Indexed in
Scopus Compendex and Geobase Elsevier,
Geo-Ref Information Services-USA, List B of Scientific
Journals, Poland, Directory of Research Journals

International Journal of Earth Sciences and Engineering

www.cafetinnova.org

ISSN 0974-5904, Volume 09, No. 02

April 2016, P.P.450-455

Utilization of Iron Ore Waste in Brick Making For the Construction Industry

SHREEKANT R L, ARUNA M AND HARSHA VARDHAN

Department of Mining Engineering, National Institute of Technology Karnataka, Surathkal, Mangalore, INDIA

***Email**: shreekant.rathod@gmail.com*

Abstract: India is one of the major iron ore producers and exporters in the world. Previous studies have estimated that around 10–15 % of the iron ore mined in India is unutilized, and is discarded as waste/tailings due to lack of cost effective technology in extracting low grade ores in the country. The waste thus produced in the form of slimes has remained a major unsolved and challenging task for the Indian iron-ore industry. Many investigators in the past have worked in this regard for comprehensive utilization of such waste so as to reduce its impact on the environment. There is a significant demand for building materials in India and it is therefore imperative to use the mining and mineral wastes in the production of bricks, concrete blocks and any other value added products. In the present paper an attempt has been made to prepare modular bricks using iron ore waste with fly ash and cement as aggregates. Bricks were prepared as per IS standards and tested for its viability for usage in construction industry. The results of the study reveal that a mixture with 70% iron ore waste, 15% cement and 15% fly ash meets the IS standards.

Keywords: *Iron Ore Waste, Aggregates, Bricks, Compressive Strength, Water Absorption*

1. Introduction

India has large reserves of metal-bearing ore and it occupies sixth position in the world with regard to iron-ore reserves. Further, India is one of the important iron-ore producers and exporters in the world too. However, approximately 10–15% of the iron ore mined in India is unutilized, even now, and is discarded as waste/tailings due to lack of cost effective technology in extracting low grade ores (Rudramuniyappa, 1997). The waste/tailings that are called ultra-fines or slimes are mainly those having equivalent diameter of less than 150 µm, and are not regarded to be useful and hence are discarded. In India, approximately 10–12 million tons of such mined ore is lost as tailings. The safe disposal or utilization of such vast mineral wealth in the form of ultra-fines or slimes has remained a major unsolved and challenging task for the Indian iron-ore industry. The cost of handling and storage of mineral waste represents a financial loss to a company, estimated at around 1.5 to 3.5% of total cost and depending on the mineral being mined (Mohanty, 2010). Therefore, comprehensive utilization of waste/tailings is important in saving resources, improving surrounding and for sustainable development.

There is a significant demand of building materials in India and elsewhere. It is therefore imperative to use the mining and mineral wastes in the production of bricks, concrete blocks and other value added products (Chakravarthi et al. 2007, Muduli et al. 2010). Since the need for building materials is growing at an alarming rate, in order to meet the demand for new buildings, new ways and techniques must be evolved. Manufacturing of building materials like brick, cement, steel, aggregates etc. which are consumed in bulk quantities, puts great pressure on natural resources (raw materials) and are highly energy demanding. Therefore, the use of alternative materials for brick construction should be encouraged. Mine wastes and tailings can be converted into bricks, which can meet the demand of bricks in metropolitan cities for the next 30 years or even more. Further, building blocks from mine waste are eco-friendly as it utilizes waste and reduces air, land and water pollution. It is energy efficient and also cost effective as reported by various investigators in the past.

2. A brief review of related work:

Hammond (1998) critically reviewed the use of mining and quarrying waste as building material. The availability, distribution and uses of wastes from most mining countries of the world were discussed. The use of mining waste materials as concrete aggregates for the purpose of construction, production of brick and tiles, cement, pozzolana and pigments for paints were identified. It was stressed that, by using waste materials, natural resources will be conserved, energy will be saved and environmental pollution will be reduced.

