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SLAG; VALUE ADDED STEEL INDUSTRY BYPRODUCTS

ŻUŻEL; WARTOŚĆ DODANA ODPADU Z PRZEMYSŁU STALOWEGO

Slag is a non metallic co-product, produced in the iron (BF) and steelmaking (BOF and EAF) process. Slag has been commonly utilized on a broad scale ever since these processes were first taken into use. Besides economical benefits, environmental requirements will enhance the need for further product development work concerning the properties of slag in the future, in order to observe the principle of sustainable development. Today, one of the important indicators of sustainable steel industry is quantity of slag (production) and its utilization. This paper discuss the utilization of slag in different fields such as cement, heat and sound isolation, filtration, agriculture, tile and glass production and explain some of important researches in last 35 years which done in Esfahan Steel Co. (ESCo) of Iran.

Keywords: BF, BOF, EAF, slag, ESCo, utilization, cement, insulation, agriculture

Żużel jest niemetalicznym produktem wytworzonym w procesach wielkopiecowym (BF) i stalowniczym (BOF, EAF). Żużel był powszechnie wykorzystywany na szeroką skalę od początku istnienia tych procesów. Oprócz korzyści ekonomicznych, wymagania środowiskowe zwiększą potrzebę dalszej pracy na rzecz rozwoju produktu, odnośnie własności żużla, w celu przestrzegania zasady zrównoważonego rozwoju. Dzisiaj, jednym z najważniejszych wskaźników zrównoważonego przemysłu stalowego jest ilość żużla (produkcja) i jego wykorzystanie. Niniejszy artykuł omawia wykorzystanie żużla w różnych obszarach, takich jak cement, izolacja cieplna i akustyczna, filtracja, rolnictwo, produkcja płytek ceramicznych i szklanych oraz wyjaśnia kilka ważnych badań w ciągu ostatnich 35 lat, wykonanych w Esfahan Steel Co.(ESCO) w Iranie.

1. Introduction

Slag is an integral part of Iron and steelmaking process. The general goal for the whole steelmaking plant is the total utilization of all slag. This paper will discuss utilization ways of BF and BOF slag and present some result of researches which done in ESCo of Iran. The slag is a non metallic by-product of steelmaking process .It primarily consists of silicates, alumina silicates, calcium aluminium silicates, iron oxides and crystalline compounds. Slag from steelmaking industry can be generated either from integrated steel plants or scrap and DRI based steel production slags are classified as blast furnace (BF) and steelmaking slag. BF slag is generated during the process of reducing iron ore by coke (carbon) in a blast furnace. Its sources are the gangue content of iron ore and lime content added to adjust the chemical composition of molten slag. Steelmaking slag generated in the process of refining blast furnace s hot metal in basic oxygen converter. BF and BOF slag generated in integrated mills but EAF slag is achieved in mini mills. Today, one of the important indicators of sustainable steelmaking is quantity of slag (production) and its utilization. About 70 years ago, slag generation in blast furnace was 980 kg/thm and by using enriched iron ore and coke with low ash content, it has decreased to 270 kg/thm.

2. Discussion

2.1. Slag utilization in different fields

As early as 1589, Germans were making cannon balls cast from iron slag and records are available which indicate that cast iron slag stones were used for masonry work in Europe of the 18th century. The history of slag use in road building dates back to the time of Roman empire, some 2000 years ago, when broken slag from the crude iron-making forges of that area were used in base construction. Roads made from slag were first built

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in England, blocks cast of slag were in general use for street paving in Europe and the US. Today slag is a nuisance it dumped and is a valuable material if properly processed. The target of current steel industry is to recycle and utilize all their by products. Slag is the important waste and by products of steel industry, which have been treated, recycled and used worldwide. Zero slag process lowers the amount of slag generated through hot metal pre-treatment, thereby expanding the range of slag utilization.

