IMPROVEMENT OF RAILROAD PLATFORMS BY COLUMN OF SOIL MIXING

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ABSTRACT – Improving the railway platforms is a major issue for SNCF, particularly for the track renewal operations. Today’s platform improvement techniques oblige to remove the track to substitute the faulting foundation by a new one. The aim of RUFEX project is to industrialize a way of reinforcing the railway platform by soil-mixing techniques avoiding the track remove.

The concept of platforms railway

Currently, the network exploited in France counts 29,275 km of old lines called circulated up to 220 km/h and 1,879 km of Lines at High Speed (LGV) (figures to the 31/12/2007). One can distinguish two categories of railway platforms:

- the structure of traditional lines, whose constitution and the mechanical characteristics remain little known to date in spite of research current (Trinh and Al, 2010 A, B; Trinh and Al, 2011);
- the structure of new lines, whose, the constitution and the mechanical characteristics of materials used are well controlled (SNCF, 2006).

This article will exclusively treat railway platforms met on traditional lines, which are the subject of the research undertaken within the framework of project RUFEX (Reinforcement and reUtilisation of the platforms and Existantes foundations). The substructure of this type of line is made of a top ballast layer, a bottom ballast known as polluted (containing in addition to the ballast fines of attrition and fines of the ground support) and of a layer of materials called blanket layer (Figure 1).

This layer forms an heterogeneous layer which was created gradually since the construction of the line under the action of the trains, by the interpenetration of the natural ground and the possible layers of materials brought back during the construction of the line or of its maintenance (ballast, broken stones, gravels, sands, products of wears, etc). The thickening, densification in the course of time and the diversity of the grounds met confer a great heterogeneity.

The blanket layer of the old railways (Figure 1 & Figure 2), like the blanket layer of the new railways, has as functions: I) to ensure, in complement of the ballast, the distribution of the load to the level of the platform; II) to ensure a granulometric role of separation between the ballast and the platform; III) to protect the platform from the streaming of the rainwater which infiltrates through the ballast; iv) to protect the platform from freezing.
2. Pathologies of the platforms

Two principal problems, related to the problems of platform are identified on the National Rail Network:

- **Mud ascent**: This phenomenon appears on the old lines. The HSL are not concerned, because they are the subject of specific treatments (purging, granular structures of base) to fight against these problems. The increase muddy (Figure 3) or gone up loamy are described by ALIAS (Alias, 1984) as being disorders affecting the platforms built on clay layer and which are containing water. The vertical movements of the sleepers to the passage of the trains cause an action of pumping and allow the increase of fines of the ground support in the ballast. In winter, the presence of mud in the ballast destroys the cohesion of this one and involves deformations of the rail, while in summer, mud becomes like "concrete" and creates hard points being able to be at the origin of a premature wear of the superstructure.

- **Defects of bearing capacity**: these defects appear in the zones where the bearing capacity of the ground support is too weak to ensure a good behaviour of the way (Figure 4). Under train traffic, the vibrations transmitted by the convoy are propagated abnormally in the blanket layer and destabilize the ballast, then the sleepers. The behaviour of the way is not then assured any more.

When one of these defects is met on the network, it is necessary to bring a solution to give again with the railway (armament & structure) of the acceptable characteristics.

3. Renewals of way
When the operations of levelling or maintenance of the material do not make it possible any more to ensure a sufficient quality of the railway, or when the defects become recurrent, it becomes necessary to carry out the renewal of the superstructure (RVB). This operation makes it possible to replace the ballast, the sleepers and the rail worn by new material adapted to the conditions of traffic of the line. The linear annual one of renewed ways should reach 800 kilometers into 2012.

It should be noted that one observes that, when the RVB work damages the blanker layer, this one generally loses its mechanical characteristics: this causes the appearance of mud asch which degrades the quality of the ground support and finally obliges to multiply the operations of tamping on a railway whose superstructure was renewed.