Amit and Rao (2005) critically reviewed present status of waste-based building materials available in India. Investigation by Zhang et al. (2006) revealed that comprehensive utilization of iron ore tailing is efficient, socially beneficial and also improves environment situation. Yongliang et al. (2011) studied the utilization of hematite tailings in production of non-fired bricks. The tailing bricks were prepared by pressing and curing process, in the presence of cementing material and coarse aggregates. Non-fired bricks with 78% hematite tailings can be prepared in the optimal conditions of forming water content and forming pressure of 15% and 20 MPa, respectively with natural curing in room temperature for 28 days. The compressive strength achieved was up to 15.9 MPa. Zhang et al. (2011) also achieved the same result as Yongliang et al. (2011) whereas Chen et al. (2011) achieved the compressive strength of up to 15.9 MPa for 20 days curing.

Zhao et al. (2011) studied the possibility of using hematite tailings as main raw material to prepare high strength autoclaved bricks. The optimum formulation of mixtures used was 70% hematite tailings, 15% lime and 15% sand and the optimum autoclave pressure and autoclave time was also observed with 1.2MPa and 6 hrs., respectively. The compressive strength, flexural strength, compressive strength of autoclaved bricks made of hematite tailings observed after 15 freezing–thawing cycles and the mass loss of the latter with optimum process condition were 21.2 MPa, 4.21 MPa, 18.36 MPa and 0.72%, respectively.

Ullas et al. (2010) used mine waste as an alternate to the natural river sand for the investigation. The optimum mix proportion of soil, sand and cement were fixed and the sand fraction was replaced by iron ore tailings at 25%, 50% and 100%. The block characteristics were observed and found that considerable amount of sand can be replaced by iron ore tailings without compromising desirable characteristics of stabilized mud-block used for masonry. It was also observed that the water absorption increases with increase in iron ore tailings content within the limits. The experimental results of Xiaoqing et al. (2011) reveal that the concrete products obtained by mixing the iron ore tailings, cement and fly ash at a ratio of 65:25:10 and with 28 days curing, the compressive strength achieved was 31 MPa.

Mangalpady et al. (2010) investigated the utilization of iron ore tailings in manufacture of concrete paving blocks. Five reference mixes of cement, jelly dust, baby jelly are used for the study. Out of ten paving blocks prepared from each type of mix, five specimens were cured for 7 days and five were cured for 28 days. The laboratory tests reveal better compressive strength without much change in water absorption. The highest compressive strength was 36.5MPa and the least, 6.8 MPa whereas the highest water absorption was 7.02% and the lowest was 2.6% for a particular mixture.

Roy et al. (2007) carried out an experimental study on gold mill tailings in making bricks- a feasibility study of Kolar Gold Fields. The bricks were prepared with the mill tailings having cement as an additive in the proportion of 5, 10, 15, 20 and 25% with curing duration of 3, 7, 14 and 28 days. These were tested and results indicated that the bricks with 20 % cement and 14 days curing are most suitable with a compressive strength of 3.43 MPa, which just meets the criteria of assessment of bricks with minimum compressive strength 3.43 MPa (Jha, 1992). However, in all the cases of mixture it was observed that the water absorption was less than 20%, irrespective of the firing temperature. Hence, it meets the criteria for assessment of quality of bricks which should be less than 20% after 24 hrs. immersion in water (Kanna, 1994). The soil tailing bricks were sun dried and then fired in a furnace at different temperatures and it was found that mixing of high percentage of mill tailings (>=70% of mill tailings) causes deformation with black cotton soil and cracks after firing with red soil for >= 55% of mill tailing. It was also observed that for lower percentage of mill tailings content, the linear shrinkage of bricks was more than 3%, and hence it did not satisfy the criteria.

Dean et al. (1996) used the gold mill tailings in addition to fly ash, Portland cement and water to manufacture concrete blocks of size 10.16 cm × 20.32 cm and achieved the average compressive strength of 18.34 MPa. This is almost 40% higher than the American Society for Testing and Materials (ASTM) requirements for load bearing block (i.e. 13.10 MPa). At the same time the bricks made with this material had compressive strength of 28.22 MPa which is 17% higher than that of ASTM requirement.

