Recent Research in Science and Technology 2014, 6(1): 101-105
ISSN: 2076-5061
Available Online: http://recent-science.com/

Utilzation of industrial waste as a filling material

Sanjeet Sahoo*, Chitta Ranjan Mohanty*, Harapriya Panda and Rakesh Ranjan Dash*****

*Research scholar, Civil Engineering Department, VSSUT, Burla, Odisha, India.
** Department of Civil Engineering, VSSUT, Burla, Odisha, India.
*Research scholar, Civil Engineering Department, VSSUT, Burla, Odisha, India.
*** Department of Civil Engineering, VSSUT, Burla, Odisha, India.

Abstract
Iron and Steel have played an important role in the development of human civilization over the recent years. Steel by itself is one of the most environment friendly products used in our daily life. Steel has been a material of choice for innumerable applications all along in the past, and it is likely to continue to be an important material for use in the foreseeable future. The world steel production has been increasing from year to year and has already crossed the 1 billion tonnes mark for the first time in 2004. During the intervening period, steel production has grown very fast, and in 2010, global steel production has exceeded 1.4 billion tonnes. The rapid increas has been led by China accounting for more than 45% of world steel production. China is not only the largest producer of steel (627 million tonnes), it is also the largest consumer of steel (576 million tonnes) followed by the United States and India. Sponge iron is the intermediate stage of steel production. During the process of production of the sponge iron, large amount of solid waste is produced. So it is necessary to manage/reuse the waste in proper ways. Over the last few years, environmental and economical issues have stimulated interest in the development of alternative materials and reuse of industrial waste/by-products that can fulfil the standard specification. Dolochar is such a type of solid waste generated from sponge iron industries. Safe disposal of dolochar waste is a major problem for the earth. It is produced in large quantities due to rapid industrialisation. Dolochar is a black coal like material having crystalline structure; contain SiO_2, Al_2O_3, Fe_2O_3, CaO, MgO and FC (Fixed carbon). Its major constituent is SiO_2. The objective of this paper is to provide a detailed study on the characteristics and effective utilisation of the industrial waste (dolochar). The waste sample was collected form a local sponge iron industry located at Sambalpur and different geotechnical parameters such as Light compaction test (C_u, C_c), Specific gravity test, Unit weight test, pH test, Sieve analysis, direct shear test (cohesion, angle of internal friction) and Chemical analysis have been evaluated to find out its suitability as a filling material.

Keywords: Industrial waste, Dolochar, Cohesion, Angle of internal friction, Cohesion, Angle of internal friction, pH

INTRODUCTION

Growth of population, increasing urbanisation, rising standards of living due to technological innovations have contributed to an increase both in the quantity and variety of solid wastes generated by industrial, mining, domestic and agricultural activities, which leads to environmental pollution. For developing country like India industrialisation was must and still this activity very much demands to build self reliant and in uplifting nation's economy. However, industrialisation on the other hand has also caused serious problems relating to environmental pollution. India can ill-afford to lose them as sheer waste. On the other hand, with increasing demand for raw materials for industrial production, the non-renewable resources are dwindling day-by-day. Therefore, efforts are to be made for controlling pollution arising out of the disposal of wastes by conversion of these unusable wastes into utilisable raw materials for various beneficial uses. (1,2)

*Corresponding Author

Sanjeet Sahoo
Research scholar, Civil Engineering Department, VSSUT, Burla, Odisha, India.

Email: sanjeet476@gmail.com

The problems relating to disposal of industrial solid waste are associated with lack of infrastructural facilities and negligence of industries to take proper safeguard. The large and medium industries located in identified (conforming) industrial areas still have some arrangements to dispose solid waste (3,4) However, the problem continues to exist with small scale industries. In number of cities and towns, small scale industries find it easy to dispose waste here and there and it makes difficult for local bodies to collect such waste. Therefore, it becomes necessary that the local bodies along with State Pollution Control Board (SPCB) work out requisite strategy for organising proper collection and disposal of industrial solid waste.

