Development of sustainable Ecosystem through use of Industrial by product for development of Urban Infrastructure: Study of Industrial by product use by firms in Indian Iron and Steel Industry.

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Abstract— ***Industrial Ecosystem is highly degenerative and during the production process, it generates a lot of by product and wastes, which includes both solid and gaseous substances. Industrial Ecosystem also contribute substantially to environmental pollution through contribution to Green House Gas emission. Management of Industrial by product and waste is a huge challenge. So effective Industrial by product and waste management is essential for sustainability of the Industrial Ecosystem. The developing countries are growing at a fast pace, due to which migration of population from hinterland to cities is taking place in an unprecedented rate. This is leading to growth of urbanization at a rapid pace. In order to cater to that, there is a need to augment the Infrastructure. So can the Industrial by products be used to build the Urban Infrastructure which will help in achieving a sustainable growth for both Industry and Urban Infrastructure ? In this article, we have examined the case of by product generation by firms in Indian Iron and Steel Industry (IISI) and their use in building urban Infrastructure. Production of Iron and Steel is a complex process and during the entire production cycle, iron ore is processed through a no. of intertwined and integrated steps to deliver the final output. Slag is one of the by product generated both during the production of Iron (Blast Furnace Slag) and Steel (LD Slag) in addition to other gaseous by products and flue dust. A lot of studies were conducted in different countries like USA, European countries , Japan and China about the use of LD slag for development of urban infrastructure like land filling and road construction. Off late studies were also conducted about the use of LD slag as a substitute for fertilizer. It has been observed that countries like USA, European countries , Japan, China etc. effectively utilize the LD slag and Blast Furnace slag for land filling, road construction, production of cement and use as a substitute for aggregate and sand. Even some of the countries are effectively utilizing the LD slag as a substitute for fertilizer. Use of LD slag not only helps in conserving the natural resources but also helps in reducing the carbon foot print thus creating a sustainable Ecosystem. But in the Indian context studies are scant about use of LD slag for land filling and road construction although few firms in Indian Iron and Steel Industry are working towards hundred percent solid waste utilization by utilizing the by products for Infrastructure development. To address this gap, we have collected data from secondary sources regarding use of LD slag for few firms in the Indian Iron and Steel Industry. India being a developing economy, needs to develop a lot of urban infrastructure to cater to the need of the future population that will migrate from the hinterland to the urban spaces. LD slag can be effectively utilized for building Urban Infrastructure especially land filling and road construction. LD slag contains lime, which makes it unstable and thus it becomes unsuitable for use in road construction. So weathering of LD slag is required to increase the stability which can subsequently be used in the subbase of the road. Use of LD slag for road construction can eliminate the use of a lot of natural resources like sand and aggregate which will lead to it's conservation and thus creation of a sustainable ecosystem. From the literature, It has also been observed that LD slag use in Hot mix Asphalt (HMA) for road construction is being deployed on a trial basis in many countries especially in China. The result of use of LD slag in HMA is showing an encouraging result and also it's use is reducing the Green House Gas emission. But in India the use of LD slag in HMA is scarce. Similarly use of LD slag as a substitute for fertilizer is being tried in other countries and the results are encouraging. But in the Indian context the use of LD slag as a substitute for fertilizer is also limited. So there is scope future research in all these areas for use of Industrial by product for creation of urban infrastructure. If found successful, then it will help in creating a sustainable ecosystem which will lead to regenerativeness.***

Index Terms- LD Slag, Indian Iron and Steel Industry (IISI),sustainable Ecosystem, Road Construction, Road sub base

I. INTRODUCTION

"Increasing uncertainties, vulnerabilities, and inequalities have been observed in secondary sectors across all geographies. The design processes in secondary ecosystems are fast degenerating, despite the best human efforts" (Nayak & Hage, 2020). Industries in Secondary Ecosystem generates a lot of waste and by products during the production process. Management of that waste and by product is a huge challenge for the Industries for their future sustainability (Chaurand et al., 2007 ; Baalamurugan et al., 2019). LD Slag is an industrial by product that is generated during the production of steel in through Basic Oxygen Furnace (BOF) route in which oxygen is injected into pig iron to convert the same to steel. Many countries started using LD slag for different purposes e.g. concrete construction, crop cultivation , CO2 sequestration etc. In world as well as in India close to 70% of Steel is produced through BOF route (Piloneta et al., 2021) and in the year 2022, India produced approximately 125 Million Tonne (MT) steel. (World Steel Association,2023) During production of one Ton steel, between 100 - 150 kg slag is produced. Thus a huge volume of LD slag is available for use, but till date a limited quantity of LD slag used as a substitute material for road construction. (Baalamurugan et al., 2019).