Yonggang et al. (2011) made fired bricks using gold tailings and clay, following the sequence of pretreatment, mixing, ageing, moulding, drying, sintering and performance testing in making of bricks. It was found that the compressive strength can reach the Standards MU10 (Fired Common brick) when using 70% to 90% fine tailings at 1000 ^{0}C with 60 minutes holding time. Sunil Kumar (2002) developed fly ash-lime-gypsum (Fal-G) bricks and hollow blocks utilizing industrial waste which was found economical and the mixture along with fly ash at 60%, 70% and 80% ratios was used for a brick size of 220×100×75 mm. The block size used was 150×150×150 mm. The samples were cured for one week using gunny bags by sprinkling water on it. Subsequently the samples were transferred to the tank containing sulfate solution at a temperature of 23±2 ^{0}C and then cured for 24, 72 and 96 days. The sample prepared with the ratio of 80:10:10 (i.e. fly ash: lime: calcined phosphogypsum) achieved the compressive strength of 5.9 MPa after 96 days casting and curing, which satisfies Bureau of Indian Standards (IS-1077:1992) of burn clay bricks (3.5 MPa). However, the water absorption of the bricks varies from 28.9%

to 37.2% which does not satisfy the IS codes i.e. water absorption should not be more than 20% (by weight).

3. Laboratory studies:

For a case study a large mechanized iron ore mine has been identified in Sandur sector of Karnataka state. The co-ordinates of the site location are N14^{0}59.344’ and E76^{0}34.797’. Samples were collected from three different locations. During chemical analysis of samples, it was found that at two locations (Sample-2 & 3) Fe_2O_3 content is more than 30% and hence these samples were not considered for preparation of bricks. Table 1 indicates the results of chemical analysis. As shown in Table 1, Fe_2O_3 content of sample 1 is less than 30%, hence it was considered for the present study. Sieve analysis was carried out to know the particle size distribution in the sample. Table 2 gives the results of sieve analysis and Figure 1 shows the respective graph plotted for cumulative percentage retained in the sieve versus sieve size.

Table 1: *Results of chemical analysis*

Parameters	Sample 1	Sample 2	Sample 3
SiO_2	40.7	21.196	38.8
Fe_2O_3	22.93	58.88	32.08
Al_2O_3	22.27	2.2976	30.45
CaO	4.79	5.3977	6.5219
MgO	0.19	0.0213	0.090
Na_2O	0.0332	0.1494	0.1217
K_2O	0.0542	0.0723	0.1385

Table 2: *Results of sieve analysis*

Sieve size (µm)	Retained Weight (gm.)	Passing weight (gm.)	etained (%)	Cum. retained (%)	Cum. passing (%)
4750	1.20	498.8	0.24	0.24	99.76
2360	3.20	495.60	0.64	0.88	99.12
1180	24.42	471.18	4.884	5.764	94.236
600	76.96	394.22	15.392	21.156	78.844
300	67.82	326.4	13.564	34.72	65.28
150	211.80	114.6	42.36	77.08	22.92
75	85.80	28.80	17.16	94.24	5.76
-75	28.8	0	5.76	100	0

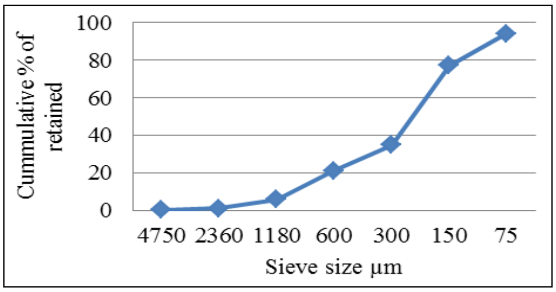

Fig. 1 *Cumulative % retained Vs sieve size*

4. Methodology of brick making:

For preparing the bricks, iron ore waste was taken as a major aggregate in combination with fly ash and cement as minor aggregate. Fly ash is safe to use, stable under different conditions and its physical and chemical properties are intact. The fly ash was collected from a thermal power plant. The bricks were prepared with five different combinations of the above said aggregates (i.e. cement, fly ash and iron ore waste) taking percentage of weight as given in Table 3. These different combinations of mix ratios were selected based on the literature review (Roy et al. 2007, Niu and Chen J. 2011, Yongliang et al. 2011 and Yellishetty et al. 2008). To prepare bricks, the mix ratio of IOW was kept steady at 70%, whereas the cement ratio was varied from 30% to 10% with 5% interval and fly ash from 0% to 20% with 5% interval. The bricks were of size 90mm×90mm×90mm, as per Bureau of Indian Standards (IS 2691:1988). It was calculated that for a single brick 2.65 kg of mixture is required and about 600 ml of water while mixing. Oil was applied to the inner part of the mould and prepared mixture was poured slowly into it so that it spread evenly inside the mould. After filling the mixture, a load of 15-18 kN was applied for proper compaction of bricks. Figure 2 shows bricks in moulds.

