GAIN: Slag layers in railway foundations
General information

Concept: **Valorisation of an industrial waste** (black slag) into a new recycled aggregate, **SFS-Rail**, to be used in **railway foundations**.

Project duration: **July 1st 2013 - September 30th 2016**.

Total Cost: **1,301,526€** with a **50% funding** by the LIFE program of the European Commission.

Partners: **COMSA**, as coordinating beneficiary, and **ADEC GLOBAL**, as associated beneficiary.

**COMSA** is a construction company, founded in 1891, which undertakes any kind of civil works, with railways as its core business. Today COMSA is positioned among the leading construction companies in the country with a strong presence in the European and International market. COMSA is the main company of the COMSA EMTE group, which is a diversified group organised in four different areas: Infrastructures, Engineering and Systems, Environment and Transport&Logistics, and Renewal Energy and Concessions.

**ADEC GLOBAL** was created in July 2010. It is the only valorisation plant in Catalonia with an environmental license for the treatment of EAFS. The company manages 100% of the EAFS annual production of the Spanish steel-producing company CELSA, which ascends to 360,000 tonnes/year (limited by the steel plant capacity), from which 280,000 tonnes/year are black slag.

Objectives

The main goal of the project is to extend the market of an industrial waste, namely the Electric Arc Furnace Slag (EAFS) by identifying a **new field of valorisation** which shows good environmental and economic returns.

EAFS is an abundant industrial waste product in the European Union; it is estimated that between 8.6 and 14.3 million tonnes of black slag were produced in 2011 by the European steel producers. The project pursues the development of a **new alternative of valorisation for the Electric Arc Furnace Slag (EAFS)**, subtype of Steel Furnace Slag (SFS). The project consists of using **black slag** (subtype of the EAFS) as a **raw material to produce a new recycled aggregate**, the **SFS-Rail**, to be used in the sub-ballast and sub-grade rail track foundation layers.

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Other goals that are expected to be achieved, derived from the demonstration of the technical and economic feasibility of SFS-Rail, are the following ones:

- **Reduction of the use of natural aggregates** in railway construction, which turn into the reduction of quarries’ environmental impact.

- **Reduction of the transport needs** associated to railway aggregates, which turns into **fuel savings and reduction of the CO₂ emissions**. It is expected that SFS-RAIL will be more accessible to work-sides than natural aggregates, because few quarries fulfil the technical requirements demanded by railway regulations.

- **Improvement of the mechanical performance of railway track**. Research done up to now on SFS-Rail shows that the mechanical properties of this product overpass the performance of natural aggregates.

- **Reduction of the material cost of railway aggregates**. The difference in sale price between natural aggregates and EAFS aggregates increase with the hardness required. So the savings are higher when EAFS substitutes hard natural aggregates, such as the railway ones.

- **Reduction of the volume of final disposal and the volume of storage of black slag**.

**Valorisation of black slag into SFS-Rail**

The valorisation plant of ADEC GLOBAL was adapted to produce SFS-Rail and to cope with the stock. To achieve an efficient and effective plant adaptation it was necessary to have very clear how the **valorisation process** would be. The result can be seen at Figure 2. For the logistics it was necessary to build new storage spaces at the valorisation plant. Meanwhile, the quality control plan was being designed and later implemented to ensure the quality of the SFS-Rail resulting from the plant.
Figure 1: Different granulometry is obtained after sieving (left). Works for new storage of aggregates (right)

Figure 2: Valorisation process from Black Slag to SFS-Rail
Implementation of SFS-Rail in operating railway lines

Once the SFS-Rail was produced, it has been tested in two operating railway lines:

- El Puerto del Musel (The Musel Harbour), in Gijón, Asturias (Spain). Line owned by Gijón Harbour Authority. Freight traffic only.
- Castellbisbal, near Barcelona (Spain). Line owned by the Spanish Infrastructure Manager (ADIF). Mixed traffic (passengers and freight)

The construction in both cases comprised three test sections (TS), as shown in Figure 3.

![Test sections](image)

Figure 3: Test sections used in both railway lines

The construction process was the following (see Figure 4).

1. Topographic stakeout
2. Removal of rails, sleepers, fasteners and auxiliary elements, stored next to the site
3. Excavation of old granular layers, later transported to landfill
4. Extension and compaction of subgrade layer
5. Placement of a geotextile for sanitary purposes
6. Extension and compaction of subballast layer
7. Extension of the 1st ballast layer
8. Positioning the track panel (sleepers, rails and fasteners)
9. Ballast filling, levelling and alignment
10. Topographic measurements to ensure geometrical quality of the works
11. Tamping until ballast achieved the required thickness
Monitoring activities were carried out to prove the goodness of SFS-Rail in real conditions under operating railway lines. The parameters monitored are the following:

- **Track settlement and geometry**, as a measure of the track alignment, thickness of the compacted layers, strength, density (compaction) and moisture.

- **Subballast and subgrade stress under traffic**, as a measure of the capability of distributing the stress towards the platform, which relates to the track strength (bearing capacity)

- **Rail deflection under traffic**, as a measure of the track stiffness (soil modulus) and its elastic deformation.