Iranian BF and steelmaking units generated 1 and 1.3 million tons slag per year respectively. Many research actions done for utilization of this volume of slag as fellows:

- The use of steelmaking and iron making slag in cement production.
- Granulated BF slag as a replacement to part of cement content of concrete.
- Slag contains significant amounts of iron units after processing of the slag in order to recovery lower grade metallic and recycles them back to furnace.
- Recycling of BOF slag into sinter, B.F. and BOF charge.
- Recycling of LF slag in EAF charge.
- Fixation (sequestration) of CO_2 by producing carbonates from steelmaking slag.
- Glass production.
- Construction tiles.
- Sand blasting materials.
- V_2O_5 and V recovery from BOF slag.
- Diabase tiles production (BF and BOFs slag and sludge, used sand, fluorine).
- Production of ceramics powders by BOF slag.
- Sound and heat isolation materials.
- Rail and road ballast.
- The use of slag as water filtration system.
- Road construction.
- Asphalt concrete aggregate granular base and embankment or fill.
- Slag for fertilizer.
- Phytoextraction of heavy metals from steelmaking slag.
- Production of centrifugal pipe and ceramic parts from molten slag.
- Production of potassium silicate fertilizer from steelmaking slag.
- Use of wet slag as a lubricant in high straining rolling for ultrafine grained steel.
- Use of steel slag leach beds for the treatment of acid mine drainage.
- Purifying trout farm water by BF slag.
- Effect of iron oxide, converter sludge and on corn growth in a calcareous dol.
- The use of BF and BOF slag for decreasing of organic load of industrial waste water.
- Water treatment plants and water refining strong structures.
- Anti skid aggregate (snow and ice control).
- Bulk filters (e.g. plastics, adhesive).

2.2. Slag usage in thermal ands insulator manufacturing

Slag wool is manufactured by adding auxiliary raw materials to air cooled blast furnace slag, adjusting constituents, melting the mixture in a cupola or an electric arc furnace and finally fibre zing it with special devices like spinner. The fibres are elongated by jet of air, steam or flame. The product is cured in ovens and formed into familiar insulation bats and blankets or chopped into lose-fill insulation used home, commercial and industrial buildings. The slag wool has a wide range of applications as heat insulating material, fire-proof wall material for houses, heat reserving and sound absorption materials for industrial applications. The fibres are non-combustible and have melting point over 1100°C, they are used in protection against fire. A company near to ESCo plant is the producer of acoustic and thermal insulator from slag wool. This company uses 80000 t/y of BF slag for producing slag wool products, in the forms of bulk wool blanket, panel and preformed pipe. Manufacturing process of BF slag wool is shown in Fig. 1 [1]. The fibrous structure and high density of slag wool insulation offer excellent sound absorption properties, making these products an outstanding part of overall wall system designed to reduce sound transmission. Fig. 2 shows variation of frequencies with sound absorption coefficient of isolator. It resists the growth of mild, fungi and bacteria because it is inorganic. Competitive advantages of BF slag insulators are as fellows:

– Because of using less silica compared with similar kinds of hasn't danger of pulmonary disease and doesn't cause sensitiveness for skins.

– Standard amount of SiO_2 in insulators shows that it's not harmful for environment and can return to ecosystem.

– Low heat conduction coefficient of insulators has caused their high insulating power.

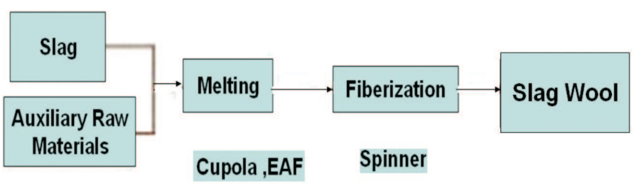

Fig. 1. Manufacturing process of BF slag wool [1]

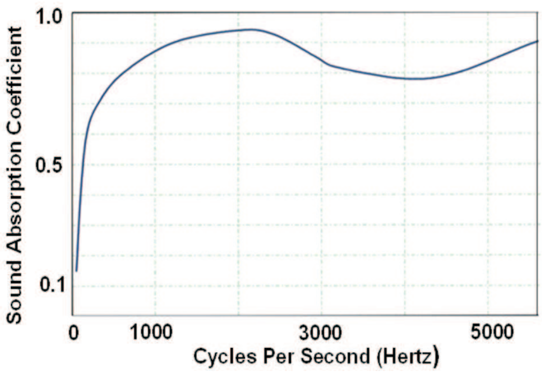

Fig. 2. Variation of frequencies with sound absorption coefficient of isolator

2.3. BF slag as cement raw material

Sepahan Cement company was established in 1969 near to ESCo plant and has been employing two production lines to produce Portland cement using slag of ESCo blast furnaces. BF slag cement with 20-40% slag content is used in general constructions. BF slag cement with higher amount of BF slag is used where the heat of concrete hydration is required to be minimized, where increased resistance against chloride ion, sulfate or sea water attack, is necessary, or reduce likelihood of aggregate reaction. Above mentioned Co. is using 15% BF slag in its cement products. Its cement production capacity is roughly 2.5 million tons per annual. Table 1 shows chemical analysis of slag sulfate resistance cement. Fig. 3 shows tetra pods (breakwaters) manufactured by anti sulfate cement in Persian Gulf costal at Gavater Beris fisher port. It is noted that slag usage in this company is limited due to MgO content of slag. This value must be less than 4% in cement.

