“Revolution in railway construction technology with innovative process for subgrade stabilization”
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1. Challenge

Mud sites on all European railways are the main cause of unstable railway tracks. The speeds must be reduced in these sections in order not to endanger the safety of traffic.
Current difficulties of subgrade stability of “Deutsche-Bahn-AG”
2. Description load distribution in the railway on to the subgrade

Rail routes are linear structures, which are be claimed by static and dynamic loads from the trains, as well as weather conditions such as rain, snow, frost and strong sunlight.

The loads and forces from the movement of trains are transferred by the vehicles into the railway.

The resulting vertical-, horizontal transverse- and longitudinal-forces, must be absorbed harmless by the track, substructure and underground, to guarantee safe movements of trains with high comfort at any time!

The vertical forces generate pressures & tensions in to the sub, which must be removed in it!

Literatur/Illustration: EI - Der Eisenbahningenieur 08/2009
Klaus Lieberenz, René Kipper
2.1 Pressures in the subgrade

About the loads of the trains, a pressure area outcomes below the track at an angle of 45 ° to reaches about 5m below the bedplate-edge. It is therefore necessary that between the base of natural soil or rock and the ground, a stable and well compacted sub-structure is build!!

Optimal would be an subgrade what is relatively waterproof and also got a high load capacity!

Literatur/Illustration: El - Der Eisenbahningenieur 08/2009
Klaus Lieberenz, René Kipper
3. The way to solve the problem

We have provided us the task with experts (appraisers, geologists and mechanical engineers), these track systems to stabilize, where so far no economically viable method has been developed.

With this group of experts and research, we have succeeded to develop a method that exactly meets this economically justifiable claim as well in terms of sustainability.

To extend the usability of the constructions in high quality and maintain.

The process takes place in 3 steps.
3.1 Drainage

The big focus here is in the area

- of dewatering of the track systems to counteract sludge site formations
  and

- to create the sludge site disposal more effective and economically feasible..

The damaged or non-existent drainage systems of many railway plants are thitherto very costly and the main problem.

For the maintenance of the dewatering, long planning and construction periods are necessary, associated with very high costs.
Drainage of railway tracks

The requirement for a stable track position is a functional drainage system. The "MST" has tackled this problem and developed a modular rail system, which a dewatering installation is constructed by assembly line technique.

conventional process, performance 3.5 m/h

„MST“ process, performance 30 m/h
4. The Modular-Rail-Technology („MST“) for dewatering
5. The subgrade stability

Route sections with rocky subsoil can only be rebuilt by conventional process engineering.

At different strengths of gravel (gravel sinks) and rock spires, the use of large machinery/cleaning machines is limited.
The milling and compaction of the subgrade, carried out on the installed track body and ensures a flat slope, to allow the water runoff (drainage).
Aim: Track-tied soil stabilization of sludge site formations

- economical, efficient and sustainable disposal of sludge site formations and unstable subgrade, in the track-tied process
- with rail-tied process technology and environmentally friendly additive
- on track widths - 960 mm - 1000 mm - 1435 mm - 1520 mm and so far...

Particular attention is paid to the following aspects;

The technical, environmentally friendly and economic meditation of the use of the proceedings for mass application in track construction. Specifically it is about track systems, which can not be converted with conventional construction equipment in assembly line techniques or be upgraded conventionally only with major economic and long construction times.

That are in particular railway tracks with tight curves, tracks with rocky subgrade and an extremely tight situation, such as mountains, tracks with lower gravel strength etc. That means construction areas for which there has been no effective and sustainable solution to date, to produce the stabilization sustainable and economically in the shortest, justifiable construction time. Here the "MST" will fill the gap.
Development & Installation - "MST" procedure with Alphasoil®-06-Technology in the track-tied process

highly stable sustainable railway-substructure with an upper relatively resilient and water-frost resistant upper bearing layer, after Alphasoil®-06.
Construction of the deep-water-drainage, infiltration system and rail trenches with assembly line techniques, milling and stabilization of the middle drainage system.

- Sideway preparation and profiling
- Slope cleaning on railway tracks
- Cleaning of rails and switches
- Stabilization of bearing layers
- Defect subgrade and rock spiers, rework in an sustainable stabilized layer
- Installation of a base grade protection layer (track-tied) and the installation of base gravel
- Stabilization of bearing layers by supplying Alphasoil®-06 additive
Current state of conventional strengthening

The current status is: „it exists to date no machinery systems, that could meet these requirements economically, viable and sustainable “

The elimination of the sludge site formations is performed with an excavator and removal of the railway tracks on maximal 12m. Hereby is just a short-term punctual improvement of stability achieved.

The other possibility is the use of large machinery. These are for short punctual problem areas, which needs long-term planning and also a considerable logistic effort (storage bins, loading docks, etc.), not economically justifiable.

