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Improved slag qualities by liquid slag treatment

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Abstract

Iron and steel slags from metallurgical processes are widely used in different fields of applications, e.g. in the building industry, road and waterway construction or as fertiliser. Nevertheless, also these well established by-products can be improved to ensure and extend their sustainable use. The efforts of the FEhS-institute regarding the treatment of liquid iron and steel slags, e.g. by changing their composition inside or outside of the iron and steel production process, have led to interesting new properties of the newly formed products and thus guarantee their use in the future. On the other hand some interesting side effects are supported by e.g. the dust recycling for the metallurgy in the electric arc furnace. The FEhS-institute has shown that slag foaming can be enhanced by dust recycling, even for stainless steelmaking processes.

Introduction

The recycling of by-products in the steel industry is not a fiction of the modern time. Early in the beginning of the production of metals, the use of slags as a source for earthworks was reported.[1] With the extension of the steel production the amount of slags and other residues has been increasing and the driving forces to utilise such materials are becoming more intense. In the recent past the availability level of raw materials has exerted additional pressure on a better utilisation of raw materials. Eventually, due to the specific high volume of residues arising from steel production, the need to utilise these materials more effectively has become a prerequisite for sustainable steel production. Today‘s practice in the steel industry worldwide is to reduce the amount of residues generated and to use the residual slags as products on high value levels. In the following some examples are given on the efforts of the FEhS-institute to reduce the amount of generated wastes, to recycle residues in metallurgical processes. The use of by-products from the German, Austrian and Swiss iron and steel industry is also discussed.

Blast furnace slag

In Germany the recycling of iron and steel slags is on a high level. The recycling rate of all iron and steel slags is over 90%. Today about 6 million t/a of blast furnace slag and 5 million t/a of steel slags are produced in Germany.[2] In Germany over 80% of blast furnace slag is water granulated, which is primarily used as main constituent in cement. It is expected that this fraction will further increase in the future. It is to be pointed out that all produced blast furnace slag is used in Germany, *i.e.* no blast furnace slag is dumped. The demand for granulated blast furnace slag for cement is higher than the generation level. The main reasons are energy savings, savings of natural resources and cost of CO_2-certificates. The use of blast furnace slag in cement reduces the discharge of greenhouse gases like CO_2,[3] since the energy input necessary for the production of cement is reduced, as the energy intensive manufacturing of clinker for the cement mixture is diminished. For the production of clinker the necessary burning heat is provided by firing of fossil fuel or by fuels prepared from residues. During limestone calcination, CO_2 is dissociated from the limestone and leaves the furnace with the off-gases. Thus, the partial substitution of clinker in cement production reduces the specific CO_2 emissions. On the other hand, blast furnace slag cement offers some important properties, which enhance the durability of concrete, such as resistance against sulphate attack, high density, just to name a few.

Steel slags

The generation and quality of steel slags varies with the crude steel production. Due to the research of FEhS-institute in the last years the producers as well as the processors of slags in Germany, Austria and Switzerland have made considerable efforts to improve their steel slag quality. The slag which cannot be completely used today is the fine grained slag, which is difficult to utilise in the building industry as well as in metallurgy. Only a small amount is used as fertiliser or for special applications in earthworks or as deposit capping. The amount of fertiliser sold in Germany has achieved a level which has not been reached for 15 years. Compared to the level 15 years ago, when a broad variety of fertilisers was offered, today it is only converter lime in a grain size of < 3 mm and with a humidy content of about 10% to 20% water. It is expected that this market is developing further. This is especially the case against the background of the shortage of phosphate, which can be used in agriculture. The phosphorous content in the slag fertiliser is today only in a range of 1% to 2%, but it is in a form that makes it suitable for plants to absorb it. Current research is focused on raising the phosphorus content in the slag.

Approved and traditional fields of application for BOF and EAF slags are: road construction, waterway construction, fertiliser and if suitable to a small amount as aggregates for concrete. Each of these fields has special demands on the quality of the slags. The highest demands on mechanical properties as well as on the volume stability are required for the use in concrete structures.