From 1980 onwards, the production of sponge iron in India has been exponentially increased. So now days it is a major challenge to utilise such waste generated by sponge iron industry. If we compare the sponge iron production between India and the rest of world of last five years as shown in Table 1, India shares/ contributes (40 – 45%) of sponge iron. So production of such a huge amount of sponge iron contributes large amount of waste generation (solid waste), which is a major issue now a days.

The main ingredient required for the production of sponge iron are iron ore, dolomite and non choking coal. Fig.1 shows the schematic production process of sponge iron. For production of 100 ton sponge iron, there are 154 ton of iron ore and 120 ton of (B-Grade) coal required. The solid waste generated during this process is around 45 ton and out of which 25 ton is char, known as dolochar (5,9).

Table 1. Comparison of sponge iron: India vs. rest of world

Year	India (million tonnes)	World (million tonnes)	Share of India (%)
2007	20.1	66.8	30.12
2008	20.9	66.1	31.65
2009	23.4	64.5	36.36
2010	26.3	69.9	37.60
2011	27.6	63.5	43.42

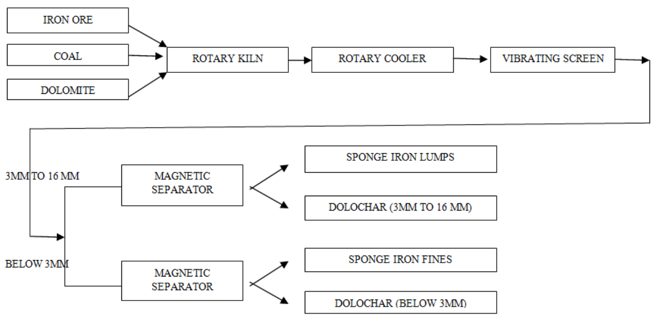

Fig 1. Schematic diagram of sponge iron production

Total capacity of sponge iron production in Odisha is about 16000 tons per day and dolochar generated is around 3.8 million tons per annum (7, 10). The generation of dolochar is extensively high due to the use of inferior quality of coal. Till now, dolochar is dumped in neighbouring dump site of all industries which needs to be effectively utilized as a filler material or as a material for road and pavement, then the disposal problem shall be widely solved. In view of finding out a suitable method of disposal of the wastes, different tests have been carried out for dolochar to evaluate its engineering and geotechnical properties (8).

EXPERIMENTAL

Material

Dolochar sample of 70 kg from a operating sponge iron plant located at Sambalpur was obtained for detailed geotechnical characterisation studies.

Geotechnical characterization

Appearance

Dolochar is generally black in colour with irregular size. The sample was passed in 4.75mm and 600μ IS sieve. Figure.2 (a) and 2(b) shows the sample and 600 passed in 4.75 mm μ IS sieve.

Fig 2 (a). Sample passed in 4.75mm IS sieve

Fig 2 (b). Sample passed in 600μ IS sieve

Sieve analysis

This is known as particle size analysis or mechanical analysis. It is a method of separation of soils into different fraction based on particle size (here dolochar is analyse instead of soil). It expresses quantitatively the proportions, by mass, of various sizes of particles present in the dolochar sample.

300 gm of dolochar sample was taken and sieved through a nest of sieves which is consists of 4.75mm, 2mm, 1mm, 600μ, 420μ, 300μ, 150μ,75μ. The total arrangement was placed in a mechanical sieve shaker and was shake it for 10 minutes. Figure.3 shows a mechanical sieve shaker.

After that the machine was switched off and the total arrangement was unlocked. Dolochar was collected from each of the sieve and weighted it with a weighing machine, it was then represent in a table 2 and Figure.4 shows particle size distribution curve

The uniformity of soil is expressed quantitatively by a term known as Uniformity Coefficient (C_u) and it was found to be 13.33. The general shape of the particle size distribution curve is described by another co-efficient known as coefficient of curvature (C_c) and it was found to be 2.13.

