNER
cyclic PB horizontal	1. preliminary tests static PB horizontal	1x	1x
	2. cyclic PB (100.000 load cycles)	1x	1x
	3. post-cyclic static PB horizontal	1x	1x

Table 1: concept proof loads *Source: Boley Geotechnik*



Graphic 6: vibration velocity in X,Y,Z - directions [mm/s] (Dilling | Prinz Ingenieurteam)

Source: Krinner

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50-Hz-fast charging station for battery-powered trains

As the first quick charging station of its kind, „VOLTAP" by the Furrer+Frey AG and the Stadtwerke Tübingen GmbH has been taken into operation succesfully.

DCJGV BQAFSLE

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Spare parts for components of the power are usually easy to come by even a few years after constructing a plant, however, a charging station for trains should still work after decades. This leads to a demanding spare part management which is solely depending on the good will of a small market. Because it seems reasonable to diversify the selection of inverter manufacturers from an economical standpoint, a "spare part zoo" of parts, that are incompatible between each other, is created.