Utilization of Kiln Accretion as a Raw Material in Rural Road Laying

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Abstract

Sponge iron plants are mostly concentrated in four Eastern states of India namely West Bengal, Jharkhand, Orissa and Chhattisgarh. Kiln accretion is an important byproduct of the sponge iron industries. Indiscriminate disposal of the accretion on the land creates a gross visual pollution and the probable subsequent pollution of ground water and soil of surrounding area is a cause of concern. The study was undertaken to find a practical and acceptable solution to reuse the accretion so that the huge mountain of disposable kiln accretion lying unutilized as a solid waste, may be utilized properly. Physical and chemical tests of the kiln accretion were conducted. The physical tests included loss on ignition, aggregate crushing strength test and aggregate impact value test, gradation of kiln accretion by sieve analysis and water absorption test .The chemical analysis identified the oxide contents of accretion. The results were then compared with the norms of the sub base materials of normal aggregate for road making purpose. The comparison shows favorable results and thus identifies a novel approach to solid waste utilization.

Keywords: Solid Waste, Accretion Kiln, Chemical Analysis, Rural Road Laying

1. Introduction

Environmental pollution is a major problem associated with rapid industrialization. The major industrial solid wastes producers are thermal power plants producing coal ash, integrated iron and steel mills producing blast furnace slag and steel melting slag, non-ferrous industries like aluminum, zinc and copper producing red mud and tailings, sugar industries generating press mud, pulp and paper industries producing lime and fertilizer and allied industries producing gypsum. Collin et al. reported the use of blast furnace slag as an aggregate in road construction (Collins et al., 1993). Sakai et al. in 1992 reported an improved performance of blast furnace slag over conventional Portland cement. Extensive research has been conducted on the beneficial uses of coal combustion (Dawson, et al., 1993, Pandey, et al., 2002, Alam, et al., 2011, Dash, et al., 2007). Utilization of red mud in cement production has also been reported by Liu, et al., 2011, Sawant, et al., 2013.

Sponge iron production has seen phenomenal growth in India. The driving force behind this has been the rising prices as well as scarcity of scrap for secondary steel making process. States of Orissa, Chhattisgarh, Jharkhand and West Bengal are the key area where several coal based units are installed with more than 700 plants of various sizes (50 – 500 TPD) (Patra, et.al, 2010; Industry Overview, 2011). Sponge iron plants also exist in Gujarat, Andhra Pradesh, Tamil Nadu, Kerala and even Maharashtra but they are smaller in number. Sponge iron production in various industries was carried out through the Direct Reduction Iron (DRI) process. The key step in DRI processes is the reduction of iron oxide (FeO) to metallic iron stage. But during the production process there is a tendency of accretion formation in the temperature range of $900^{o}C$ to $1100^{o}C$ inside the Rotary kiln refractory lining (Dash, et al.). Accretion is the catastrophic accumulation of sintered particles of solid bed which form rings at places along the length of the kilns. This is a regular phenomenon in the DRI rotary kiln. It narrows down the opening of the kiln and creates hindrance to material flow resulting ultimately in shutdown for cleaning. The formation of accretion at frequent intervals results in reduced campaign life, low productivity, damage to kiln lining and ultimately production cost. Besides this a big stock of accretion is pilling up. Kiln accretion is actually a type of Fayalite, which is heterogeneous mix of iron oxide, coal ash and silica. Industrial disposal of the accretion on land and subsequent pollution of ground water and soil of surrounding place is a cause of concern. It is high time to address the problem and to take the remedial measures, as it can pose a very serious problem in future as the sponge iron industry is growing at a very fast rate.

In this study an attempt has been made to utilize the kiln accretion after carrying out detailed analysis of the physical and chemical parameters.

2. Experimental Section

Several kiln accretion samples were collected from different sponge iron plants such as Abhishek Steel, Raipur, Topworth, Durg etc. The samples were analyzed to find out physical test parameters such as aggregate crushing strength test (determined by crushing strength tester machine), aggregate impact value test {by impact tester) as per method IS:2386 (part IV), gradation of kiln accretion by sieve analysis and water absorption test of aggregate were performed. The tests were carried out as per the quality assurance for rural roads by equipments and test procedures, as per the guideline framed by the National Rural Roads Development, Government of India, New Delhi. Standard chemical analysis methods were used for the determination of chemical parameters.

3. Result and Discussion

The raw materials used in Sponge Iron Production by direct reduction of iron oxide are mostly inferior, lower sized and to some extent the waste raw materials not used in other standard process of iron and steel making. The huge dump of Iron ore fines and inferior coal can be well utilized in sponge iron plant. For every 100 ton per day of sponge iron plant, the daily consumptions are: 160-175 ton of iron ore, 120-150 ton of coal, 3.5-5.00 ton of dolomite/limestone, 2.0-2.2 ton of water, 300,000-350,000 Nm^3 of air. In such a unit, the gas and solids generated per day from the kiln would be: 500,000-550,000 Nm^3 of gas, 1.8-2.0 ton of CO_2, 10-15 ton of dust (either discharged to the atmosphere or collected in pollution control equipment), 2.5-3.5 tones of kiln accretion (calculated on per day basis, though it is removed only after each kiln campaign lasting at least 100 days) and 25-30 ton coal char. Thus, the total solid disposal load per day for 100 tones per day can be of the order of 40-50 ton per day. Mini Coal-based sponge iron units are operating without much pollution control equipment (proper GCP, effluent water treatment, etc.).