Developing countries are rapidly moving towards large scale urbanization due to economic development as a result of which there is migration of workforce from Agriculture sector to Industrial sector. This is putting a huge pressure on Urban Infrastructure, India is also passing through the same phase where in rapid urbanization is happening due to migration of the labour force. Thus it's imperative to create Infrastructure to accommodate the migrating population. In view of this Government of India is planning to implement projects to create the Infrastructure to accommodate the population. But creation of Infrastructure will put additional burden on the natural resources and the impact on environment is also huge. So alternative resources needs to be explored for creation of the urban Infrastructure.

In this article we have explored the use of LD slag for creation of urban Infrastructure. This will not only help the use of Industrial waste and by product but also reduce the use of natural resources like minor mineral in the form of sand and aggregates for construction of roads and other Infrastructure. In order to do so, the study narrows its focus to answering the following research questions (RQs) to understand the creation of sustainable urban Infrastructure through use of Industrial waste and by products..

- Whether Industrial waste from Steel Industry (LD slag) can be used for creation of future Urban Infrastructure in India ?
- Whether use of LD slag for creation of urban Infrastructure can lead to a sustainable Industrial and urban Ecosystem ?

Based on literature review we postulated that, Industrial waste and by products can be used for creation of Urban Infrastructure. Use of LD slag for construction of road can reduce the use of natural resources like sand and aggregate and also it contributes to reduction in Green House Gas emission (GHG) (Cass & Mukherjee , 2011). The uniqueness of the study aims to widen the scope of the use of Industrial waste and by products for creation of sustainable urban Infrastructure and bridge the gap in the extant literature on the same. This study contributes in multiple ways through its analysis of various use of Industrial by products for creation of Infrastructure in the Indian context.

The article is organised into five parts. The first section is a general introduction, while the second section focusses on the review of literature. The third section details the research methodology, which includes the data collection method, analysis of the data and discusses the outcome of our research. We conclude our chapter by spelling out the scope for further investigation in the fourth section.

II. LITERATURE REVIEW

Economic development of a country remained one of the major goals of any incumbent Government, as it is expected to improve the quality of life of people of that country. Various researchers have found a close correlation between economic development and investment in Infrastructure (Fan & Chan-Kang, 2008). Among different types of Infrastructure, Transportation Infrastructure is considered to be crucial for economic development of a region (Sahoo

& Dash, 2012 ; Maparu & Mazumder,2017). Investment in various Transport Infrastructure may support growth of urban population and support it's spatial spread and Pradhan(2007) found a close correlation between development of Infrastructure and urbanization. To support Industrialization, a large no. of workers needs to reach the firms in city centres or peripheral industrial and commercial zones . Hence clustering of employment requires expensive transportation infrastructure. Also firms need to get their goods to markets (Akbar et al. 2018 ; Henderson & turner,2020). Ghosh and Kanjilal (2014) studied the unidirectional causality that binds energy consumption to economic activity and economic activity to urbanization and they have advocated for integrating long term energy planning with rapid urbanization in India.