TABLE 1

Chemical analysis of slag sulfate resistance slag (%)

Constituent	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	K_2O	Na_2O	SO_3	IR	LOI
(% wt)	26.30	8.3	2.1	55.8	4.2	11.76	0.3	2.1	0.2	0.4

Fig. 3. Tetra pods in Persian Gulf costal at Gavater Beris fisher port

Main characteristic of BF slag cement are
1. Suitable for erection massive concrete constructions such as dams due to its low heat of hydration.
2. Suitable for sewage facilities, offshore constructions.
3. It is better in long term strength than Portland cement.
4. Effective to control alkali aggregate reaction.
5. Excellent water resistance due to greater compactness of hardened concrete with ordinary Portland cement.

Fig. 4 shows composition of BF and BOF slag with respect to Portland cement. Addition of BF slag into cement provides beneficial effect on the environment by reducing CO_2 emissions. CO_2 emission for normal cement is 1011 kg per ton. Addition of BF slag with rate of 30, 50 and 70 percent into cement decreases CO_2 emissions to 730,539,300 kg/t respectively. A burning process is required to produce clinker. In the case of granulated slag, however only drying and crushing are required .This means that use of slag as a cement raw material is characterized by saving of resources and energy [1].

2.4. Production of Portland cement from BF and BOF slag and limestone

In this research, BF and BOF slag after magnetic separation are mixed with limestone of six different compositions. The ground materials are fired in a pilot plant scale rotary kiln to 1350°C for 1 h. The clinker is cooled, crushed, mixed with 3% gypsum, and ground to fineness of more than 3000 cm^2/g. Initial and final setting times, consistency of standard paste, soundness, free CaO, and compressive and fractural strength after 3, 7 and 28 days are measured. Samples with higher lime saturation factor developed higher C_3S content and better mechanical properties. Blending 10% extra BF slag, 43% calcinated lime and 8% BOF slag kept the compressive of concrete above standard values for type 1 ordinary Portland cement. Table 2 illustrates composition and analysis of the six different mixes [2]. Samples M_3, M_5 and M_6 showed relatively god mechanical properties. It was concluded that, in this compositions, the C_3S developed better, sample M_6 needs more attention because there is no BOF slag, the iron content is low and SR ($SiO_2/Al_2O_3+Fe_2O_3$) and AR (Al_2O_3/Fe_2O_3) are high, therefore, a higher firing temperature is required to decrease free CaO. Cement M_3 was blended with 10% BF slag as in the Portland BF cement, and compressive strength of 140.3, 193.8, 333.3 kg/cm^2 were obtained after 3, 7, 28 days, respectively. The minimum compressive strength of concrete for type 1 Portland cement according to ASTM C150-86 for same period is 120, 190, and 280 kg/cm^2, respectively.

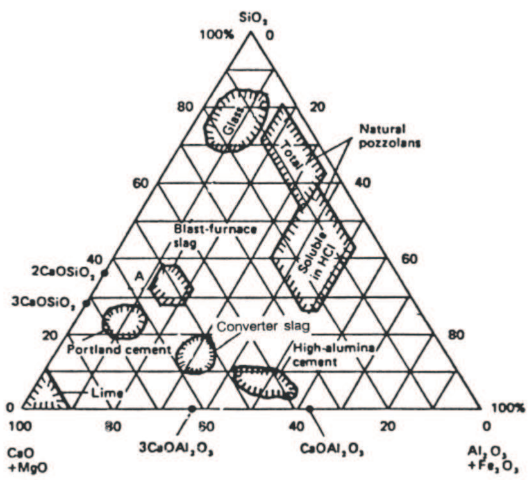

Fig. 4. Composition of BF and BOF slag with respect to Portland cement [2]

TABLE 2
Composition and analysis of the six different mixtures [2]