The “DB-AG” has according to a study (2014) the effect of expenditure of 7 million euros for 3.6 km sludge site disposal. That is 1,950 €/m, at a length of 10 - 12m damaged area (sludge site formations).

Example: 50m distance for sustainable elimination

<table>
<thead>
<tr>
<th>method</th>
<th>construction time</th>
<th>gravel</th>
<th>PSS</th>
<th>costs</th>
</tr>
</thead>
<tbody>
<tr>
<td>conventional</td>
<td>24 h</td>
<td>110 t</td>
<td>150 t</td>
<td>1.950 €/m</td>
</tr>
<tr>
<td>MST</td>
<td>14 h</td>
<td>none</td>
<td>none</td>
<td>1.350€/m</td>
</tr>
<tr>
<td>saving</td>
<td>10 h</td>
<td></td>
<td></td>
<td>600 €/m</td>
</tr>
</tbody>
</table>

Consequently, this is a saving of about 40% construction time and 30,000 € (thirty thousand euros) per sludge site formation.
Comparison - Conventional - Large Machines - MST Method

Material, Construction Time and Costs

<table>
<thead>
<tr>
<th></th>
<th>Conventional</th>
<th>Large machines/ cleaning/ 30%</th>
<th>&quot;MST&quot; - process/ 30%</th>
</tr>
</thead>
<tbody>
<tr>
<td>construction time / layers</td>
<td>10</td>
<td>8</td>
<td>5</td>
</tr>
<tr>
<td>m</td>
<td>3000</td>
<td>3000</td>
<td>3000</td>
</tr>
<tr>
<td>gravel removal disposal</td>
<td>14.346 t</td>
<td>4.304 t</td>
<td>2.000 t</td>
</tr>
<tr>
<td>soil removal</td>
<td>11.340 t</td>
<td>11.340 t</td>
<td>none</td>
</tr>
<tr>
<td>total disposal</td>
<td>25.686 t</td>
<td>15.644 t</td>
<td>2.000 t</td>
</tr>
<tr>
<td>PSS supply and installation</td>
<td>11.340 t</td>
<td>11.340 t</td>
<td>none</td>
</tr>
</tbody>
</table>
Second aim: Soil stabilization in dam layers

The technical, environmentally friendly and economic meditation of the use of the proceedings for mass-application in track construction.

Specifically, it is among others in marshland, the railway embankment constructively prepare like this, that he is receptive for the dynamic loads, but also allows a stable track position.
complete rail-substructure, constructed in several stable high bearing, relatively resilient and water-resistant layers on possible unstable subsoil, constructed after Alphasoil®-06 technology.
Shortening the construction time and thus considerable cost, with the same sustainability

2,300 m compared with large machines and "MST"

PM 2000
24h preparation

„MST" process
5h preparation

60h stabilization

<table>
<thead>
<tr>
<th>Process</th>
<th>con.time</th>
<th>gravel</th>
<th>process</th>
<th>con. time</th>
<th>gravel</th>
<th>PSS</th>
<th>costs</th>
</tr>
</thead>
<tbody>
<tr>
<td>PM 2000</td>
<td>96 h</td>
<td>3 643 t</td>
<td>konventi</td>
<td>24 h</td>
<td>110 t</td>
<td>150 t</td>
<td>1.950 €/m</td>
</tr>
<tr>
<td>„MST&quot;</td>
<td>62 h</td>
<td>none</td>
<td>„MST&quot;</td>
<td>14 h</td>
<td>none</td>
<td>none</td>
<td>1.350 €/m</td>
</tr>
<tr>
<td>Saving</td>
<td>10 h</td>
<td>Saving</td>
<td>Saving</td>
<td>10 h</td>
<td></td>
<td></td>
<td>600 € /m</td>
</tr>
</tbody>
</table>
3.1 Alphasoil®-06 introduction

- environmental safety

- fire safety

- installation is simple and possible with the conventional construction equipment and some special machines

- sure laboratory forecast for required quantity

- pre-mixed material possible

- various construction methods

- several application areas

- The standard application provides that the bottom layer is treated at a depth of 25cm - 30cm with Alphasoil®-06.

- The existing experience confirms the expectation that Alphasoil®-06 can permanently improve the soil.
**Attribute**

ALPHASOIL®-06 is a chemical product what is surface-active and thereby releases the adhesive water film of the soil colloids. This allows an irreversible agglomeration of the fine and finest particles of the treated soils.

Alphasoil®-06 is not a binding agent like cement. But it can release the own ground bonding force of the soil and affect soil behavior like this, that a permanent increase of compaction under load and transport occurs.