Use of LD slag for construction of roads and manufacture of concrete have been studied by many scholars. Use of Concrete is the most essential material in any civil engineering construction and it's production process requires improvement to comply with global issues in energy and environmental conservations. In Modern times, concrete is made by mixing cement, water and aggregates and few additives are added mainly to improve its density and mechanical properties. Effective replacement of steel slag as coarse aggregate in concrete improves compressive strength by 4 to 7% at all the replacements of normal coarse aggregate (Das et al., 2006; Nadeem & Pofale, 2012 ; Baalamurugan et al., 2019). Study of use of BOF slag as coarse aggregate in road surface layers was performed by Piloneta et al. (2021). It has been observed by them that use of BOF slag improves the technical and environmental performance of asphalt mixtures compared to the natural aggregates (Barišić et al., 2016;Piloneta et al., 2021). Yi et al. (2012) analysed use of LD slag trend in China and found the use of LD slag is only 22% in China. So they explored the feasibility of using the accumulated LD slag and suggested that the same can be used for recycled raw material in various processes of steel industry, aggregate for road construction, cement additive and concrete admixture (Branca et al., 2020 ; Guo et al., 2021). Li et al. (2022) examined the use of LD Slag as a base material for road construction. Based on their study they have concluded that LD slag is suitable for semi rigid base in road construction. But use of LD slag as a base material needs to be further examined considering the GHG emission in it's production process (Li et al., 2022) . Shen et al. (2020) studied the preparation process of carbonated steel slag pervious concrete and concluded that it meets the requirements for cleaner production and sustainable development. There are mainly three facets involved in this. First it effectively utilize the waste generated during production of steel i.e. LD slag. Secondly it also reduces the use of natural resources, energy consumption and CO_2 emission. Lastly it also improves the material properties, i.e., the higher porosity and strength of pervious concrete (Shen et al.,2020). Gwon et al. (2018) studied the use of steel slag as a substitute for fertilizer and it's impact on environment due to adverse impact of LD slag on land fill site which lead to air and water pollution. They observed that LD slag substantially reduced the CH_4 emission rate and increased the microbial activity and increased grain yield (Gwon et al.,2018).

Considering the huge production of LD slag in China, Lai et al. (2021) studied the use of LD slag as a replacement of coarse and fine aggregate in production of fifteen different types of concretes, which they termed as "Greener" concrete. They have observed that the mechanical properties (later-age compressive strength) and microstructure of all the 15 types of concrete could significantly improved through replacement of approximately 50% coarse aggregates. and 30% fine aggregates by LD slag. Thus they have concluded that use of LD slag for production of concrete not only improves the environmental performance and material greenness but also it improves the mechanical and structural properties of the concrete (Lai et al., 2021). For the construction of the entire road pavement structure, the use of steel slag has been considered due to the increase of stiffness in the mixtures (Dondi et al., 2021; Gao et al., 2021)

Use of LD slag as a substitute for fertilizer and micronutrient for plants were studied by many scholars. Altland et al. (2015) found that use of LD slag as a substitute for fertilizer can provide micronutrients to some category of crops where as it may not be effective in providing the micro nutrients in other category of crops. Based on their study they have concluded that LD slag can at best replace part of fertilizer as a substitute to provide micronutrient to plants, but can't act as a substitute for fertilizers. Hence steel (LD) slag should not be used as the sole source of micronutrient for plants (Das et al.,2006; Altland et al., 2015 ; Altland et al., 2016). Connor et al. (2021) examined the utilisation of LD slag as a soil amendment, and it's environmental implications and risk assessment of their utilisation in agricultural soils. They have observed that increased utilisation of LD slag can stimulate the economic growth which will lead to sustainability for future generations by creating a closed-loop system and circular economy within the metallurgical industries. Slags can be used as a soil amendment, and slag characteristics may reduce leachate potential of heavy metals, reduce CO2 emissions, as well as contain essential nutrients required for agricultural use and environmental remediation.- In addition to that they have also concluded that, the high reactivity of CaO and MgO in steel slag can cause overliming in soil and repeated soil application. This pollution can also be seen in slag heaps as well as leachate release from slags used in concrete and road construction (Chaurand et al., 2007 ; Chand et al. , 2016; Connor et al., 2021). But Chand et al. (2016) analysed the property of LD slag of three different Steel plants in India i.e. Rourkela Steel Plant, Bokaro Steel Plant and Tata Steel and concluded that the leaching due to LD slag is well below the permissible limit and hence reflects the non hazardous nature of the LD slag.