Fig 3. Sieve shaker

Table 2. Typical table for sieve analysis

Serial no	IS Sieve size D in mm	Mass of soil retained(gm)	Percentage mass retained	Cumulative percentage retained	Percentage finer (N)
1	4.75mm	105	35	35	65
2	2mm	88	29.33	64.33	35.67
3	1mm	50	16.66	80.99	19.01
4	600 μ	14	4.66	85.65	14.35
5	420 μ	7	2.33	87.98	12.02
6	300 μ	5	1.66	89.64	10.36
7	150 μ	8	2.66	92.3	7.7
8	75 μ	18	6	98.3	1.7
9	pan	4	1.33	99.63	0.37

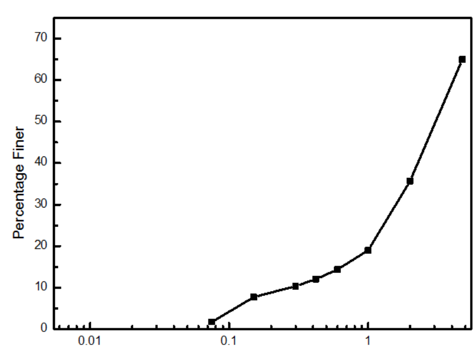

Fig 4. Particle size distribution curve

Specific gravity (G)

First some sample was taken and was sieved through 4.75 mm IS sieve. A specific gravity bottle was taken and dried for some hour for the removal of water particles. Then empty weight of specific gravity bottle, specific gravity bottle and dolochar, specific gravity bottle and dolochar along with water and specific gravity bottle and water was taken and specific gravity was found to be 2.13.

Unit weight

This apparatus consists of sand pouring cylinder, tray with a central circular hole, container for calibration, balance, etc and is used as for the measurement of unit weight of soil.

Here we used dolochar instead of sand to find its unit weight. First dolochar sample was passed in a 600µ IS sieve and retained in 300µ IS sieve, then the empty weight of the cylindrical was taken after that the cylinder was filled with dry and clean dolochar almost to the top. The cylinder was placed centrally above the calibrating container such that the bottom of the conical portion coincides with the top of the container. The dolochar sample was allowed to run into the container by pulling out the shutter and this process was continued until no further runs out of the dolochar sample, then the shutter was closed. Figure.5 shows sand replacement apparatus. The unit weight of the sample was found to be 0.966 gm/cm^{3}or 966 kg/mt^3.

Fig 5. Sand replacement apparatus with calibrating cylinder

Standard proctor test

First of all dolochar was sieved in 4.75mm IS sieve and 2.5 kg of sample was taken from that. After that the weight of the clean, empty mould was taken, then the base plate, mould and collar was properly lubricated by applying lubricant on its inner face. Figure.6 (a) and 6(b) shows standard proctor mould, rammer and moisture tin. First 10% of water corresponding to the weight of dolochar was taken and both the sample was properly mixed with hand. The total dolochar was divided into 3 parts and 1st part was placed in the mould after all the attachment of base plate, mould and collar. Then the sample was compacted by a 2.6 kg rammer, with a free fall of 310 mm. For each layer 25 no of blows was given to the sample.

Same procedure was carried out for 2nd and 3rd layer. After that the collar was detected and the surface was levelled by straight edge. The base of the mould was detected and the weight of the mould along with wet dolochar was taken. Then the dolochar sample was taken from the middle of the mould in the moisture tin whose empty weight was taken before. After that sample was placed in the moisture tin and the dolochar was taken out. Then the moisture was placed in the oven for 24 hour at 105-110˚c.Then the weight of the moisture tin was taken. The process was repeated for different water content (10, 13, 15, and 18) %. Table.(3) and (4) calculated the moisture content and dry density of the sample. Figure 7 show the moisture content vs. Dry density curve.