The raw slags are processed to comply with the special demands of each field of application. However, increasing demands on environmental behaviour might restrict the use of by-products slag as construction materials. Thanks to the good mechanical properties of steel slags, their use as aggregates for road construction is possible. The limiting factor is the insufficient volume stability of the slag due to its free oxides content, *e.g.* CaO and MgO. The reaction of free lime or MgO with humidity or water forms hydroxide phases, causing an increase in volume.[4]

Recently, in most of the applications of steel slags, competitive materials from wastes of other industrial origins have infiltrated into the traditional markets for steel slags. That requires the development of new markets for the slag in the fields of high quality demands, which cannot be fulfilled by the other industrial by-products to ensure the utilisation of the slag in the future. However, the potential of iron and steel slags is not fully exploited yet. Therefore, new treatment processes to improve the quality of steel slags are required. The target of the efforts of the steel industry and the FEhS-institute is to improve the utilisation of slag by improving their properties. For example the amount of slag that has to be deposited, *e.g.* due to its fine grain size, has to be minimised in the future.

Increasing the quality of water granulated blast furnace slags

The water granulated blast furnace slag has latent hydraulic properties. It is used as constituent in cement and as addition in concrete.[5] The hydraulic properties of the glassy slag are influenced by the chemical composition. A low slag basicity ratio is reflected by a low compressive strength of mortar or concrete. A low concentration of CaO and Al_2O_3 influences the development of strength, especially in the early stage of hardening. Experiences in the recent past indicate a drop-down of both, slag basicity ratio and Al_2O_3-content. Both could be counterbalanced by increasing CaO and Al_2O_3 in the burden. Apart from metallurgical reasons this would increase the amount of blast furnace slag. An option to overcome this obstacle is the modification of the composition of the liquid blast furnace slag after tapping, prior to the water granulation.

In laboratory and operational trials the modification of the blast furnace slag composition by different modifiers and at different locations has been tested by FEhS-institute.[6] Tests were done with lime calcium carbide, synthetic fluxes of lime and aluminium oxide, BOF slag and slag from secondary metallurgy. During operational trials the injection of modifiers has been tested in the main runner (slag and hot metal), in the skimmer and in the slag runner (slag only). Addition into the slag runner was not successful because the heat capacity of the slag limited the amount of solid modifiers. Experiments with exothermic modifiers, like calcium carbide, were stopped for safety reasons. Trials on the pneumatic injection in the skimmer had to be stopped because too much hot metal was spilled over to the slag runner and might have caused trouble in water granulation and for the product quality.

The addition of lime into the main runner was successfully tested. Lime was pneumatically injected during tapping in the runner. The lime was totally dissolved in the slag and the slag basicity ratio was increased from 1.1 to 1.4. This increase was the reason for roughly 25% gain in compressive strength of mortar prisms. Unfortunately the injection process had to be operated batch wise. Continuous operation throughout the entire tapping time was not possible up to now due to the limited capacity of the available bunker system and the required injection rates of up to 100 kg lime per minute. But, further operational test campaigns are proposed for continuous treatment of liquid blast furnace slags with CaO-, Al_2O_3- and MgO-containing slag modifier.

Increasing the quality of basic oxygen furnace slags for the use in road construction

Decreasing the contents of free oxides of steel slag leads to extended use of these slags in the fields of application with high demands on volume stability. The main reason for the insufficient volume stability is the free lime content in the slag. To overcome this problem ThyssenKrupp Steel and FEhS-institute have developed a treatment process for liquid BOF slags to bind the free lime content into stable slag phases.[7] The principle of this process is to bind the free lime as well as free MgO into a stable matrix of calcium silicates and ferrites. This can be achieved by the addition of SiO_2 containing materials, such as quartz sand but also by glass cullet and spent foundry sands. The treatment with quartz sand is the most efficient, since the amount of SiO_2 is high and no other components will cause side reactions.

The amount of sand addition depends on the free lime content of the slag, which is related to the slag basicity. The chemical analysis of free lime would require too much time. The process is started manually. The treatment process itself works fully automatically. On average an addition of about 130-140 kg sand per ton of liquid slag together with an oxygen consumption of about 0.8 - 1 m^3/t of slag is needed to reduce the slag basicity from 4.5 to less than 3 in order to produce a slag with less than 2% of free lime in the solid slag.

