Waste Utilisation : Towards Cleaner Environment

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ABSTRACT

The concept of waste utilisation is based on the notion that waste is a resource, but at wrong place and using this concept, many new technologies have been developed. Two case studies have been discussed in the present paper where mineral and metallurgical wastes have been used as raw materials to develop value added products at the National Metallurgical Laboratory. In the first case, iron ore tailings, a waste which is generated during iron ore washing, has been used to develop ceramic floor and wall tiles. These tiles confirm all the EN standard specifications and have better scratch hardness and strength then the conventional tiles. In the second case, wear resistant ceramic liners has been developed using fly ash. The wear resistant properties of these liners are better then metal and alloy liners and at par with high alumina ceramic liners. These products can be used in wear prone zones of material handling equipment, chutes, bunkers, hoppers, mills, etc. The philosophies behind the development of these technologies, the processing involved and the properties of the products have been discussed in the paper.

Key Words : Waste utilisation, value added products, ceramic floor & wall tiles, wear resistant ceramic liners.

INTRODUCTION

Until recently, industrial production was considered a linear process, where the main inputs were energy and raw materials, and the expected output was product with a proportional amount of waste or other by-products. However, increased public opposition and growing cost of waste disposal which increases the cost of production has put the industries under tremendous pressure. Also increasing concern world-wide for environmental protection, growing economical constraints and depleting natural resources have led many R&D institutions to look into the possibility of an integrated material cycle. Many new concepts such as clean technology, zero waste products etc. have emerged, but these are still at the conceptual stage and waste generation is a ground reality. To overcome this problem, a new concept of waste utilisation has emerged, which is basically a change of attitude towards waste. It believes that waste is a resource, but at a wrong place and by using the concept, many new technologies have been developed and commercialised.

In India, mineral and metallurgical industries are vital components of national economy and accounts for a major percentage of the gross national products. The last decade has seen a rapid growth of these industries in India, which has been further, accelerated with the liberalisation. At the same time, these industries have added huge quantities of waste and secondary materials to our environment. The intrinsic value of these secondary material resources is widely recognised, but their industrial exploitation has rarely been considered to have economic advantage. These materials are therefore usually dumped on open grounds or buried in landfills, and its impact on the environment has been disastrous.

The present paper includes two case studies where mineral and metallurgical wastes namely iron ore tailing and fly ash has been successfully used for developing ceramic tiles and wear resistance ceramics respectively. The philosophy used for development, processing routes and properties in comparison with other products are discussed in this paper.

EXPLOITATION OF IRON ORE TAILINGS FOR THE DEVELOPMENT OF CERAMIC TILES

India ranks as the sixth largest producer of iron ore in the world with a total reserve of 19.3 billion tonnes. The current practice of washing iron ore in India results in the generation of huge quantity of tailings. The generation of tailings is estimated to be 10- 25 wt% of the total iron ore mined, thus amounting to around 18 million tonnes per year in India[1]. These tailings are stored in massive ponds and pose severe environmental hazards. Safe disposal or utilisation of these materials thus remains a challenging task for the iron ore industry in India. One of the possible solution is to convert the tailings into value added products for building industry. With the traditional building materials industry under pressure and unable to cope up with the demand, there is growing concern in many developing countries for updating production processes, as well as promotion of alternative building materials. Ceramic floor and wall tiles are one of such value-added products where industrial wastes can be used as raw material[2-5]. A typical tile body consists of SiO_2 as major oxide and CaO, MgO, Na_2O and K_2O as minor compounds. For supplementing these compounds, the raw material is selected from a group of plastic and non-plastic minerals. Clayey minerals such as kaolinite, illite, montmorillonite, etc. belong to the first group and contribute to the strength development of green tiles. The second group consists of feldspar, talc, quartz, pigmatite and quartzite, and is used as flux. The philosophy used in the present study is to use iron ore tailing as source of silica as it contains around 40-50% SiO_2. The other necessary compounds were supplemented by using conventional raw materials such as clay, feldspar and talc. Although Fe_2O_3 is kept to a minimum in conventional ceramic tiles as they lead to a coloured body, use of iron bearing minerals and materials for ceramic tile is reported in literature. Marghusian et al[6] reported that production of wall tiles containing up to 65% iron slag has been developed by the Japanese investigators. Similarly, the Italians are reported to have formulated various iron slag containing bodies with good mechanical properties and little firing shrinkage[7]. Lenkei et al[8] used Hungarian blast furnace slag to produce porous tiles fired below

1100°C. Das et al[9] also reported the suitability of iron ore tailings for ceramic tile compositions. From a review of these papers, it may be observed that iron-bearing materials may be used as an inexpensive source of alkaline earth oxides for fast fired tile bodies.