Fig 6 (a). Standard proctor mould, rammer & sample Fig 6 (b). Moisture tin

Table 3. To find the average moisture content of dolochar

Serial no	Moisture tin no	Weight of moisture tin in gm	Wt of moisture tin+ wt of wet soil in gm	Wt of moisture tin+ wt of dry soil in gm	Wt lost in gm	Wt of dry soil in gm	Moisture content in %age	Average moisture content in %age
1	230	18.795	35.289	34.2	1.089	15.405	7.069	12.32
2	235	12.552	26.133	24.6	1.533	12.048	12.72	same
3	222	16.063	31.732	29.9	1.832	13.837	13.239	same
4	207	13.497	24.430	27.2	2.23	13.703	16.273	same

Table 4. To find dry density of dolochar sample

Serial no	Volume of the mould	Weight of the mould in gm	Wt of mould +wt of soil in gm	Wt of wet soil in gm	γ_t in gm/cm^3=w/v	Average moisture content in % age	γ_d in gm/cm^3 $\gamma_d=\gamma_t/1+w/100$
1	1000	1905	3025	1120	1.12	7.069	1.046
2	1000	1905	3095	1286	1.286	12.72	1.14
3	1000	1905	3204	1299	1.299	13.239	1.147
4	1000	1905	3108	1203	1.203	16.273	1.0346

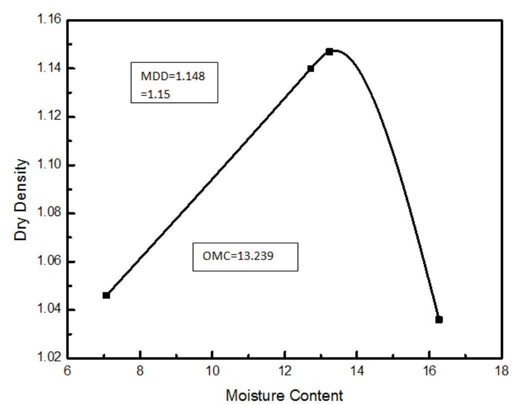

Fig 7. Diagram of maximum dry density & optimum moisture content

Direct shear test

Dolochar sample was taken and it was placed in the circular shear box. Figure.8 (a), 8(b), 8(c) shows direct shear box, dial gauge and total arrangement of direct shear machine.

The shear box consists of two parts, one upper part and one lower part. The lower part was in contact with the shear container which freely slides with roller and shear force was applied on that by the help of geared jack. The sample was sandwiched between a pair of metal grid plate (perforated in case of drained condition). A pressure pad of brass was placed over it to transmit the Three observation were taken for each case (dry and wet) and the load was increased (0.5, 1, 1.5kg/cm^2) Shear force was applied by an electrical motor. Dial gauge was fitted to the container to measure the shear displacement. The rate of shear displacement throughout the test was 1.25mm/minutes. Table 5 and 6 calculate the normal and shear strength of dry and wet sample and its respective curve is represented in Figure.9 (a) and 9(b).

Fig 8 (a.) Direct shear box

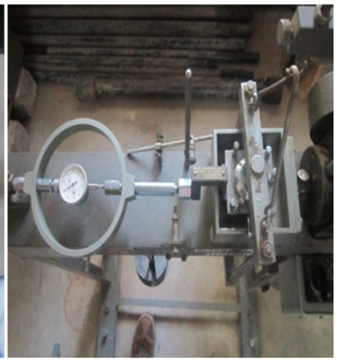

Fig 8 (b). Dial gauge and shear box arrangement

Fig 8 (c). Total arrangement of direct shear machine with loading pad

Calculation

Area of the shear box=28.27cm^2, D=diameter of shear box (circular) =6cm, Volume of shear box=Area*Height of shear box=28.27*2.5=70.675cm^3

Dry sample

Weight of dolochar taken for the shear box= M.D.D*volume=81.276gm

Table 5. Dry

Serial no	Initial dial gauge reading	Final dial gauge reading	Normal stress σ_n=kg/cm^2	Shear force In kg	Shear stress τ = kg/cm^2
1	0	44	0.5	30	1.06
2	0	65	1	44.3	1.56
3	0	86	1.5	58.6	2.06

Wet sample

OMC, that is 13.239% of water was added to 81.276gm .So the total weight of dolochar taken = 92.03gm (44 division=30 kg)

Table 6. Wet

Serial no	Initial dial gauge reading	Final dial gauge reading	Normal stress σ_n=kg/cm^2	Shear force In kg	Shear stress τ = kg/cm^2
1	0	47	0.5	32.04	1.133
2	0	62	1	42.1	1.48
3	0	76	1.5	51.6	1.82