The bricks thus prepared was kept for 24 hours in the mould and then removed and kept under sunlight for drying with proper curing by spraying water, as shown in Figure 3. Compressive strength of all the prepared bricks were tested by applying load axially at uniform rate of 14 N/mm^2 per minute till it fails and the maximum load at failure was noted (IS 3495-Part I:1992). Testing of bricks was done using universal compression testing machine as shown in Figure 4. The failure plane after compression is shown in Figure 5. Further, water absorption test was also carried out as shown in Figure 6.

Fig. 2 *Mixture filled in bricks mould*

Fig. 3 *Curing of bricks*

***Fig. 4** Testing of bricks for its compressive strength*

***Fig. 5** Failure planes after compression*

***Fig. 6** Water absorption test on prepared bricks*

5. Results and discussion:

In total, five sets of bricks were prepared with different ratio of cement (C), fly ash (FA) and iron ore waste (IOW), which are designated as Ratio - A, Ratio - B, Ratio - C, Ratio - D and Ratio - E as mentioned in Table 3. For each ratio of mixture, 40 bricks were prepared and every ten set of bricks were cured for 7 days, 14 days, 21 days and 28 days. Out of ten bricks five were tested for its compressive strength and five for its water absorption, as per Bureau of Indian Standards IS 3495-Part I: 1992 and IS 3495-Part II: 1992). Table 3 also gives the results of compressive strength and water absorption for all the five sets of bricks of different ratio.

According to IS standards, the compressive strength of bricks should be minimum 3.5 MPa (IS 3495-Part I: 1992), whereas water absorption should not be more than 20% for 24 h immersion (IS 3495-Part II: 1992). From Table 3 it can be concluded that the compressive strength of bricks reduces with reduction in percentage of cement in mixture. However, with increase in curing period the minimum strength of bricks could be gained. It may be noted that in all the cases the water absorption is within the permissible limit.

***Table 3:** Results of compressive strength and water absorption on prepared bricks*

Mix Ratio	No. of Curing Days							
	7	14	21	28	7	14	21	28
	Compressive Strength (MPa)				Water Absorption (%)			
30:00:70 C:FA:IOW (Ratio A)	8.58	8.82	11.30	11.52	14.45	8.78	6.85	5.43
	7.50	8.71	11.25	11.43	14.25	8.81	6.81	5.40
	7.97	8.77	11.14	11.75	14.20	8.83	6.78	5.44
	7.60	8.75	11.20	11.58	14.22	8.77	6.75	5.46
	7.75	8.80	11.28	11.65	14.36	8.80	6.79	5.40
Average	7.88	8.77	11.23	11.59	14.30	8.80	6.80	5.43
25:05:70 C:FA:IOW (Ratio B)	5.87	7.55	7.54	8.67	13.70	8.75	6.82	5.36
	5.95	7.38	7.72	8.65	13.65	8.70	6.77	5.39
	5.71	7.29	7.61	8.74	13.68	8.76	6.74	5.41
	5.80	7.45	7.59	8.70	13.66	8.74	6.71	5.37
	5.78	7.50	7.65	8.69	13.69	8.71	6.73	5.35
Average	5.82	7.43	7.62	8.69	13.68	8.73	6.75	5.38
20:10:70 C:FA:IOW (Ratio C)	4.33	5.37	6.38	6.96	13.54	8.72	6.78	5.35
	4.74	5.45	6.92	6.85	13.52	8.69	6.76	5.32
	4.63	5.25	6.67	7.12	13.50	8.67	6.74	5.29
	4.70	5.36	6.70	6.90	13.48	8.65	6.71	5.30
	4.55	5.40	6.75	6.88	13.51	8.70	6.73	5.34
Average	4.59	5.37	6.68	6.94	13.51	8.69	6.74	5.32
15:15:70 C:FA:IOW (Ratio D)	3.39	4.14	4.53	4.37	12.96	8.71	6.69	5.30
	3.08	4.06	4.27	4.58	12.86	8.66	6.73	5.27
	3.21	4.21	4.40	4.44	12.89	8.62	6.71	5.29
	3.17	4.18	4.35	4.50	12.85	8.60	6.75	5.25
	3.10	4.15	4.40	4.48	12.90	8.63	6.70	5.22
Average	3.19	4.15	4.39	4.47	12.89	8.64	6.72	5.27
10:20:70 C:FA:IOW (Ratio E)	2.90	2.95	3.02	3.10	12.84	8.60	6.70	5.23
	2.63	2.84	3.03	3.09	12.80	8.56	6.68	5.20
	2.79	2.80	2.90	3.23	12.83	8.59	6.66	5.19
	2.75	2.85	2.95	3.20	11.98	8.52	6.65	5.21
	2.65	2.84	3.05	3.15	12.00	8.50	6.62	5.25
Average	2.74	2.86	2.99	3.154	12.49	8.55	6.66	5.22