The treatment starts with the blowing of oxygen to open the slag lid followed by co-injection of quartz sand plus oxygen. The quartz sand is injected pneumatically into the slag pot. The sand is transported by N_2. The necessary oxygen is added in the cone of the dispenser. Oxygen is required for the treatment process in order to supply additional heat by chemical reaction to solve the added sand, totally and to keep the slag liquid. The treatment of the liquid BOF slag with sand or other SiO_2 materials is successful. The free lime and as far as it can be observed from the treated slag also the free MgO are fixed into stable slag phases after solidification. Microscopic investigations confirm these results. The free lime content is less than 2% for the treated slags. The volume stability of the slag is improved.

Treated BOF slag has nearly no volume increase in the steam test described in EN 1744 Part 1.[8] The treated slag has excellent properties and can be used in fields of application with high quality demands. Different tests have been performed to show the good properties under practical conditions. Aggregates of treated BOF slag have been used as chippings for asphalt, where they show the same performance as materials from high quality natural stone. Even the use of the treated slag as aggregates in concrete paving stones has been tested successfully. Stones for the applications in waterway construction must fulfil requirements like high specific weight, resistance against braking of waves and of course high volume stability. These demands are fulfilled by the treated BOF slags. Tests have shown that the treated slags are comparable or even better than the highly valuable natural aggregates of basalt and diabase.

Additionally, the environmental compatibility has to be determined. Long-term experience confirmed that only a reduced number of parameters must be determined to control the environmental compatibility of the treated BOF slag. After an initial investigation on the leaching behaviour of the treated BOF slag, further examinations have to be carried out regularly only on a few parameters relevant to the environment for this material.

Besides the experience in using steel slags in road construction in Germany, the same experience is known from other countries. The use of steel slag in the wear course in a road extends the life time of the roads. It is established that the life time of a road built totally with steel slags is extended by about 2 to 5 years, depending on the traffic load of the road. Several countries already make use of this experience.

Increasing the quality of basic oxygen furnace slags for the use as fertiliser

Phosphorous is an essential plant nutrient. 85% of the phosphates imported to Germany are used in agriculture. There are limited resources of suitable quality so the rise in global population and the demand for food will increase the price for raw phosphates at the same time as their availability decreases. Domestic phosphate sources are only given in the form of secondary raw materials such as *e.g.* the ashes from the incineration of sewage sludge or meat and bone meal. The P_2O_5-content ranges from 15 to 30% but is not readily available to plants because of the mineral bonds.

Up to the 1990s, Thomas slag, a by-product of steelmaking was widely used in agriculture as an efficient phosphate fertiliser. Due to the switch in steelmaking to ore qualities low in phosphorous and therefore to the LD-converter metallurgy, this type of fertiliser is no longer available. Today´s BOF slag is low in phosphorous and is processed into a highly effective and much used granular converter lime.

A FEhS-project aims to produce a granular converter lime enriched with P. In laboratory and operational tests molten/liquid BOF slag has been mixed with phosphatic ashes. In this way P contained in the ash, which is not readily available to plants, is converted into calcium silicophosphate, which is readily available. The new product has similar properties as the well approved Thomas slag. FEhS-institute creates a Thomas slag of the second generation. By adding a secondary phosphate source to molten steel works slag, a thermal digestion process occurs, which converts the phosphate into a form readily available to plants. In this FEhS-research-project, the technical feasibility, the additive and processing technology are elaborated as are the logistics. Furthermore, the solubility and plant availability of the new product are tested.

Optimising the metallurgical work of electric arc furnace slags

The differentiation between the different kinds of dusts is important, since the use of the dusts varies with the type of unit. Although the utilisation rate of the dust is more than 80% overall, the ratio varies distinctively from unit to unit. The dust generation from iron and steelmaking in Germany and Austria is yearly around 2 million ton. Most of the dust is consumed nearly completely in the steel industry itself. However, as expected, dusts from blast furnaces and LD-converters are the main categories which are used only partially. Mainly the fine parts of the dusts are difficult to utilise.

It is not only the grain size but also the composition that matters. In these fine dusts the concentration of elements with low boiling point is condensed (mostly on iron particles). The concentration of valuable elements worth to be recovered in these dusts is too low for economic recovery operations. However, these contents are too high to allow recycling of the dust into the metallurgical circuit. Therefore, some investigations were started to recycle the dust together with other residues in a special furnace like the Oxy-Cup ® or other special reduction furnaces.