The mechanical performances of the platform has a fundamental role in the quality of the railway: insufficient foundations make difficult the maintenance of the geometry of the railway, require frequent maintenance actions which reduce considerably the life cycle of the railway and the ballast in particular. The quality of the platform is thus an essential factor to ensure the effectiveness of an operation of renewal of the railway. Recent investigations showed that the platform and its foundations could have insufficient characteristics on approximately 5% of linear renewed. The reflexion on the ownership cost and strategy FDMS (Reliability – Availability – Maintainability – Safety) thus lead the SNCF to:

- Improve the diagnosis of the platforms in order to detect these weak zones and to improve the effectiveness of the renewals of railway;
- Seek technical solutions allowing to improve the capacity of the ground support.

The various undertaken studies show that the railway structures, primarily made up of granular materials, are more or less permeable thus making the railway very sensitive to the action of water. This is why a great attention was paid to the devices of drainage from the construction of the first lines. But the oldness of the network made these devices punctually obsolete. These defects of platform are thus primarily due to problems of drainage and/or defects of blanket layer. The techniques of "traditional" reinforcement of the platform are of course incompatible with the output of mechanized work of renewal of railway, this is why this work is generally completed "except continuation" i.e. before the passage of the train carrying out the RVB. This work generally leads to the provisional remove of the railway and has of this fact a significant impact on the exploitation of the line. After removal of the railway, this work consists classically of an excavation from 20 to 30 cm under the level of the ballast, the installation of geotextile, the implementation of a granular blanket layer as defined in the French reference table, then to put down the railway and ballast. These earthworks become very constraining, because space available is tiny, generally with circulations on the contiguous railway.

Thus the traditional techniques of reinforcement of platform being too expensive, very poor output and bringing a strong constraint to the exploitation of the network, the SNCF is in the search of a process making it possible to improve quality of a ground support by respecting the capacity of circulation of the lines of the network, i.e. without requiring the remove of the railway. From the point of view of predictive maintenance and the framework of a policy of Reliability Availability Maintainability Safety (FDMS) to which adhere the SNCF and RFF, project RUFEX would bring economic and durable solutions adapted with an aim of improving quality of the railway.

4. The Innotrack experiment

The technique of the reinforcement of railway platforms without removal of the track was initiated at the time of the project Européen INNOTRACK (INNOvative TRACK systems), controlled by the International Union of the Railroads (UIC), which were held over the period 2006-2009. The principal objective of this research is to reduce the cost related to the cycle of life of the railway infrastructures. Within this framework, the SNCF controlled the sub-project relating to the structures support, in which the LCPC was also implied (Central Laboratory of the Bridges and Chaussées) and coordinated an experimental and numerical study of the contribution of a device of reinforcement of railways. This study was undertaken in collaboration with two companies (Keller Fondation and Soletanche Bachy), the SNCF and the LCPC, to know if it is possible to test alternatives of soil-mixing using a new tool, developed by Soletanche Bachy, with variable geometry called Springsol. The test took place in the railways of the station High Picardy on the Northern LGV, aiming to show that it was possible with this
Challenge G: An even more competitive and cost efficient railway tool to implement the columns of soil mixing under the railway and this without remove of the track (Figure 6) and the catenary, and without degradation of the mechanical characteristics of the ballast nor pollution of the trackbed.

During these tests, three columns were carried out beside the railway platform and were mechanically tested. The two named first P1 and P2 were carried out by the company Keller Fondation and the third (P3) by Solétanche Bachy. The characteristics of the columns tested are included in the table below.

<table>
<thead>
<tr>
<th>N° Colonne</th>
<th>Diamètre (mm)</th>
<th>Profondeur (m)</th>
<th>E/C</th>
<th>Dosage en ciment (kg/m$^3$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>P1</td>
<td>600</td>
<td>5.30</td>
<td>1</td>
<td>338</td>
</tr>
<tr>
<td>P2</td>
<td>600</td>
<td>5.30</td>
<td>0.83</td>
<td>397</td>
</tr>
<tr>
<td>P3</td>
<td>400</td>
<td>6.24</td>
<td>1</td>
<td>300</td>
</tr>
</tbody>
</table>

The purpose of these tests were to study, in particular, the forces of friction exerted around the column of soil mix according to the depth and the typology of materials met. The results of these tests were synthesized and analyzed by Le Kouby and Al (2010).