For dry case cohesion(c) =0.58 & angle of internal friction (Φ) =43.53^0(from graph). For wet case cohesion(c) =0.78 & angle of internal friction (Φ) =34.99^0(from graph)

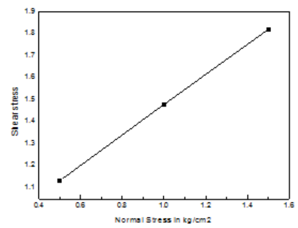

Fig 9 (a.) Dry case

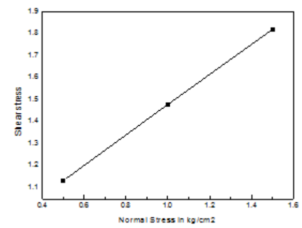

Fig 9 (b). Wet case

P^H value

The p^H value of dolochar sample was found to be 10.5. It is alkaline in nature**.**

Chemical properties

Few sample was tested in Regional Research Laboratory (RRL), Bhubaneswar and its chemical properties was determined and it was found that dolochar mainly contain silica (40-50) %.

RESULTS

Table 7 shows all the geotechnical properties of the above mention experiment.

Table 7.

Sl. No	Property name	Value
1	Sieve analysis Coefficient of Uniformity, Cu Coefficient of Curvature, Cc	 =13.33 =2.13
2	Specific gravity	=2.13
3	1. Direct shear (dry) Cohesion Angle of internal friction 2. Direct shear(OMC) Cohesion Angle of internal friction	=0.58 =43.53^0 =0.78 =34.99^0
4	Unit weight	=966 kg/mt^3
5	Proctor density Optimum moisture content Maximum dry density	 =13.239 =1.15
6	Plastic limit	=0 (Non plastic, cohesion less)
7	P^H Value	=10.5
8	Chemical analysis SIO_2 AL_2O_3	 =43.23% =20.05%

	Fe_2O_3	=7.06%
	CaO+ MgO	=3.47%
	Loss in ignition	=19.87%
	Total	=95.68%

CONCLUSION

1. From the above tests it is clear that dolochar is a good filler material as it obtained less dry density and also contains some other satisfactory dates.
2. If dolochar would give good results in CBR (California Bearing Ratio), then it can be used as a sub-base and base course in the construction of road.
3. Leachability test should be conducted to check the possibility of leachate formation as it affects the environment through ground water.
4. Dolochr contain more than 20% of carbon and which is not used, if this carbon is recovery then it is beneficial to the society and it also help to save some part of fuel.

REFERENCES

[1] Vimal Kumar, *et al.,* 2005. A Case Study: Manifold Increase in Fly Ash Utilisation In India@ Fly Ash India.

[2] M. Ahmaruzzaman, 2010. A review on the utilization of fly ash" Progress in Energy and Combustion Science 36 : 327–363

[3] Emilliani Anak Geliga and Dygku Salma Awg Ismail, 2010. Geotechnical Properties of Fly Ash and its Application on Soft Soil Stabilization" UNIMASE-Journal of Civil Engineering, Vol. 1: issue 2

[4] Arvind Kumar Rai *et al.,* 2010. "A Study on Backfill Properties and Use of Fly Ash for Highway Embankments" Journal of Advanced Laboratory Research in Biology

[5] P.U. Asnani, 2006. "Solid waste management"

[6] "Sponge iron Industry: the regulatory challenge" Prepared by Centre for Science and Environment. www.cseindia.org

[7] Ranjan Kumar Dwari *et al.,* 2012. "Characterization of dolochar wastes generated by the sponge iron industry" International journal of minerals, Metallurgy and materials, 19 (11): 992

[8] N. S. Pandian, 2004. "Fly ash characterization with reference to geotechnical applications" J. Indian Inst. Sci., 84, 189–216

[9] P.A. Botha, 1993. "Iron-ore sinter produced from a mix containing waste Materials" J. S. Afr. Inst. Min. Metall., 93 (1):13-19.

[10] Survey of Indian sponge iron industries, 2006. " Prepared by: joint plant committee