III. RESEARCH METHODOLOGY

1.3.1 : Data Collection:

The objective of this study was to understand the use of Industrial waste and by product for development of urban Infrastructure which will reduce the load on use of natural resources for creation of urban Infrastructure thus leading to sustainability. Since India is in the path of rapid Industrialization which lead to rapid urbanization. Waste and by-product generation in Industrial Eco system is quite huge and same is true for Iron and Steel Industry (IISI). In steel-making process, hence steel industry is considered as the sample industry to understand the phenomenon. Slags are generated in during various stages of steel production. Production of steel through processing of Iron ore is a complex process and involves multiple process steps. Depending upon the process in which the slag is generated, it is classified as Blast Furnace (BF) slag, Linz-Donawitz (LD) slag, Electric Arc Furnace (EAF) slag or Ladle Furnace (LF) slag (Gwon et al., 2018). Based on the literature review it is observed that, use of LD slag for various applications is quite low in India compared to other countries. So two firms from Indian Iron and Steel Industry were selected as sample firms to study the pattern of use of LD slag for construction of urban Infrastructure.

The two firms selected from Indian Iron and Steel Industry are Tata Steel Limited (TSL) and Steel Authority of India Limited (SAIL). SAIL is a public sector steel company and was set up by the Government of India after independence. At present, SAIL is operating five integrated steel plants (ISPs) and four alloy steel and special steel plants. The integrated steel plants are located in eastern and central India. It is the second-oldest steel producer in the country after M/s Tata Steel Limited. The data was collected from the Sustainability Report of SAIL, which is also available in the public domain. Another firm that forms a part of our sample is M/s Tata Steel Limited (TSL). TSL is the oldest steel firm in the Indian iron and steel industry and was established in 1907. At present, TSL is operating plants across the globe. In India, TSL has its operating plants at Jamshedpur and Odisha. The data is collected for the Indian operation of TSL from their Integrated Report, which is also available in the public domain. Data collected for SAIL and TSL is presented in the table below.

Table 1.1 : Data collected from the Sustainability Report of Steel Authority of India Ltd.