6. Conclusions

It is a general phenomenon that the compressive strength of brick increases with increase in percentage of cement as well as with the curing period. The present study demonstrates that the mix composition with 70% iron ore waste, 15% fly ash and minimum 15% cement gives the compressive strength and water absorption properties of bricks meeting IS standards. This is achieved with 14 days curing period. As indicated in the Table 3, for the same mix ratio D, with 7 days of curing, the average compressive strength achieved was 3.19 MPa, which does not meet the minimum required criteria for compressive strength as stipulated by the IS standards. Further, with 70% iron ore waste, 10% cement and 20 % fly ash, though the water absorption is below 20%, bricks will not fulfill the minimum required compressive strength of 3.5 MPa. However, attempt was not made for cement ratio in between 15 to 10% for the preparation of bricks. The maximum compressive strength reported in the present study is 11.75 MPa for 28 days of curing, whereas the study carried out by Yongliang et al. (2011) shows compressive strength up to 15.9 MPa for 28 days of curing. The addition of fly ash in the brick making helps in reduction of weight of bricks while improving the binding property of the mixture. It is felt that utilization of iron ore waste generated in mines can be extremely useful in reducing environmental degradation in and around the mines along with improving the aesthetic beauty of the surroundings.

References:

[1] Amit, R. and Rao, D. B. N., "Utilization potential of industrial/mining rejects and tailing as building materials", *Management of Environment Quality: An International Journal*, 16, PP. 605-614, 2005.

[2] Bureau of Indian Standards (BIS), IS 3495-[Part-I]:1976, "Methods of Tests of Burnt Clay Building Bricks" specification", 1976.

[3] Bureau of Indian Standards (BIS), IS 3495-[Part-II]:1976, "Methods of Tests of Burnt Clay Building Bricks" specification", 1976.

[4] Bureau of Indian Standards (BIS), IS 2117:1991, "Guide for manufacture of hand-made common burnt-clay building bricks", 1991.

[5] Bureau of Indian Standards (BIS), IS 2720-(Part III/Sect.2):1980, "Determination of s pecific gravity", 1980.

[6] Bureau of Indian Standards (BIS), IS 1077:1992, "Common burnt clay building bricks specification", 1992.

[7] Bureau of Indian Standards (BIS), IS 2180:1988, "Specification for heavy duty burnt clay building brick", 1988.

[8] Bureau of Indian Standards (BIS), IS 2691:1988, "Specification for burn clay facing bricks", 1988.

[9] Bureau of Indian Standards (BIS), IS 8112:1989, "43 Grade ordinary Portland cement–specification", 1989.

[10] Bureau of Indian Standards (BIS), IS 11650:1991, "Guide for manufacture of common burnt clay building bricks by semi-mechanized process", 1991.

[11] Bureau of Indian Standards (BIS), IS 6165:1988, "Dimensions for special shapes of clay bricks", 1988.

[12] Chakravarthi, M. K. A. S. Bhat, V. and Koushik, K.N., "Build well with waste", *Parisara, ENVIS Newsletter*, 2(9), PP. 1-8, 2007.