Various chemical and physical analyses were carried out to identify the utility of the accretion kiln. The chemical analysis of kiln accretion samples collected from different sponge iron plants such as Abhishek Steel, Raipur, Topworth, Drug showed very high % of Fe_2O_3 which make it unsuitable to brick mortar, refractory mass, refractory powder and old brick grogue as in Table 1. Interestingly, the trace elemental analysis for Pb, As and Hg and also S and P showed presence below the detection limit of the instrumental technique utilized

The value of aggregate crushing strength which is important to assess the resistance of material to disintegration against crushing load is presented in Table 2. For aggregate, the permissible limit is maximum 50% for sub base, 40% for base and 30% for wearing course. So the result is acceptable as it was within the permissible limit of minimum 30%. Hence it can be easily used for sub base. Table 3 indicates the aggregate impact value which helps to determine the resistance of material to disintegration against impact loading. For aggregate the permissible limit of crushing is maximum 50 for sub base, 40 for base and 30% for wearing course. So the above result is acceptable as it is much less than the limiting percentage or the maximum value, hence it can be easily used for sub base.

A combination of well graded coarse and fine aggregates is essential for producing a durable granular mix. It is seen from the Table 4 that the percentage of weight passing through the different IS sieve designation from 53 mm to 11.2 mm is within the permissible range as desired for use as an aggregate in case of sub base material for rural road making.

The water absorption test of kiln accretion was carried out for knowing the property like shear strength and compaction characteristics as they are greatly influenced by its water content and the changes there in. Maximum permissible limit is 2% as indicated in Table 5.

Based on the above results it is clear that kiln accretion can be utilized as the blending material, with aggregate, in rural road making, as a sub base. Different physical test parameters of kiln accretion mostly match with the conventional aggregates under use. Hence, such use of the accretion as sub base in road making is a viable and useful waste utilization technique. Such utilization will help in reuse of accretion in the same fashion as of fly ash. Majority of the iron ores contain high iron and low alumina as well as silica contents. The chemical analysis has also showed the absence of deleterious elements (S, P, As, Pb, etc), so on use of such waste, the toxic leachate generation will not be a problem. Such accretion can also be used for the filling of abandoned underground and open cast mines after completion of mining job.

4. Conclusion

The research proves that the kiln accretion can be utilized as the blending material with aggregate while making road, as a sub base in case of rural roads as the different parameter of kiln accretion mostly matches with the conventional aggregates which are being in use. Such utilization will be cost effective waste utilization strategy. This use will be a great help for combating the disposal problem of the kiln accretions and will also provide saving on mining and transportation of the borrow materials,

Acknowledgement

The support of Chhattisgarh Pradhan Mantri Gramin Sadak Yojana (C.P.M.G.S.Y), Durg Department is thankfully acknowledged

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Table 1. Chemical analysis of kiln accretion sample

Chemical Constituent	Sample – I %	Sample –I I %	Sample –III %
SiO_2	28	26	26
Fe_2O_3	49.26	49.4	48.5
TiO_2	0.74	0.96	1.1
Al_2O_3	11.3	11	12.6
CaO	3.2	3.4	3.5
MgO	7.5	7.9	8.3
S	BDL	BDL	BDL
Pb	BDL	BDL	BDL
P	BDL	BDL	BDL
As	BDL	BDL	BDL
Hg	BDL	BDL	BDL

Table 2. Determination of aggregate crushing strength of the test sample

Observation	Test Numbers		Average
	1	2	
Weight of aggregate sample filling in cylinder= W_1 g	2000	2000	-
Weight of aggregate retained on 2.36 mm sieve after test W_2 g	1393	1357.5	-
Weight of aggregate passing 2.36 mm sieve after test $W_3 = (W_1 - W_2)$ g	607	642.5	-
Crushing strength = (W_3/W_1) X100	30.35%	32.12%	31.23%

Table 3. Determination of aggregate impact value of the test sample

Observation	Test Numbers		Average
	1	2	
Weight of aggregate sample filling in cylinder W_1 g	500	500	-
Weight of aggregate retained on 2.36 mm sieve after test W_2 g	363.5	375	-
Weight of aggregate passing 2.36 mm sieve after test $W_3 = (W_1 - W_2)$ g	133.5	125	-
Aggregate impact value = (W_3/W_1) X100	26.7 %	24.8%	25.75 %

Table 4. Determination of gradation of aggregate (GR – III) of the test sample

I.S.Sieve Designation	Weight of sample retained (grams)	% of weight retained	Cumulative % of weight retained (%)	% of weight passing (%)	Permissible limit (%)
1	2	3	4	5	6
63 mm	-	-	-	-	100
53 mm	105	2.1	2.1	97.9	95-100
45 mm	2107	42.14	44.24	55.76	65-90
22.4 mm	2246	44.92	89.14	10.84	0-10
11.2 mm	542	10.84	99.98	0.02	0-5

Table 5. Determination of water absorption test of the test sample

Observation	Test Numbers		Average
	1	2	
Weight of saturated surface dry aggregate in air W_1 g	511	512.5	-
Weight of oven dried aggregate in air W_2 g	500	500	-
Water absorption = $(W_1 - W_2) \times 100/W_2$ (%)	2.19%	2.5%	-
Mean value of water absorption	-	-	2.34 %