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An innovative approach towards utilisation of wastes generated from iron & steel industries

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ABSTRACT

The iron and steel industries around the world are responsible for the generation of large amount of waste materials mainly because they process huge quantity of raw materials. Neither the governments nor the society have forced the industries to develop ways and means of managing the waste in a creative way. However, with very little land available for disposal of wastes and also because whatever was a waste material two decades ago can not be considered a waste today due to ever increasing shortage of natural resources including ores, minerals and fuels, the pattern of thinking of scientists and technologists have changed. Newer materials and products are now being developed from wastes generated from different process industries including metallurgical industries. In this paper, the authors aim to present the development of a few products carried out at the National Metallurgical Laboratory, Jamshedpur from solid waste generated from iron & steel industries including captive power plants. Some of these products are wear resistant ceramic lining materials, refractory aggregate for high alumina cement castable, ceramic floor & wall tiles, etc. The theoretical aspects behind development of these products have also been touched upon.

INTRODUCTION

The concept of utilization of solid wastes in iron and steel industries embraces the three basic principles of recovery, recycling and converting to high value added products. The utilization of wastes has attained in more recent years a fourth and most important dimension in its relation to environment and problem of disposal. A fifth dimension lies in the domain of research and development and relates to the addition of values to wastes so as to make them into economical and useful products. As has been mentioned in various literatures[1,2] recycling is an integral feature of modern steel plant operations. Of the materials recycled, dust from various operations is recycled from the economic and environmental point of view. Recovery of values from dust and slag has been receiving considerable attention internationally in recent years. Some of the well attempted examples by various countries are recovery of phosphorous, niobium and manganese from slags, recovery of zinc from blast furnace and BOF dust etc. Besides recycling and recovery, continuous efforts are being made by many foreign institutions and industries to convert solid wastes into value added marketable products namely various types of ceramic based products, composites and low cost building materials etc.

India ranks as the sixth largest producer of iron ore in the world generating as high as 18 million tonnes of slime per year[3,4]. These slimes stored in massive water ponds pose enormous environmental hazards. The beneficiation/ safe disposal of slime or converting it into a value added product thus remain a challenging task for iron ore industry. Increased generation of electricity through thermal route leads to huge production of fly ash and it is anticipated[5] that by the year 2000 Indian thermal power plant would be producing around 90 million tonnes of fly ash annually. It is also estimated that Indian iron & steel industries generating around 5 million tonnes of blast furnace slag.

Although utilization of steel plants solid wastes to produce value added products has been accepted as an engineering reality in several countries, however, its entry in India has been rather slow. The technological possibilities for the utilisation of such wastes in making high value added products deserve special attention of R&D scientists because of lot of potential in achieving required properties.

In such an attempt, National Metallurgical Laboratory, Jamshedpur, has developed few ceramic products from the waste generated by iron and steel industries using the principles of sintering and vitrification techniques. In this paper the authors discusses some of the related properties of the products developed along with their potential application areas. The theoretical aspects of sintering and vitrification process which are responsible behind the development of these products are also briefly touched upon.

RAW MATERIALS

In the present investigation, iron ore slime, fly ash and blast furnace slag are considered as major raw materials and these are collected from Tata Iron and Steel Companies Limited, Jamshedpur. The chemical analysis of these three raw materials are given in Table-1.

In addition to above major raw materials, technical grade Al_2O_3, special additives and alumino-silicate minerals are also used as other raw materials in the present study.

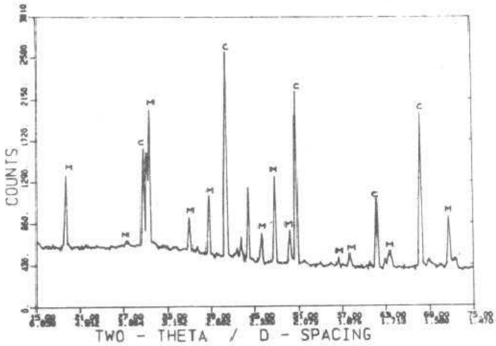

Fig.1 : XRD pattern of the sintered sample (M=Mullite, C=Corundum)