In Europe about 600.000 ton of dusts are generated during EAF-steel production in the electric arc furnace. Valuable metals like zinc and lead from the production of carbon steels as well as chromium and nickel from the production of high-alloy steels are usually recovered from these dusts by external processors. The recovery of the valuable metals, however, is expensive and is a financial burden for the steel production. Therefore, a process is being developed by FEhS-institute to reduce the costs for zinc recovery and to improve the reimbursement for zinc and to improve the process itself (foamy slag). The main target is the recycling of dust back into the EAF. The dust is transported pneumatically to an injection lance which is mounted on a multi-lance manipulator. The lance is positioned in the melt preferably to the houndary of slag and steel. By the injection of the dust the contents of Zn and Pb are increased in the newly generated dust, as expected, which leads to a more economical recovery of these metals. Beside this, also a positive effect regarding an optimisation of generation of foamy slag has been stated.

The recycling of dust from stainless steelmaking aims at the recovering of Cr and Ni into the steel melt. This is achieved by the reduction of the slag at the same time as dust is injected. Additionally, a stable foaming slag practice shall be realised. Due to the different secondary metallurgical treatment lines of steelworks, each steel plant has to define its own way of dust recycling.[9] By the injection of dust no modification of the basicity index of the slag is found. The chromium content in the slag is decreased. A stable foaming slag practice has been achieved due to dust injection. The injection has no negative influence on the steel quality.

Increasing the quality of stainless steel slags

In stainless steel production, raw material costs dominate the total production cost for the primary product.[10] Since chromium is one of the major constituents of stainless steel, it also represents a large portion of the raw material costs. Consequently, a high chromium recovery is essential for the overall process economy.[11] During melting of scrap in the Electric Arc Furnace (EAF) chromium is oxidised into the slag to a great extent. Therefore, reduction of chromium oxide is necessary for both the recovery of the chromium and to improve the environmental behaviour of the slag. Therefore, the reduction process in EAF stainless steel production has two important effects on its economy. Reduction of chromium oxide in slags in stainless steelmaking process is a prerequisite for further utilisation of the slag.

Nevertheless, it is not economical to reduce all the chromium from the slag. Instead, it is necessary to bind the remaining chromium content in the EAF-slag into stable mineral phases to suppress the leaching of chromium from the slag. This target can be realised by modification of the liquid EAF-slag. Fluxes forming mineral phases of the spinel type are most suitable.[12] In laboratory tests at the FEhS-institute to reduce chromium from EAF slag, no significant dependency between the chromium content in slag and the leaching behaviour of the slag had been determined. This is the reason why FEhS-institute decided to do further investigations to stabilise chromium in the slag. The evaluation of several slags from stainless steelmaking of different steelworks all over Europe, which use different process performances, different slag reduction practices and different slag formers, indicated that some of these influencing factors would have consequences on the leaching behaviour of slag. Therefore, the further research was focussed on fixing the remaining chromium content in the EAF-slags into stable mineral phases. The results of the following laboratory investigations to fix the chrome into stable slag phases have shown a relationship between the MgO-, Al_2O_3-, FeO- and Cr_2O_3-content in the EAF-slags from stainless steelmaking and the leaching behaviour of chrome from these slags. Systematic investigations at the FEhS-institute on the slag's mineral composition showed an increase of spinels in the slag matrix by suitable treatment.

Chromium is bound into these spinel phases, which are stable compounds in the slag. The formation of spinel types $Me^{I}O*Me_2^{II}O_3$ (where Me^{I} is Mg^{2+}, Fe^{2+} and Me^{II} is Fe^{3+}, Al^{3+}, Cr^{3+}) will result in strong binding of chromium and the Cr-leaching will be decreased to very low values. Thus, the research has been focussed on finding additions to the liquid slag which will induce the formation of spinel type phases in the solidifying slag.

Especially for EAF-slags from stainless steelmaking a proportional factor was proposed to describe the influence of the different compounds in the slag on the binding efficiency of chromium into stable slag phases and so on the leaching behaviour of chromium, respectively. The so-called "factor sp" summarises the influence of the most important spinel forming compounds in the EAF-slags:

> *factor sp* = $0.2\ MgO + 1.0\ Al_2O_3 + n \bullet FeO_x - 0.5\ Cr_2O_3$ [wt-%] (where *n* depends on the oxidation state of the slag).