Based on the raw material characteristics, various tile compositions were formulated using iron ore tailings with some other materials such as clay, talc, feldspar etc. The raw materials were wet milled for 6 hours to obtain the desired fineness. The slurry obtained is screened, spray dried and compacted using a liquid binder. 4" X 4" rectangular samples were compacted using uniaxial pressing at 250-300 kg/cm^2 pressure. To get the glazed tiles, first engob and then glaze is sprayed at the surface of the green tiles. The shaped articles were fired at 1060-1200°C in air for vitrification. The flow sheet of the above process is given in Fig.1. After the vitrification, the tiles were characterised. The properties of these tiles in comparison with European Nation (EN) standards are given in Table 1.

Table 1 : Properties of tailing based tiles developed in comparison with EN standards

Properties	EN Standard specification	NML developed tiles
Dimension tolerance	± 0.5%	As per specification
Thickness tolerance	± 0.5%	As per specification
Straightness of sides	± 0.5%	
Rectangularity	± 0.6%	As per specification
Surface flatness	± 0.5%	As per specification
Surface quality	95% free from visible defects	Improvements needed
% Water absorption		
Gr.I	<3	3-6
Gr.II		7-10
Gr.III	3-6	13-17
Scratch hardness (Mohr's)	14-16	Min. 6
Flexural strength (kg/cm^2)	Min. 5	>250
1150°C fired tiles	225	
Thermal shock resistance of	To withstand min. 10 cycles	
1150°C fired tiles		
Chemical resistance		Confirms Class AA
	Class AA	

The tiles exhibited better scratch hardness and flexural strength. However, water absorption properties and the degree of straightness of the sides need further improvement. It may be mentioned here that the present studies were carried out with laboratory facilities. The properties may improve further with the use of commercial tile production facility.

From the above study, it can be observed that the tailings generated by iron ore industry may be used as one of the raw materials for making ceramic floor and wall tiles. Its high silica content favour formulation of tile body compositions. These tiles are superior with respect to scratch hardness and strength, maintaining most of the other properties comparable to EN specifications. Iron ore tailings substitute some of the expensive minerals used in commercial tile compositions and lower the product cost. Further, these tailings are in powder form, thus requiring less grinding time, there is thus scope for energy saving. This new development may be a cost-effective solution in managing tailings of iron ore and controlling environmental pollution. It may be relevant to mention here that the Indian tile industry as a whole consumes around 1000 x 10^3 MT mineral deposits as input for production per annum. Even with a conservative estimated replacement of minerals by iron ore tailings, the consumption of iron ore tailing works out to be 300 x 10^3 MT/annum. This definitely results in significant conservation of mineral resources of India.

EXPLOITATION OF FLY ASH FOR THE DEVELOPMENT OF WEAR RESISTANT CERAMIC LINERS

Wear is one of the predominant tribological failure mechanisms caused by the interaction of application environment. For improved performance and longer life, the choice of wear resistant liners have become increasingly critical. Ceramic liners, in terms of their hardness, mechanical stability and chemical inertness gives several fold longer life than conventional metal and alloy liners. High alumina ceramics (85 - 99 % Al_2O_3), owing to its inherent properties of high hardness, excellent surface quality and moderate toughness are considered optimum for low temperature applications environment where techno-economics is the criteria[10]. In the present work, fly ash has been used as partial substitute of alumina to develop wear resistant product. The particles of fly ash used ranges in size from <5 to 120 micrometer and is spherical in diameter. Being light in weight, it has potential to get air borne and pollute the atmosphere but at the same time, its reactivity is very high due to fine particle size. The major constituents of fly ash are SiO_2 , Al_2O_3 and Fe_2O_3 along with some minor constituents such as CaO, MgO and TiO_2 . The main active constituent of fly ash is amorphous silica in hollow, spherical glassy particles called cenosphere. The potential of fly ash as a raw material for ceramic applications was reviewed by Sen et al[11] and Das et al.[12] They reported that addition of limited quantity of fly ash in alumina improves the erosion resistance. Kumar et al[13] obtained a hard and dense ceramic product by reaction sintering of fly ash and alumina mixture. The philosophy used here is the advantageous physical, chemical and mineralogical properties of fly ash, which forms needle shaped mullite on sintering. These needles shaped mullite acts as reinforcement in the matrix and contribute towards strength development.