Sl. No.	Year	Quarter	Crude Steel Production (MTPA) (per quarter)	Production of LD Slag (Mt) (Per quarter)	LD Slag in MT/MT of Crude Steel	Percentage Utilization (%)	Ln (LD Slag (Mt))	Ln(LD Slag in MT/MT of Crude Steel)	Ln (Percentage Utilization (%))
1	2010-11	Q1	3.20348	320668.35	100.10	84.4	12.68	4.61	4.44
2		Q2	3.27078	327732.16	100.20	84.3	12.70	4.61	4.43
3		Q3	3.4323	344259.69	100.30	84.2	12.75	4.61	4.43
4		Q4	3.55344	356765.38	100.40	84.6	12.78	4.61	4.44
5	2011-12	Q1	3.19065	328317.89	102.90	84.6	12.70	4.63	4.44
6		Q2	3.24405	335434.77	103.40	84.7	12.72	4.64	4.44
7		Q3	3.3909	350958.15	103.50	84.8	12.77	4.64	4.44
8		Q4	3.5244	365480.28	103.70	84.4	12.81	4.64	4.44
9	2012-13	Q1	3.18054	334274.75	105.10	70.2	12.72	4.65	4.25
10		Q2	3.27448	346112.54	105.70	70.6	12.75	4.66	4.26
11		Q3	3.43552	364852.22	106.20	70.4	12.81	4.67	4.25
12		Q4	3.52946	376593.38	106.70	70.3	12.84	4.67	4.25
13	2013-14	Q1	3.23204	349706.73	108.20	80.8	12.76	4.68	4.39
14		Q2	3.31352	360842.33	108.90	80.9	12.80	4.69	4.39
15		Q3	3.4629	376763.52	108.80	81.5	12.84	4.69	4.40
16		Q4	3.57154	388940.71	108.90	81.8	12.87	4.69	4.40
17	2014-15	Q1	3.29667	361974.37	109.80	83.4	12.80	4.70	4.42
18		Q2	3.39404	375380.82	110.60	84.5	12.84	4.71	4.44
19		Q3	3.56096	395978.75	111.20	83.7	12.89	4.71	4.43
20		Q4	3.65833	408635.46	111.70	84.6	12.92	4.72	4.44
21	2015-16	Q1	3.39864	368752.44	108.50	78.4	12.82	4.69	4.36
22		Q2	3.48432	379442.45	108.90	77.8	12.85	4.69	4.35
23		Q3	3.6414	396184.32	108.80	78.2	12.89	4.69	4.36
24		Q4	3.75564	409740.32	109.10	78.1	12.92	4.69	4.36
25	2016-17	Q1	3.451	378919.80	109.80	71.3	12.85	4.70	4.27
26		Q2	3.5235	387585.00	110.00	70.9	12.87	4.70	4.26
27		Q3	3.6975	407464.50	110.20	71.2	12.92	4.70	4.27
28		Q4	3.828	422994.00	110.50	70.8	12.96	4.71	4.26
29	2017-18	Q1	3.55974	412929.84	116.00	60.2	12.93	4.75	4.10
30		Q2	3.64986	424843.70	116.40	60.6	12.96	4.76	4.10
31		Q3	3.8301	446589.66	116.60	59.4	13.01	4.76	4.08
32		Q4	3.9803	464899.04	116.80	59.6	13.05	4.76	4.09
33	2018-19	Q1	3.8794	436820.44	112.60	55.7	12.99	4.72	4.02
34		Q2	3.9609	446789.52	112.80	56.1	13.01	4.73	4.03
35		Q3	4.1565	469829.09	113.03	56.9	13.06	4.73	4.04
36		Q4	4.3032	489273.84	113.70	56.2	13.10	4.73	4.03
37	2019-20	Q1	3.82755	456626.72	119.30	55.9	13.03	4.78	4.02
38		Q2	3.9083	467041.85	119.50	56.2	13.05	4.78	4.03
39		Q3	4.08595	489088.22	119.70	56.1	13.10	4.78	4.03
40		Q4	4.3282	518951.18	119.90	56.4	13.16	4.79	4.03
41	2020-21	Q1	3.62236	456137.00	125.92	61.9	13.03	4.84	4.13
42		Q2	3.69846	463786.88	125.4	62.2	13.05	4.83	4.13
43		Q3	3.85066	484413.03	125.8	61.4	13.09	4.83	4.12
44		Q4	4.04852	512542.63	126.6	61.9	13.15	4.84	4.13

Table 1.2: Data collected from the Sustainability Report of Tata Steel Ltd.