Sample no.	**M_1**	**M_2**	**M_3**	**M_4**	**M_5**	**M_6**
Calcined lime (%)	28.0	36.0	43.0	28.0	31.0	51.0
Iron slag (%)	48.0	51.0	49.0	54.0	42.0	49.0
Steel slag (%)	24.0	13.0	8.0	18.0	27.0	0.0
Limestone (%)	40.0	49.0	57.0	40.0	44.0	64.0
Iron slag (%)	40.0	41.0	37.0	45.0	34.0	36.0
Steel slag (%)	20.0	10.0	6.0	15.0	22.0	0.0
Calculated Chemical Analysis						
CaO (%)	56.0	57.9	60.5	54.8	58.0	63.0
SiO_2(%)	21.9	22.4	21.7	23.5	20.3	21.5
Al_2O_3(%)	4.6	4.7	4.5	4.9	4.2	4.4
Fe_2O_3(%)	5.5	3.3	2.3	4.3	6.2	0.7
MgO (%)	5.9	6.2	6.0	6.4	5.4	6.1
Others (%)	6.1	5.5	5.0	6.1	5.9	4.3
LSF	80.5	83.0	90.3	74.8	89.0	96
SR	2.3	2.8	3.2	2.5	2.0	4.2
AR	0.8	1.4	2.0	1.1	0.7	6.3
Measured Chemical Analysis						
CaO (%)	54.2	58.2	58.7	57.7	58.4	61.8
SiO_2(%)	19.39	19.9	19.0	20.9	17.9	18.3
Fe_2O_3(%)	5.4	3.0	2.6	3.8	6.6	1.5
MgO (%)	5.9	4.8	5.1	6.0	6.6	5.8

2.5. Diabase tiles production from BF, BOF slag and other waste materials

In this study manufacturing of wear and acid resisting tiles produced from iron and steel making waste materials was studied. BF and BOF slag, BOF and sinter plant sludge, BF dust, used foundry sand fluorine and carbonate sodium charged in required percentage in typical glass melting furnace. Raw materials and molten glass chemical compositions are shown in Tables 3 and 4, respectively. After melting of input mixture, it cast in preassembled mould by using press. The tiles immediately transferred into a heat treatment furnace with temperature of 700°C for annealing and then, cooled down to normal temperature in the furnace. Cast and heat treated tiles are shown in Fig. 5. Evaluation of manufactured tiles was done as below. Bending strength was measured according to ASTM C158-95 and found to be about 88 MPa. Hardness of tiles was measured as 750-800 Vickers. Chemical attack resistance of tiles was measured in

H_2SO_4 (98%) solution. After weighting, the tiles were immersed in acid solution and kept then they were removed, dried and weighted again there for 48 hours. No weight loss and no changing of apparent form were observed for the tiles. The manufactured tiles are used successfully in ESCo coke making plant as guide cover of coke channel.

TABLE 3

Chemical composition of anti wear and acid tiles [3]

Constituent	SiO_2	CaO	MgO	Al_2O_3	FeO	Fe_2O_3	MnO	TiO_2	K_2O	Na_2O	CaF_2
(% wt)	38.01	14.77	3.40	3.18	5.04	26.88	1.19	1.05	0.43	0.21	5.27

TABLE 4

Molten glass chemical compositions [3]

Materials	Mixture composition				
	BF Slag	BF Dust	BOF Slag	BOF Sludge	SP Sludge
SiO_2	36.4	10.0	14.6	1.5	10.4
CaO	35.4	35.4	45.2	6.3	12.2
MgO	8.9	1.8	4.9	1.7	3.8
Al_2O_3	9.6	1.9	3.9	0.7	3.1
FeO	1.1	10.5	7.4	11.8	5.8
Fe_2O_3	0.0	36.4	12.0	71.2	28.7
MnO	1.5	0.3	4.0	1.5	0.6
TiO_2	3.1	0.0	1.1	0.3	0.8
K_2O	0.8	0.4	0.1	0.5	0.5
Na_2O	1.4	0.3	0.3	0.3	0.3
PbO	0.0	0.2	0.0	0.1	1.0
ZnO	0.0	0.3	0.0	0.0	1.3
P	0.0	0.2	1.2	0.1	0.2
S	1.2	0.6	0.2	0.2	0.8
C	0.6	30.8	1.5	1.1	25.5
LOI	0.0	32.0	0.0	3.5	30.4
Total	100.0	100.0	100.0	100.0	100.0