This factor enables to estimate the leaching behaviour of a EAF-slag from stainless steelmaking when its composition is known. On the other hand, the effects of adding spinel forming agents to the liquid slag on the leaching of chrome can be estimated.[13] With the knowledge obtained from laboratory tests at the FEhS-institute, operational tests were conducted at different stainless steel plants. On lab scale the influence of iron(II) and alumina was most successful. Therefore, the tests started by the addition of bauxite during tapping of steel and slag into the transfer ladle which was operated by the steel plant. Slag samples from the slag yard showed that due to the homogeneous distribution of Al_2O_3 and FeO_x in the slag the solution of bauxite into the slag was complete. Due to the resulting contents of Al_2O_3 and FeO_x in the slag, the "factor sp" increased, consequently, the examination of the leaching behaviour of the slag showed that the leaching of chromium was diminished down to the detection limit. Thus this first in-plant test confirmed the relationship expressed by the developed "factor sp" by FEhS-institute.

The first treatment of liquid slag in the transfer ladle by addition of bauxite exhibited the feasibility to optimise the EAF-slags from high alloy steelmaking with respect to their environmental behaviour. The good technical properties of the slags did not change. The aim to bind the remaining chromium in the slag into stable spinel phases has been reached.

Moreover, some new discoveries have been gained in regard to the addition practice. The moment of adding the treatment agent is important for the practice. The most suitable point of time is when the transfer ladle is filled to one third. This guarantees good mixing in the ladle. Also very important is the grain size of the material to be added. Best results can be achieved with materials with a small range of grain size 3-8 mm. The achieved results allowed planning additional tests in a pilot scale at an other steel shop of a stainless steel producer. Since the addition of bauxite to a low value product "slag" seemed to be too expensive, other suitable materials had to be used. Due to the experiences in laboratory and the good results from the first tests at the steel shop, residues with high alumina content were chosen for further tests.

Different mixtures of oxide material were investigated, and finally a material called TE (75-85 wt% Al_2O_3 and 10-20 wt% SiO_2) was selected, which seemed to be suitable for the treatment of EAF slag. The grain size of the TE was 3-8 mm. This material was tested at the EAF of a stainless steel producer. An installation to add alloying agents to the steel during tapping was revamped, in order to use it for the addition of spinel forming agents into the slag at tapping. The first transfer ladle was filled up nearly "slag-free", and during tapping steel and slag into the second transfer ladle the spinel forming agent was added. The small amount of untreated slag in the first transfer ladle was sampled as reference. Additionally, the treated slag in the second transfer ladle and in the slag pot was sampled to determine the effects of the addition. The amount of the addition was calculated according to the "factor sp" and the actual EAF-slag composition. According to the treatment the Al_2O_3-content and therefore the "factor sp" increased in the slag. Due to the added SiO_2 in the mixture, the basicity CaO/SiO_2 in the slag decreased to about 1, which corresponded with better technical properties. The most important effect, however, was the leaching of chromium. In accordance with the earlier investigations it has been shown that a high "factor sp" will result in low chromium leaching.

At the end of the test campaigns with the oxide mixture TE to treat the EAF-slags 10.000 tons of optimised EAF-slags with sufficient environmental and technological properties were produced. The treated slag is volume stable. Disintegration due to the dicalcium-silicate transformation must not be taken in account, since these treated slags have basicities CaO/SiO_2 of less than 1.5. The free lime content in the treated EAF-slags is negligible, so that no volume increase due to $Ca(OH)_2$ formation can occur. The strength of the treated EAF-slag from stainless steelmaking is similar to that of EAF-slag from carbon steelmaking. Taking all the results together, the treated material is a highly valuable material.

Other results on the application of "factor sp" from Finish stainless steel producers have been reported.[14,15] The calculation of the "factor sp" allows the steelworks to predict the environmental behaviour of the slag. Then they are able to manipulate the composition of its liquid slag in order to produce slags with low chromium leaching. The found relationship between the "factor sp" and chromium leaching from stainless steel EAF slags has been confirmed.

Increasing the quality and optimising the recycling of secondary metallurgy slags

Slags from secondary steel metallurgy are often composed of calcium-aluminates with partly high CaO and MgO contents. Due to the disintegration of the slags due to the change of modification of dicalcium silicate, the handling and processing generate distinct dust problems. The use of fine grained material, however, in the building industry is limited.