[13] Chen, Y. Zang, Y. Chen, T. and Liu, T. "Utilisation of hematite tailings in non-fired bricks production". *Fifth International Conference on Informatics and Biomedical Engineering (ICBE)*, PP.1-4, 2011.

[14] Dean, J. D. Stephens, J. E. and Bancroft, J. "Use of mine tailings in construction materials". *Tailings and Mine waste, Balkema, Rotterdam*, PP. 567-575, 1996.

[15] Hammond, A. A., "Mining and quarrying wastes: A critical review", *Engineering Geology*, 25(1), PP. 17-31, 1988.

[16] Indian Bureau of Mines (IBM), "National mineral inventory–an overview", *Ministry of Mines, Govt. of India*, PP. 6-15, 2013.

[17] Jha, J., *Engineering Minerals*, Khanna Publishers, Delhi, India, PP. 1-45, 1992

[18] Khanna, P. N., *Índian Practical Civil Engineers*' Handbook, Engineers Publishers, New Delhi, India, PP. 12/1-12/44, 1994

[19] Mangalpady, A. and Sampath Kumar, N.N. "Studies on Iron tailings towards usage for paving blocks manufacture". *International Journal of Earth Sciences and Engineering*, 3(6), pp.861-868, 2010

[20] Mohanty, M. Dhal, N. Patra, P. Das, B. and Rama Reddy, P., "A novel approach for utilization of iron ore wastes", *Reviews of Environment Contamination and Technology*, 206, PP. 29-47, 2010.

[21] Muduli, S.D. Rout, P. K. Pany, S. Mustakim, S. M. Nayak, B. D. and Mishra, B. K., "Innovative process in manufacturer of cold setting building brick from mining and industrial wastes", *The Indian Mining Engineering Journal*, 49(8), PP. 127-130, 2010. 4-7, 2014

[22] Roy, S. Adhikari, G. R. and Gupta, R. N., "Use of gold mill tailing in making bricks: a feasibility study", *Waste Management and Research*, 25, PP. 474-482, 2007

[23] Rudramuniyappa, M.V., "Iron ore and their impact on environment in Sandur- Hospet region, Bellery district, Karnataka, India", *National Metallurgical Laboratory Proceedings, Jameshdpur*, PP. 273-278, 1997

[24] Sunil Kumar, "A perspective study on fly ash–lime–gypsum bricks and hollow blocks for low cost housing development", *Construction and Building Materials*, 16, PP. 519–525, 2002

[25] Ullas, S. N. Reddy, V. and Rao, K S N., "Characteristics of masonry units from iron ore tailings", *International conference on Sustainable Built Environment (ICSBE), Kandy*, PP. 108-114, 2010

[26] Xiaoqing, N. and Jichun, C., "Effect of additives on the properties of concrete products made from iron ore tailings", *IEEE Journal*, PP. 1670-1673, 2011

[27] Yonggang, Y. Shenhong, Z. Qiuyi, L. Bennju,

Y. and Yu, C., "Research on making fired brick with gold tailings", *International Conference on Computer Distributed Control and Intelligent Environment Monitoring*, PP. 1687-1690, 2011

[28] Youngliang, C. Yamin, Z. Tiejun, C. Yunliang, Z. and Senxu, B., "Preparation of eco-friendly construction bricks from hematite tailings", *Construction and Building Materials*, 25, PP.2107-2111, 2011

[29] Youngliang, C. Yimin, Z. Tiezun, C. Tao, L. Yunliang, Z. and Xiangke, J., "Utilization of hematite tailings in non-fired bricks production", *Bioinformatics and Biomedical Engineering (ICBBE),* PP. 1-4, 2011

[30] Zhang, S, Xue, X. Liu, X. Duan, P. Yang, H. Yang, T. Jiang, D. Wang and Liu, R., "Current situation and comprehensive utilization of iron ore tailing resources", *Journal of Mining Science*, 42(4), PP. 105-110, 2006

[31] Zhao, Y. Zhang, Y. Chen, T. Chen, Y. and Bao, S., "Preparation of high strength autoclaved bricks from hematite tailings", *Construction and Building Materials*, 28, PP. 450–455, 2011