Sl. No.	Year	Quarter	Crude Steel Production (MTPA) (per quarter)	Production of LD Slag (Mt) (Per quarter)	LD Slag in MT/MT of Crude Steel	Percentage Utilization (%)	Ln(Production of LD Slag (Mt) (Per quarter))	Ln(LD Slag in MT/MT of Crude Steel)	Ln (Percentage Utilization (%))
1	2010-11	Q1	1.63	212922.63	130.50	30.0	12.27	4.87	3.40
2		Q2	1.67	219061.66	131.50	31.0	12.30	4.88	3.43
3		Q3	1.75	228655.83	130.80	29.0	12.34	4.87	3.37
4		Q4	1.81	237449.96	131.20	30.0	12.38	4.88	3.40
5	2011-12	Q1	1.70	212220.89	124.50	34.0	12.27	4.82	3.53
6		Q2	1.73	216985.88	125.20	33.0	12.29	4.83	3.50
7		Q3	1.81	226083.66	124.80	35.0	12.33	4.83	3.56
8		Q4	1.88	236302.62	125.50	34.0	12.37	4.83	3.53
9	2012-13	Q1	1.93	261569.40	135.75	34.5	12.47	4.91	3.54
10		Q2	1.98	270286.95	136.25	34.5	12.51	4.91	3.54
11		Q3	2.08	282018.76	135.50	35.5	12.55	4.91	3.57
12		Q4	2.14	291868.44	136.50	35.5	12.58	4.92	3.57
13	2013-14	Q1	2.18	281515.28	129.20	34.5	12.55	4.86	3.54
14		Q2	2.23	291069.52	130.30	35.5	12.58	4.87	3.57
15		Q3	2.33	303958.06	130.20	34.5	12.62	4.87	3.54
16		Q4	2.41	313734.77	130.30	35.5	12.66	4.87	3.57
17	2014-15	Q1	2.21	294346.11	133.10	35.5	12.59	4.89	3.57
18		Q2	2.28	306227.37	134.50	36.5	12.63	4.90	3.60
19		Q3	2.39	318660.10	133.40	35.5	12.67	4.89	3.57
20		Q4	2.45	331299.98	135.00	36.5	12.71	4.91	3.60
21	2015-16	Q1	2.37	313137.02	132.10	42.5	12.65	4.88	3.75
22		Q2	2.43	323947.49	133.30	43	12.69	4.89	3.76
23		Q3	2.54	338043.73	133.10	43	12.73	4.89	3.76
24		Q4	2.62	349696.80	133.50	43.5	12.76	4.89	3.77
25	2016-17	Q1	2.38	313494.12	131.60	52.5	12.66	4.88	3.96
26		Q2	2.43	322269.13	132.50	53	12.68	4.89	3.97
27		Q3	2.55	336141.79	131.70	53.5	12.73	4.88	3.98
28		Q4	2.64	349326.83	132.20	53	12.76	4.88	3.97
29	2017-18	Q1	2.36	323120.14	137.00	58.5	12.69	4.92	4.07
30		Q2	2.42	330816.74	136.80	59.5	12.71	4.92	4.09
31		Q3	2.54	348675.98	137.40	58.5	12.76	4.92	4.07
32		Q4	2.64	360767.23	136.80	59.5	12.80	4.92	4.09
33	2018-19	Q1	2.43	357503.31	147.00	100	12.79	4.99	4.61
34		Q2	2.48	364517.26	146.80	100	12.81	4.99	4.61
35		Q3	2.61	384081.54	147.40	100	12.86	4.99	4.61
36		Q4	2.70	396018.75	146.80	100	12.89	4.99	4.61
37	2019-20	Q1	2.41	362211.93	150.00	100	12.80	5.01	4.61
38		Q2	2.47	369360.39	149.80	100	12.82	5.01	4.61
39		Q3	2.58	387696.16	150.40	100	12.87	5.01	4.61
40		Q4	2.73	409043.74	149.80	100	12.92	5.01	4.61
41	2020-21	Q1	2.22	336627.32	151.40	100	12.73	5.02	4.61
42		Q2	2.27	345515.43	152.20	100	12.75	5.03	4.61
43		Q3	2.36	359497.82	152.10	100	12.79	5.02	4.61
44		Q4	2.49	378467.04	152.30	100	12.84	5.03	4.61

In addition to the above data, qualitative data were also collected form the Integrated Annual Report/Sustainability Report regarding the initiatives taken by both the firms regarding use of LD slag for different purposes. The detailed analysis is presented below.

IV. DATA ANALYSIS, DISCUSSION AND RESULTS

V. : Variables:

The objective of this study was to understand the use of Industrial waste and by product for development of urban Infrastructure which will reduce the load on use of natural resources for creation of urban Infrastructure thus leading to sustainability. As mentioned earlier slag is generated during various stages of steel production and thus classified as Blast Furnace (BF) Slag, Linz-Donawitz (LD) Slag, Electric Arc Furnace (EAF) Slag etc. We have selected LD slag as the sample for understanding the use of LD slag for building urban Infrastructure in India. Hence “production of LD slag” is used as the independent variable and “percentage utilization” of slag is considered as the dependent variable. To eliminate the biasness, the natural Logarithm (Ln) of both the dependent and the independent variable are considered for the analysis. The proposed equations for the analysis is given below:

a. Y_1 (Percentage utilization) = $\alpha_1 + \beta_1$* (Production of LD Slag) + u_1 (For SAIL)
b. Y_2 (Percentage utilization) = $\alpha_2 + \beta_2$* (Production of LD Slag) + u_2 (For TSL)

The result of the regression Model with respect to data collected from SAIL is shown below.