Three type of composition has been developed using 15, 25 and 40 wt% fly ash for high, moderate and low wear applications. The raw materials were wet milled for 8 hours. The slurry obtained after milling was passed through 150-mesh sieve to remove any unwanted coarser particles. The screened slip was filtered, pressed and dried in a drier at 110°C till the moisture content was reduced to < 0.5%. The dried mass was then converted to fine powder. 6 to 7% of liquid organic binder was sprayed on the dried powder and mixed uniformly to produce small granules required for better compaction. The ready granules were compacted in desired dimensions using 350 kg/ cm^2 uniform uniaxial pressure. The shaped samples were air dried and fired in an electric furnace at 1600°C for 2 hours in air. The rate of heating was kept at 5°C/ minute. The process flow sheet is given in Figure-2. After the sintering, the products were characterised and the properties are given in Table 2.

Table 2 : Chemical composition & physical properties of wear resistant products

	15% Fly Ash	25% Fly Ash	40% Fly Ash
Chemical Composition (wt%)			
Al_2O_3	70.57	66.83	60.18
SiO_2	20.26	25.16	30.11
Fe_2O_3	1.41	2.04	2.36
MnO_2	4.95	3.69	4.16
Physical Properties			
Colour	Brown	Brown	Dark Brown
Bulk density (gm/cc)	2.71	2.55	2.44
Linear shrinkage (%)	9.70	10.40	12.40
Hardness (Mohr's scale)	9	9	9
Compressive strength (kg/cm^2)	>10,000	>10,000	>10,000
Fracture toughness (MPa $m^{1/2}$)	3.03	2.08	1.51
Abradibility index	21.54	30.71	32.82

After comparing the properties with high alumina ceramic liners (85%Al_2O_3), it is found that composition with 15wt% fly ash have comparable properties and better fracture toughness. These products can be used in material handling equipment which are prone to heavy, medium and low wear such as chutes, bunkers, hoppers, storage bins, cyclone separators, etc.

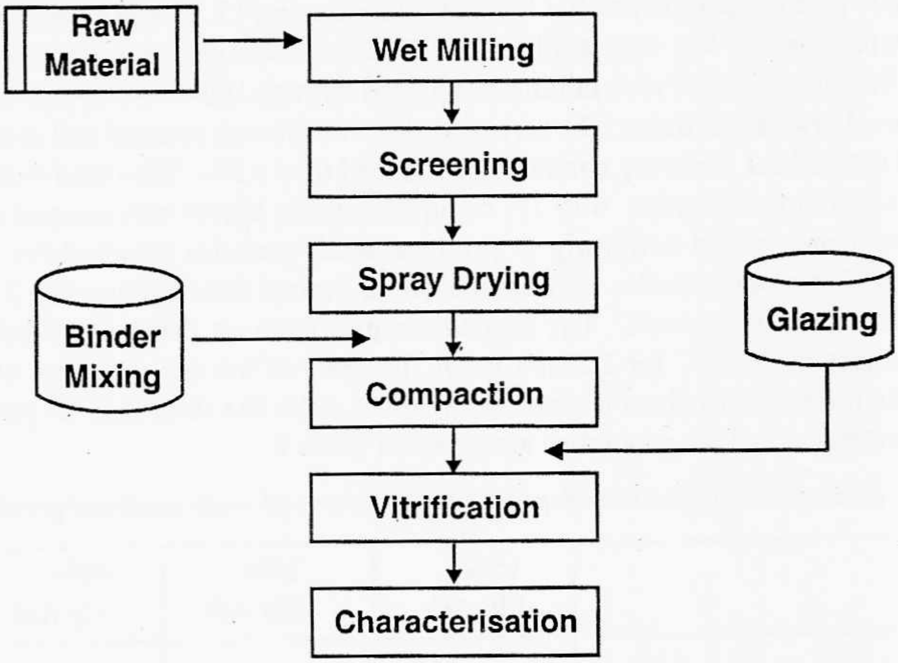

Fig. 1 : Process flow sheet for manufacturing ceramic floor and wall tiles from iron ore tailings