The most appropriate technology has been selected for monitoring the mentioned parameters, as shown in Figure 5.
Results and conclusions

Technical performance of SFS-Rail

Regarding the track constructed in Castellbisbal, the overall track settlement and geometry are presented in Figure 6, showing an overall progressive but restrained settlement during time. This is more pronounced where SFS-Rail is employed in both layers, since the conventional aggregates have not been replaced and they are already compacted.
Regarding partial settlements of SFS-Rail layers, the readings show as these layers collaborate on 8% of total settlements, in the section with only subballast of SFS-Rail, and the collaboration is 6% and 8% respectively in the section with subballast and subgrade of SFS-Rail. These percentages remain after twelve months.

The stress measured on the subballast and subgrade layers made of SFS-Rail is presented in Table 1, showing admissible values (under 0.15 MPa) while evincing a reduction on the stress of the subgrade compared to the subballast layer, hence proving SFS-Rail bearing capacity and its capability to distribute stress. Stresses are scaled up in the second reading due to a higher axle load of the commuter unit circulating at the time of the measurements.

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<th>1&lt;sup&gt;st&lt;/sup&gt; reading</th>
<th>2&lt;sup&gt;nd&lt;/sup&gt; reading</th>
<th>3&lt;sup&gt;rd&lt;/sup&gt; reading</th>
<th>4&lt;sup&gt;th&lt;/sup&gt; reading</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stress (MPa) on SFS-Rail subballast layer</td>
<td>0.077</td>
<td>0.104</td>
<td>0.097</td>
<td>0.088</td>
</tr>
<tr>
<td>Stress (MPa) on SFS-Rail subgrade layer</td>
<td>0.032</td>
<td>0.042</td>
<td>0.056</td>
<td>0.033</td>
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Rail deflection under traffic is presented in Table 2, indicating a compaction of the infrastructure with time while manifesting acceptable values (under 3 mm in the second reading) and a reduction in deflection when SFS-Rail is used, which demonstrates the increase in soil modulus (track stiffness) with respect to conventional aggregates.

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<th>1&lt;sup&gt;st&lt;/sup&gt; reading</th>
<th>2&lt;sup&gt;nd&lt;/sup&gt; reading</th>
<th>3&lt;sup&gt;rd&lt;/sup&gt; reading</th>
<th>4&lt;sup&gt;th&lt;/sup&gt; reading</th>
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<tbody>
<tr>
<td>SFS-Rail subballast and subgrade layers</td>
<td>1.2</td>
<td>1.0</td>
<td>0.9</td>
<td>0.9</td>
</tr>
<tr>
<td>SFS-Rail subballast layer and subgrade layer with conventional aggregates</td>
<td>2.7</td>
<td>1.3</td>
<td>1.3</td>
<td>1.3</td>
</tr>
<tr>
<td>Control section (conventional aggregates)</td>
<td>4.5</td>
<td>3.0</td>
<td>3.0</td>
<td>3.1</td>
</tr>
</tbody>
</table>

In Gijón, as it happened with Castellbisbal, the track settlement is more pronounced where SFS-Rail is employed in both layers, since the conventional aggregates have not been replaced and they are already compacted. Track settlement is shown in Figure 7.
A software model has been developed (see Figure 8) to take into account all these results and optimise the railway track sections with SFS-Rail. A track solutions catalogue has been confectioned with the results of the software optimisation.

**Socio-economic impact**

From the impact of the investment and the computation of the economic indicators, it has been seen that the profitability of the project is high enough to carry out the activities and develop the technology proposed. The Net Present Value (NPV) of the project reaches 264,277 € according to the analysis done for the next five years after the project’s implementation, indicating that the project will generate gains above the profitability required (5%). In the same way, the low initial investment needed for the
adaptation of the valorisation plant (85,000€), and the economic benefits from selling SFS-Rail, gives an Internal Rate of Return (IRR) of 70%, which shows a very high profitability. The payback period is of just 1.5 years.

Considering the potential impact of the project in the next years, the social benefit obtained in economic terms will be 772,233 € per year besides the creation of new employment in the steel recycling industry. What’s more, it will affect to the demographic distribution in the next years and the mobility induced for the job creation will increase the intraregional and interregional daily trips. Finally, the quality of life indicators of the population will be improved because of the reduction in the industrial waste and the reduction in the quarries activity.

**Environmental impact**

The potential impact of the LIFE GAIN activity in terms of reduction of industrial waste is 216,000 tonnes, which will suppose that all the production of the plant is used for SFS-RAIL. In this way, the project allow us to manage more than the 16% of the total Spanish annual slag production, solving a considerable percentage of the industrial waste management problem. This impact could be increased with the transferability of the project technology to adapt other valorisation plants of the country.

To evaluate the environmental impact of SFS-Rail, with regard natural aggregates, a Life Cycle Analysis (LCA) and an Environmental Impact Assessment (EIA) have been carried out during the project. Figure 9 summarises the EIA results for all the possible GAIN solutions defined in the track solutions catalogue, which depend on soil and base plate stiffness.

![Environmental Impact per km](image)

* Figure 9: Environmental Impact of GAIN solutions with regard conventional track

* More information is available on the project’s website: [www.life-gain.eu](http://www.life-gain.eu)