Table 1.3: Regression Statistics (SAIL)

Regression Statistics	
Multiple R	0.835676111
R Square	0.698354563
Adjusted R Square	0.691172529
Standard Error	0.088686189
Observations	44

Table 1.4 : F Statistics

ANOVA					
	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	0.764786998	0.764786998	97.23631809	1.70199E-12
Residual	42	0.330340089	0.00786524		
Total	43	1.095127087			

Table 1.5 : Regression Output

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	17.17739062	1.310096031	13.11155077	1.93232E-16	14.53350979	19.82127145	14.53350979	19.82127145
X Variable 1	-1.001424853	0.101555655	-9.860847737	1.70199E-12	-1.206372463	-0.796477243	-1.206372463	-0.796477243

Based on the output of the Regression Model, the final equation for SAIL is as shown below:

- Y_1 (Percentage Utilization) = (17.177) +(- 1.001) * (Production of Slag)

From the output of the regression model for SAIL, the following can be inferred.

For SAIL with dependent variable "Percentage Utilization" and independent variable as " Production of Slag" , The R2 value is found to be 0.69835, and the F-value of the model was 97.2363 (significance level: 1.70199E-12). This implied that the explanatory power of the regression model is moderate. There is a positive intercept in the regression equation but the slope coefficient is negative which implies that the relation between production of slag and it's utilization is negative. If we look at the data, then it can be inferred that, due to increase in capacity of the firm , the crude steel production had gone up in the last decade which resulted in increased slag production. But with increase in slag production, the rate of use of slag had not been gone up in the same ratio. As a result surplus slag is available for further use.

Similarly qualitative data was also collected from the Sustainability report of SAIL. The collected data along with it's interpretation is presented below.

- In FY 12-13, SAIL had taken up through R&D master plan for development of technology for dry granulation of LD slag.
- In FY 13-14, SAIL and South Eastern Railway jointly taken up a project for utilization of weathered LD slag as ballast for rail track.
- In FY 15-16, based on pursuance of SAIL, the Bureau of Indian Standards (BIS) suitably amended the relevant IS: 383, permitting utilization of iron and steel slag as a replacement of natural aggregate up to the extent as has been given in the IS: 383 (Revision-III), 2016.
- In FY 18-19 SAIL had undertaken the following initiatives either inhouse or in association with other research institutes to improve the utilization of LD slag use.

- Steam maturing of BOF slag for further utilisation as construction material in road making and as ballast material for rail track.
- Dry granulation of BOF slag for further utilisation in cement manufacturing.
- Use of BOF Slag as soil ameliorant for treatment of acidic soils.
- Study on Use of composite slag (mix of BF slag and BOF slag) for making of Portland Slag Cement (PSC)
- Utilisation of SMS slag in construction of rural roads under Pradhan Mantri Gramin Sadak Yojna (PMGSY).
- In FY 20-21, SAIL along with other industry partners, signed an MoU with ICAR-IARI Delhi for "Development of steel slag based cost effective eco-friendly fertilizers for sustainable agriculture and inclusive growth"

The result of the regression Model with respect to data collected from TSL is shown below.

Table 1.6 : Regression Statistics (TSL)

Regression Statistics	
Multiple R	0.802385852
R Square	0.643823055
Adjusted R Square	0.635342652
Standard Error	0.277200304
Observations	44

Table 1.7 : F Statistics

ANOVA					
	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	5.833610303	5.833610303	75.91892	5.79459E-11
Residual	42	3.227280351	0.076840008		
Total	43	9.060890653			

Table 1.8 : Regression Output

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	-21.38123153	2.90540889	-7.359112725	4.47E-09	-27.24458406	-15.51787901	-27.24458406	-15.51787901
X Variable 1	2.002595776	0.229836125	8.713146282	5.79E-11	1.538767698	2.466423854	1.538767698	2.466423854

Based on the output of the Regression Model, the final equation for TSl is as shown below:

- Y_1 (Percentage Utilization) = (-21.3812) +(2.0026) * (Production of Slag)

From the output of the regression model for SAIL, the following can be inferred.