- Better compressibility by changing the nature of water;
- Greatly reduced water absorption by capillarity-stopping;
- Reduced fluid and water permeability;
- Extensively reduced source and shrinkage behavior;
- Extensively reduced Water sensitivity;
- The effect of the consolidation/agglomeration is continued in the treated soil; under load and transport the density reaches values in excess of 100%;
- The Proctor Optimum of the treated soil is lower, the density higher. In such cases where these general characteristics are not visible, you will find a corresponding increase of the voids in the soil, which is triggered by the particle size distribution change due to the irreversible agglomeration.
...by electronic digitally controlled injection in the the mixing & crushing mill, the charged amount of Alphasoil®-06-working solution mixing and milling adequately into the soil.
Important characteristics

The aim of Alphasoil®-06 is to achieve a great improvement of the soil material in stability at each in situ soil. This provides a reliable method for a lasting improvement and massive financial savings of road projects and railway constructions with the Modular Rail Technology (“MST” are available.

- Reduces the water permeability and capillary water management;
- Reduces IP (plasticity index);
- Shifts the Proctor Optimum to the left and to an higher density;
- Massively increased the carrying value (with soaked CBR 3 -5 times in more than 50% of cases by more than 5 times);
- Reduces the water absorption and thus the swelling- and shrinkage behavior of the treated soil;
- Reduces the softening due to water absorption; after the soil has dried out even in part, the moisture content levels off at or below the PO (Proctor optimum);
- The full effect of the treatment is visible after the treated soil under the PO could dry out and improved by time under traffic load enormously;
- The improvement effect is permanent;
Compaction

- Eases and improves soil compaction;
- No air pockets in the correct compacted bearing layer;
- No traffic stoppage; Traffic can be involved for the compaction;
- Under Traffic a permanent recompaction takes place, which leads to a continuous increase in strength.
Incorporation of Alphasoil®-06 is relatively simple; Installation is carried out by the tracks strengthening after the "MST" process (track-tied strengthening) below the sleepers and will be incorporated by milling machines and compacted with rollers.

The soil treatment may also be effected by premixing, whereat the in a mixing plant produced soil material (Mixed in Plant) stored in clusters, what can be at any time installed without further processing (trackless strengthening).

The effect thereby is not lost.

The construction work at the site can be interrupted any time without adverse consequences.
Required functions of a suitable machine:

removing gravel / produce dewatering

- Crushing mills (MST) for milling of the subsoil
- Injection System (MST) for inserting Alphasoil®-06
- Mixing mill (MST) for mixing the treated soil
- Grader (MST) to create a subgrade
- Roller system combined (MST), for churning and compaction of the treated soil.
Our new machine technology, is the next evolutionary step in the construction process in the field of improved efficiency (dewatering) and the sludge sites disposal. The savings are up to 60% of costs and up to 70% reduced construction time.

- flexible - modular - environmental - electric drive - energy efficient - met EU emissions standard - few hydraulic components - all track widths from 900mm - 1520mm, etc. ...
- manufacturing assembly line techniques - saving potential -
- use on standard container trucks - trucking -
- economically in consumption and spare parts -
The module system can be assembled on site for the work. Drive assemblies are retracted during the transfer, so that the transport of the modules results in a pure truckload.

Repair on individual modules can be done on site without blocking a track.

The modules can be set on trains and transported without restriction.

The units are mainly powered by electricity, so the pollution is in an accident almost impossible or very low.

The generators are all damped and reduce the noise level by the multiple, compared with conventional construction equipment.
- The usability of the tracks is again almost completely be made in a short construction period, with minimal planning effort;
- The transport takes place on public container wagons or container road trains (trucks) ISO 668;
- It is the first construction equipment plant, in which the EU's highest emission standards are adhered to and which also can be used accordingly smoothly in residential areas, stations, tunnels, etc.;
- Individual modules can be replaced in a very short time and be transported by truck to and from the workshop;
Disconnect the system on Wagon length (approx. 14 m) is possible. When placing at stations it is possible to divide the plant on free tracks.

The Modular Rail Technology ("MST") can be used generally on all railway lines with different track widths with a few conversion measures. The use of a European country to the next, is also quickly and inexpensively without any problems possible.

Allows machine processing production of drainage systems by assembly line technique (TE, railway trench, etc.), Stabilization of the bearing layers (sludge site disposal) for railway tracks, in which to date, no rail-tied deployment of track-laying machines, for technical and economic reasons, has paid off.
In addition to the new method for sludge site disposal and subgrade stabilization provides the "MST" a number of other applications;

In its flexibility and economy a serious alternative to the established large machinery manufacturers;

Qualitative and temporal winnings, compared to conventional processes with two-way excavators;

Easy assembly and transportation by ISO container format and use on standard container trucks;
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Concrete repair by crack injection
Operation at „Deutsche Bahn AG“