One possible solution is the stabilisation of the slag by rapid cooling or by adding stabilisation elements, such as boron or phosphates (see also paper by Pontikes *et al.* elsewhere in these Proceeedings). Disadvantage is the cost for boron or phosphor oxide and the required handling for the homogeneous solution into the liquid slag. Finally, due to the high MgO content, this material may cause some problems for the utilisation , due to volume stability. From a physical point of view such material is less valuable than building material. Nevertheless the FEhS-institute has developed different methods for operational practice to stabilise the ladle furnace slags.

The recycling of secondary slags into primary steelmaking or into the blast furnace is a second choice to use these materials. Within a project supported by ECSC different recycling routes have been investigated by FEhS-institute, mainly for EAF steelmaking.

The recycling of liquid slag is possible if the logistical prerequisites are given in the steel shop. But mostly it is not possible to transfer the casting ladle with liquid slag back into the steel shop‘s charging area. Therefore, FEhS-institute investigated the recycling of the stabilised or sieved solid slag into the metallurgical cycle of the steel shop. In the early state of the recycling project it became clear that the recycling of the material into the BOF converter is not advantageous. Secondary steel slags contain considerable amounts of sulphur. Although the sulphur capacity of the slag is not fully exploited, steel workers refused to feed this slag into the converter as flux. Thus, FEhS-institute investigated the use of this slag for the blast furnace practice. The coarse material was brought to the blast furnace burden without any problems.

Moreover, the recycling of secondary metallurgy steel slags in EAF steel works has been examined by the FEhS-institute.[16] In this research work different ways to recycle liquid slag as well as the solid slag have been studied. The aim of the project was to use the secondary steel slag completely. Some methods are possible but not always economical. The recycling of coarse particles results in the greatest benefits. After screening, the material is charged with the scrap basket into the EAF. Under the consideration of an exchange of lime it is necessary to replace one part of lime by two parts of slag. There has been no negative effect on the sulphur content, neither on the energy consumption. On the contrary, it has been observed that melting behaviour and the foaming of the slag has been enhanced, especially when mixing the slag with spent refractories.

With the protection of the described advantages it is possible to recycle about 45% of the generated secondary steel slag before reaching the break even point between the costs for slag processing and lime. The benefits are the reimbursement for the lime as well as the reduction of CO_2-emissions. Furthermore, the natural resource limestone is exploited more intensively and landfill space is saved. This is a contribution to sustainable steelmaking in the future.

Conclusions

The FEhS-institute performed investigations to find solutions towards the target of waste free steel production. Steel production without any co-products is not possible, hence it is necessary to develop new products of high quality level from the by-products. In this paper six examples of the most important developed measures by FEhS-institute towards a waste free steel shop are presented. All six measures are in the pilot-scale phase or are already used in the operational practice in the steel shops. Further development takes place.

In laboratory and operational trials for example the modification of the blast furnace slag composition by different modifiers and at different locations has been tested by the FEhS-institute. During operational trials the injection of modifiers has been tested in the main runner, in the skimmer and in the slag runner. The addition of lime into the main runner was a success. The lime was pneumatically injected during tapping into the liquid slag. The lime was totally dissolved in the slag and the slag ratio was increased. This increase was the reason for gaining in compressive strength of mortar prisms. This method allows the treatment of liquid slag without affecting the metallurgical work in the process itself.

Another example is the treatment of liquid BOF slag, a method to produce highly valuable aggregates from this kind of slag. This is also an example for the treatment of liquid slag outside the main process. The treated slag is volume stable and has properties comparable to the best available natural product. Therefore, new applications for these slags have been developed, especially in waterway construction and the surface layers of roads. In Germany this treated BOF slag is called LIDONIT ®.

The last example is the treatment of liquid high alloyed steel slags. The slags from EAF stainless steelmaking often do not fulfil environmental requirements. Therefore, a method to bind the chromium into stable spinel like slag phases has been developed. Thus the operator can decide whether a slag will have environmental problems and by addition of spinel forming agents the slag can be adjusted to stable chromium binding. At the same time the mechanical properties of this slag will be improved.

These are just a few examples of recent activities of the FEhS-institute to promote the use of iron and steel slags as has been the intention of the slag research institute founders in the 1950´s. The good reputation of the FEhS-institute is reflected in the list of members and cooperative partners in Germany and Europe.

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