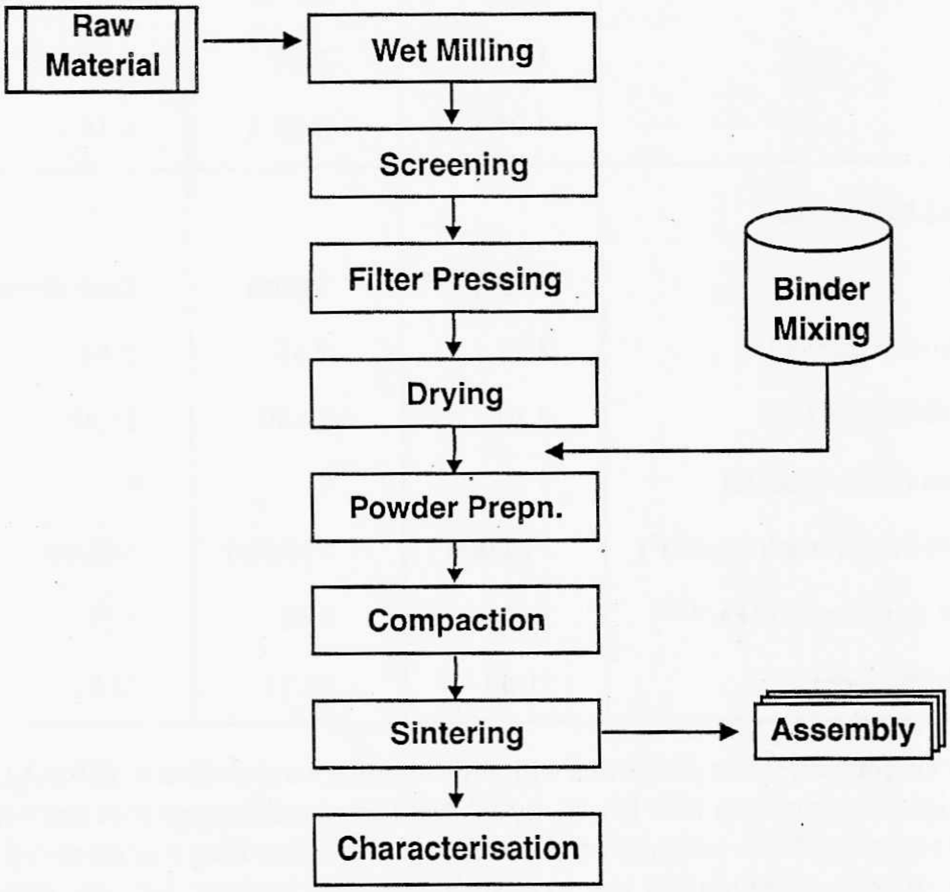

Fig.2 : Process flow sheet for manufacturing wear resistant ceramic liners from fly ash

CONCLUSIONS

The environmental cost will continue to rise if the mineral and metallurgical industries try to satisfy the continued and increasing demands from society for cheap materials. The challenge for the industry and for governments is to ensure that this cost is borne by the consumer, and not by society as victim or taxpayer. This applies particularly to developing countries, where mineral and metallurgical industries will develop most rapidly into the present millennium, and where environmental controls are often overlooked. Although, many industries operate at very high standards, however, they are still judged by their worse, rather than their best examples and society is still suspicious. There are a number of potential developments, which could produce environmental benefits. The utilisation of waste products, recycling and re-use can reduce the environmental impacts of the industry. However, application of a scientific approach for the utilisation of wastes are required which ensures that the measures adopted are cost-effective. The efficiency of resource use throughout the life cycle of products and services should be optimised in the design, production, sale and use of products and services. It should also be ensured that the employment of such measures do not compromise occupational health, safety or product integrity.

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