Fig. 5. Tiles manufactured by molten glass [3]

2.6. Recovery of vanadium from BOF slag

BOF steelmaking slag has become an important secondary raw material and this bearing slag is great interest for recovery of vanadium, during refining of BF hot metal with oxygen, oxidizes and gradually becomes part of BOF slag. In ESCo, about 220000 tons BOF slag produced yearly due high amount of vanadium in this slag 2-3% V_2O_5, recovery of V seems to be necessary. Chemical composition of the slag is indicated in Table 5 [4].

TABLE 5
XRF results of chemical composition of BOF slag constituents [4]

Constituent	CaO	Fe_2O_3	MnO	Al_2O_3	SiO_2	V	P_2O_5	TiO_2
(% wt)	53.74	20.95	9.3	1	8.39	0.948	2.078	1.261

Salt roasting basic leaching is the process which was applied to separate and extract from BOF slag. Ground slag was roaster after mixing with determined quantities of sodium carbonate. The optimum temperature time and Na_2CO_3 content in the roasting process were found to be 1000°C, 45 min and 10% respectively. Temperature, time, leached concentration and particle size were optimized for leaching process. It was determined that sodium carbonate is the major leaching agent in comparison NaOH. The most suitable conditions for leaching process were found to be 80°C, 60 min, Na_2CO_3 to NaOH mass ratio of 40-50: 10 and particle size between 100-120 mesh. More than 80% of V was recovered under optimum conditions. It was found that at roasting temperature higher than 1000°C, Na_2CaSiO_4, a glassy phase was formed and lead to a decrease in vanadium recovery [4].

2.7. Ceramic pipe manufacturing by using of molten BF slag

In this project molten BF slag was used to produce ceramic pipe and pieces. In the first stage, molten BF slag cast in sand mould, later it cast in centrifugal mould BF slag is usually melilite (solid solution series of gehlenite, $2CaO.Al_2O_3.SiO_2$, and akermanite, $2CaO.MgO.2SiO_2$) with a small amount of calcium sulphide (oldhamite) <1%. Sometimes merwinite ($3CaO.MgO.2SiO_2$) is also present and more rarely dicalcium silicate $2CaO.SiO_2$. Results shows cast parts has akermanite, merwinite, glass (amorphous) and small amount of forsterite phase. By controlling of crystallization it is possible to manufacture ceramic piece with required mechanical strength and hardness. In this study BF molten slag is used as is it. Future research will be done by some modification of molten BF slag. The physical specification of centrifugal cast pipes shown in Table 6.

TABLE 6
The physical specification of centrifugal cast pipes

Property	Amount
Mechanical strength	970 kg/cm^2
Water absorption	0.3 %
Porosity	0.96 %
Density	3.21 (g/cm^3)

2.8. Converter slag as a liming agent in the amelioration of acidic soils

Conventionally, BF slag has been utilized principally as a raw material for silicate fertilizers. Additionally, BF slag contains such fertilizer component as lime and magnesia as well as Fe and B. silicate fertilizers, popularly known as silicate-calcium fertilizers are widely recognized as given good result with aquatic rise. For farms lime, magnesia and silicates abundant in BF slag, improve the chemical properties of soil.

• Farmer use agricultural slag for maximum yields of cultivated crops and pasture

• Home vegetable gardeners need an easy to spread slag liming materials. It also helps to improve soil texture minor nutrient fertilization from agricultural slag is a big attraction.

• Parks, golf courses and lawns need to correct soil acidity in order to assure optimum benefit of applied fertilizer. Agricultural slag flows easily though lawn spreads.

• Nurseries and greenhouse use agricultural slag is making rich soil for plant beds and strip mining need a liming material to neutralize high soil acidity.