For TSL with dependent variable "Percentage Utilization" and independent variable as " Production of Slag" , The R2 value is found to be 0.6438 , and the F-value of the model was 75.91892 (significance level: 5.79459E-11). This implied that the explanatory power of the regression model is moderate. There is a negative intercept in the regression equation but the slope coefficient is positive which implied that the relation between production of slag and it's utilization is positive. . If we look at the data, then it can be inferred that, due to increase in capacity of the firm , the crude steel production had gone up in the last decade which resulted in increased slag production. But with increase in slag production, the rate of use of slag had also gone up in the same ratio. Similarly qualitative data was also collected from the Sustainability report of TSL. The collected data along with it's interpretation is presented below.

- In FY- 15-16 TSL, set up pilot plant for open steam aging of LD slag to be used construction material for roads.
- In FY 16-17 TSL was the first Steel company in India to process Steel/LD slag as replacement of natural aggregates in road-making through screening and weathering. TSL developed the market through joint experiments with National Highway Authority of India, Jharkhand State Rural Road Development Agency and Jharkhand Road Projects Implementation Company Limited and obtained accreditation from Indian Road Congress for use of LD slag as a material for road construction.
- In January 2018, TSL Launched branded LD slag products – Tata Aggreto and Tata Nirman.
- Tata Aggreto was ready-to-use material with consistent sizes, that replaces natural aggregate for road making.
- Tata Nirman was launched for usage as raw material in fly ash brick making

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From the qualitative data obtained from the Sustainability report of both SAIL and TSL, it can be inferred that the use of LD slag for road construction is picking up in India. In future LD slag can be extensively used for road construction. Due to the Chemical and Mechanical properties , use of LD slag will replace the use of natural resources like aggregate in road construction and thus resulting in conservation of natural resources. Thus LD slag can be used for construction road which will lead to creation of urban infrastructure, conservation of natural resources and environment in India. In addition to that firms in Indian Iron and Steel Industry had started exploring the use of LD slag as a substitute for fertilizer in future.

CONCLUSIONS AND SCOPE FOR FUTURE RESEARCH

Industrial Ecosystem is highly degenerative and a lot of by product and waste is generated during the Industrial production. Managing that by product and waste is a huge challenge for the Industries for their sustainability. Developing countries are rapidly moving towards large scale urbanization due to economic development, as a result of which there is migration of workforce from Agriculture sector to Industrial sector. This requires development of large scale urban infrastructure to cater to the need of the urban population. If Industrial by product and waste can be used for creation of urban Infrastructure, then it can create a sustainable eco-system. Thus we have selected LD slag, a by product of steel industry as a case to study it's use for creation of urban infrastructure.

Two firms from Indian Iron and Steel Industry i.e. Steel Authority of India Limited (SAIL) and Tata Steel Limited (TSL) were selected as the sample firms for this study. Data was collected regarding production and utilization of LD slag. Collected data were both of quantitative and qualitative in nature. From the analysis of quantitative data for SAIL, it was observed that there is a negative relationship between production of slag and it's utilization. This implied that there is surplus slag available in the system for further use in creating urban Infrastructure. But in case of TSL, the relationship between production of slag and it's utilization was positive which implied that the produced slag is fully utilized. From the qualitative data, it is observed that at present LD slag is mostly used for construction of roads. For road construction use of slag replaces the aggregates which leads to conservation of natural resources which in turn helps in protection of environment thus leading to creation of a sustainable urban infrastructure and sustainability for steel industry.

This study has few shortcomings also, which is mentioned herein. Creation of sustainable urban infrastructure through use of industrial waste from Indian Iron and Steel Industry can be ascertained through qualitative analysis as mentioned above, but the same could not be established through quantitative analysis due to non availability of adequate quantitative data. Same can be further explored and can become a potential topic for further research. In India, use of LD slag for other than road construction is also scarce. So alternate use of LD slag e.g. as a substitute for fertilizer, for amelioration of soil property etc. is in nascent stage and can be further explored. Also, this study can be extended to future research outside the steel industry, for further deepening the understanding of the use of Industrial waste for building urban Infrastructure thus leading to sustainability in both urban eco-system and industrial eco-system.

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