Simultaneously with these tests, columns were carried out in platform and tested in order to determine their impacts on the reinforcement. The columns were carried out so as to respect the design of the column P3 (Table I). The columns were requested by a train of maintenance in order to see the impact of the reinforcement on the attenuation of the railway structural deformations. The configuration of the reinforcement used during these tests was a grid with five columns with a first "square" grid of four columns carried out in end of sleepers and a central column carried out between railways.
Challenge G: An even more competitive and cost efficient railway

The results produced by these tests showed a weak impact of the reinforcement on the total compressing of the railway. This result should not be seen like a limit of the reinforcement, because the "consolidated” railway is a shunt track of LGV carried out in accordance with the technical reference frames in progress which impose high objectives of bearing capacity of the structure.

But the results obtained on the tests carried out except railway show the contribution of such reinforcement on structures of weak bearing pressure. This is why, under the impulse of Soletanche Bachy, project RUFEX was initiated to answer among other the problems related to the platforms of weak bearing capacity.

5. Interest of project RUFEX

The maintenance feedback and studies show well that the quality of the platform plays a fundamental role in the quality of the behaviour of the railway and in the perenniability of the superstructure. As seen above, the tests carried out in the railways of the station High Picardy on the Northern LGV proved that it was possible to implement under the railway the columns of soil mixing using an opening tool (Springsol), and this without removing the track equipment, and without degrading the mechanical characteristics of the ballast nor to pollute the structures of base.

The prospects offered by the technique for the soil mixing in the field of the railway maintenance of the platforms are the subject from now on of new developments to industrialize the process:

- The modelling of the interaction between the platform and the columns of treated ground, in particular under the conditions of loading of the railways;
- The dimensioning and grid of the columns in order to avoid the formation of hard points;
- The role of materials constitutive of the soil mixing, in particular in the improvement of platforms.

Beyond the problems of the platforms, new solutions will be explored for the rehabilitation of technical blocks or more generally of ground works:

- The transitions zones are works placed on the level of the transition between a railway platform and a structure: on this level, the railway passes brutally from a relatively flexible foundation to a rigid base ensured by the structure out of concrete. The transitions zones are compacted fills, whose rigidity grows in a progressive way while approaching the structures, in order to carry out this transition. The soil-mixing technique can bring effective solutions for their maintenance;
- Railways are sometimes posed on very old embankments. Maintenance and the setting in safety of these slopes pose true problems of exploitation. The techniques currently used pass all by interventions under railways starting from the slopes, by means of sub-horizontal drillings, in spaces often extremely constrained and exiguous. The techniques of soil mixing can be also used to reinforce this type of foundation, while working since the platform, with vertical drillings adapted better to take again the loads;
- The appearance of subsidence on the Northern LGV resulted in completing work of injection in order to eliminate the risks from deformations of the railway. The feedback showed the
difficulty of controlling the grout injected. The technique of the soil mixing, from the low pressures implemented, seems an interesting alternative solution.

It is within the Research project RUFEX that the collaboration started in Project INNOTRACK between the SNCF, the LCPC and Soletanche Bachy is continued. RUFEX also associates research on the railway aspects the School of the Ecole des Ponts ParisTech. The geotechnical engineering and design department TERRASOL and the INSA of Lyon also take part in it, within the framework of research on the reinforcement of existing building foundations.

The project started into 2010, for three years and coordinates several convergent objectives of research:

1. A research relating to the analysis of the life cycle of the railway platforms, and aiming in particular characterizing the mechanisms of ageing under the effect of the trains traffic, (dynamic and cyclic loading, particular role of water circulations) and at defining methods of preventive or curative reinforcement. This research is generic, insofar as its results can be extended to all the structures under cyclic and/or dynamic loading (vibrating machine foundations, harbour structures, etc).
2. A research relating to the optimization of the dimensioning of the reinforcement of foundations, aiming at improving the conditions of feasibility and the economic conditions of the renewal of the built inheritance (real, industrial facilities, structures etc).
3. A research aiming at controlling the characteristics in-situ of the mixture of soil-mixing: resistance and homogeneity. Like the two preceding ones, this research presents a generic character because it aims at raising one of the technological bolts which are opposed to the whole of the processes of soil-mixing, all tools confused.
4. A search for technological and industrial nature, aiming at developing a new line of tools, without equivalent on the market, and optimized for the needs expressed by the building owner: the maintenance of the railway platforms without interruption of service, and reinforcement of the existing foundations.