Soil acidity is a major factor limiting crop yield in vast areas of the world .Acid soils occupy about 3.95 billion ha and account for 30% of world's ice free land area .The most important by-product in amending acid soil is BOF slag. In this study, the possibility of using BOF slag as a soil amendment was investigated in three acid soils. Converter slag contains 52.8% CaO and 22% MgO plus large amount of other elements such as Fe, P, Si and Mn. First stage was incubation phase and treatments were 0, 0.5, 1, 2, 4, 8 and 16% (w/w) of BOF slag per kg soils and its moisture content was adjusted closer to field capacity. The change pH, EC and AB-DTPA-extractable Fe, Mn, Zn, P and K were determined after 1, 10, 30 and 60 days. Second phase was a green house study. Treatments were 0, 0.5, 1 and 2% w/w and 0, 1, 2 and 4% w/w of BOF slag in rice and orchard soils, respectively. Slag increased soil pH and rate of increase was proportional to the amount of slag used. The slag decreased Fe at pH range of 7.4-8.5 but increased at higher pH. While use of slag proportionally, increased P and Mn availability. In greenhouse studies the application of 1 and 2% (w/w) of slag in the tea garden soil and 0.5, 1 and 2% slag in rice field soil increased plants shoot dry yield and plant Mn uptake. Fe and K uptake increased in rice field. K uptake decreased in tea garden soil and Fe uptake was changed not. In conclusion the BOF slag was a suitable amendment for acidic soils [5]. The results allow concluding that the slag <1 mm was efficient to correct the acidity. On the other hand, the slag from 2 to 10 mm sized didn't present satisfactory results. In addition, any water contamination was verified at the leaching columns, suggesting that the slag <1 mm has great potential use in the agriculture as an environmental safe liming material [6].

2.9. Purifying trout farm water by BF slag

Air cooled BF slag has used as an ideal filter medium in the treatment and subsequent recycling of water from race way containing toxic matters. The slag function is to filter out solids and ensure retention of micro organisms which remove and metabolize toxic ammonia created by the fish that otherwise would prevent recycling the water besides its excellent structural and chemical qualities for this unique application, the BF slag was found to be a perfect habitat for the nitrogen fixing micro organisms because of its alkalinity and its vesicular structure which prevents micro organisms being lost during back flushing. By this process it is possible to increase the water supply capacity up to 100%. Before the water can be returned to the front end of the raceways it must pass through the slag treatment system as shown in the Fig. 6.

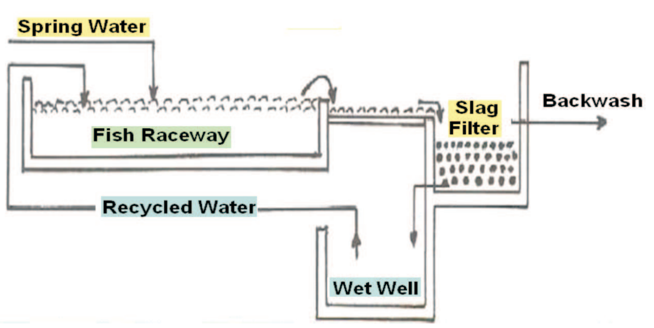

Fig. 6. Purifying trout farm water by BF slag

2.10. Usage of BF and BOF slag for reduction of industrial waste water's organic load

Decreasing the organic loads of industrial waste water to achieve environmental standards, before to discharge it into the absorber circumstance is an important matter (task). Absorber or chemical oxidation with oxidizers such as iron and manganese oxides for removing of non analysable organic compound from industrial waste water is assumed as normal wise process. In this study, the impact of BF and BOF slag on refining of COD of two types industrial waste water in batch reactor with suspension, in the experimental scale ,was researched some of specification of BF and BOF slag such as pH, electrical composition are determined (Table 7) [7].

TABLE 7

Some Specifications of ESCo BF and BOF Slag [7]

Parameter	CFC (meq/100g)	EC (μs/cm)	pH	Spe. Surface (m^2/g)	Density (g/cm^3)
B.F slag	1.9	191	8.0	0.51	1.1
BOF slag	2.5	5360	11.2	2.2	1.7

Results of research showed that addition of BF slag to waste water of ShahinShahr (city) and ESCos (having phenol) decreased the content of COD to 47 and 23 percent, respectively. For BOF slag this rates were 59 and 61 percent, respectively. The hard, stable and vesicular nature of air-cooled BF slag provides an excellent medium for percolating filter beds in sewage treatment works where its high surface area maximises biological activity.

2.11. Application of phytoremediation for decrement of heavy metals in BOF slag

In this research method of phytoremediation in decreasing the amount of heavy metals in BOF slag of ESCo is studied. The study is conducted with the use of randomized complete block statistical design in factorial frame with two factors of soil including 3 level such as soil, slag, 50% soil and 50% slag) and improving matter (FeEDDHA,NPK, without fertilizer) carpobrotus plant used for the study of absorption rate V and Zn elements from slag. The results show that carpobrotus plant has good potentials for resisting of slag circumstance and absorption of V metal from slag and more than 629 mg V absorbed per each kg dry matter from sub rate slag, but Zn absorption rate from polluted soil with slag was not noticeable, addition of FeEDDHA to sub rate for the comparison of samples showed there no noticeable change in V metal absorbtion and in vase sample including NPK noticeable decreasing of the comparing with control sample observed. According to analysing of variance data, absorption of Zn metal in slag cares and 50% soil and 50% slag had noticeable decreasing with compared sample addition of FeEDDHA resulted as increasing of absorbed Zn metal in noticeable level as compared with the control sample while NPK has no appreciable influence on Zn metal absorption through Carpobrotus plant. Effect of increasing FeEDDHA and NPK rate on dry weight of plant as compare with control sample was noticeable having Carpobrotus plant in slag and 50% soil and 50% slag sub rate resulted in noticeable rate of plant weight decreasing and its performance. Therefore one major result from this work is to emphasise that Carpobrotus plant has high absorption potential for V metal [8].

2.12. Slow release potassium silicate fertilizer

The effect of silica (SiO_2) as a fertilizer is generating interest since it increases the resistance of rice to various diseases and vermin. Slag generated in the hot metal desiliconization slag as the main material, a potassium silicate has been developed. The newly developed fertilizer is difficult to dissolve in water, and slowly dissolves in the weak citric acid released by plant roots. The slowly release potassium silicate fertilizer is produced by adding a potassium material to desiliconization slag. This fertilizer contains potassium in slow releasing from, which was effectively absorbed by plant. At the desiliconization station into hot metal pre-treatment process, hot metal first subjected to desiliconization treatment and then

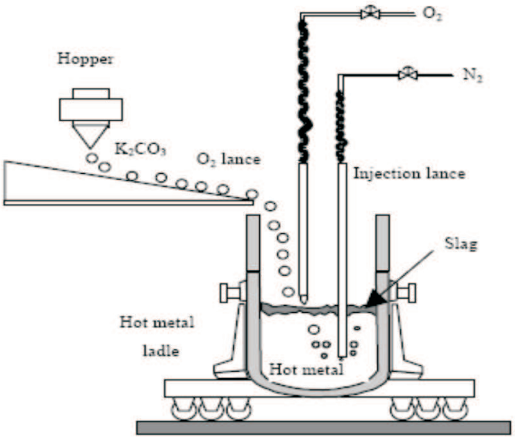

Fig. 7. Production of potassium silicate fertilizer from BOF slag [9]

KCO_3 Continuously added into hot metal ladle from the hopper above ladle while agitating the hot metal using N_2 gas as shown (Fig. 7) [9]. Uniformly melted slag is recovered from the hot metal ladle. The chemical composition of the slow release potassium silicate fertilizer is shown in Table 8 [9]. This research in ESCo is under study stage.

TABLE 8
Chemical composition of the potassium silicate fertilizer [9]

Constituent	K_2O	SiO_2	CaO	MnO	MgO	FeO	Al_2O_3
(g/kg)	221	377	213	37	9	31	35

3. Conclusion

- From resources and energy saving and CO_2 emissions view points; BF slag is an efficient material for cement and isolation industry.
- Research and long term experience have demonstrated that concrete made with ground granulated BF slag shows many advantages, such as better workability, resistance to alkali-silica reaction, chloride ingress and sulphate attack. Ground granulated BF slag typically replaces 50% of Portland cement in a concrete mix. That replacing Portland cement with slag cement in concrete can save up to 59% of the embodied carbon dioxide emissions and 42% of the embodied energy required to manufacture concrete and its constituent materials.
- BF slag is a source of alumina and silica in glass and tile manufacturing.
- Air cooled BF slag is an ideal filter medium in the treatment and subsequent recycling of water and waste water.
- The agricultural BF slag product is as an economical alternative to agricultural limestone or dolomite and as a better source of materials to apply. It is revealed that use of basic slag as a source of lime will be very much effective to increase as well as to sustain the productivity of acid soils.
- Slag has been shown to be an effective phosphorous removal media at fish hatcheries**.**
- Slag is beautiful things not waste material.

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