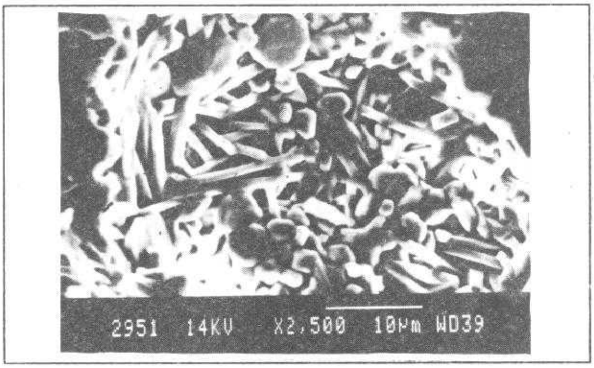

Fig.2 : SEM photograph taken on the fractured surface of the sintered specimens

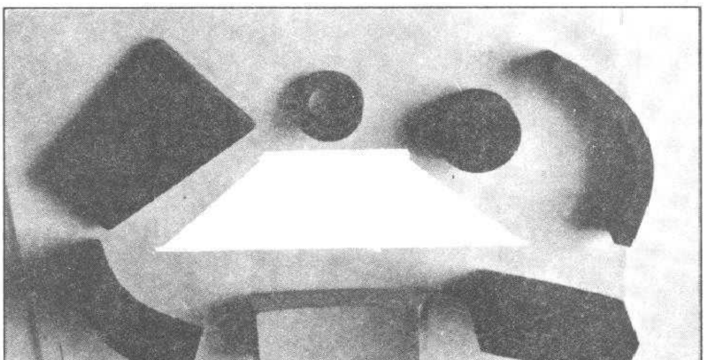

Fig.3 : Photograph of NML developed wear resistant ceramic tiles

Table-1 : Chemical analysis of solid wastes used in the present study

Chemical constituents	Iron ore slime	Fly ash (wt %)	B.F. Slag
SiO_2	0.64	55.21	33.74
Al_2O_3	3.08	27.80	18.98
Fe_2O_3	92.26	4.80	0.25
Cao	Trace	1.68	33.27
MgO	Trace	0.48	9.88
TiO_2	0.39	1.65	1.08
L.O.I.	3.07	7.55	1.85

PRODUCTS DEVELOPED BY SINTERING PROCESS

In this process, fly ash, alumina with sintering aids are intimately mixed in powder form as per the required proportions[6] and then compacted into a desired shape. Before firing, the powder compact is composed of individual grains separated by pores depending on the particular material used and the processing method. The green porosity level ranged between 25%- 80%. This porous compact converted to a strong, dense ceramic object during sintering at high temperatures. The different mechanisms of mass transfer during sintering process are widely discussed in literature[7,8]. Those are mainly evaporation and condensation, viscous flow, surface diffusion, grain boundary or lattice diffusion and plastic deformation that occur in most of the ceramic systems.

The approach selected here to synthesize mullite ($3Al_2O_3 . 2SiO_2$) materials by reaction sintering of fly ash with alumina. Fly ash contains 27.8% Al_2O_3 and 55.2% of SiO_2. (Table-1). With Al_2O_3 added the fly ash to make up the deficiency, and under appropriate reaction sintering conditions, the ash and Al_2O_3 mixture react to form mullite phase.

The sintered samples obtained in this study were examined by XRD to evaluate the phase formation. The XRD pattern is shown in Fig.1. The results reveals the presence of mullite and corundum phases. This indicates that the present mix of fly ash and alumina powder have been converted to mullite and corundum under the sintering conditions used in this study. Hwang et al[9,10] in their study observed similar phase formation under various sintering conditions. A slight increase in mullite formation as temperature increases was also noticed by them. The fracture surface in the sample was examined by SEM and the SEM photograph is shown in Fig.2. The figure illustrates the microcrystalline structure with well distributed needle shaped mullite crystals

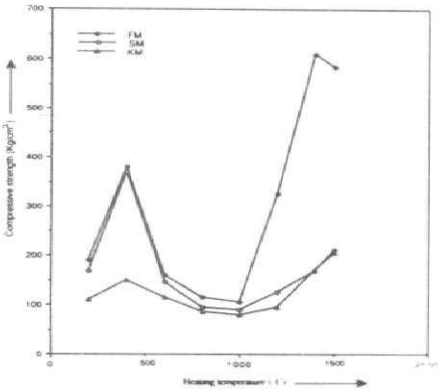

Fig.4: Variation of compressive strength of castable briquettes in relation to heating temperature (FM= fly ash based refractory aggregate; SM= sillimanite based refractory aggregate; (KM= kyanite based refractory aggregate)

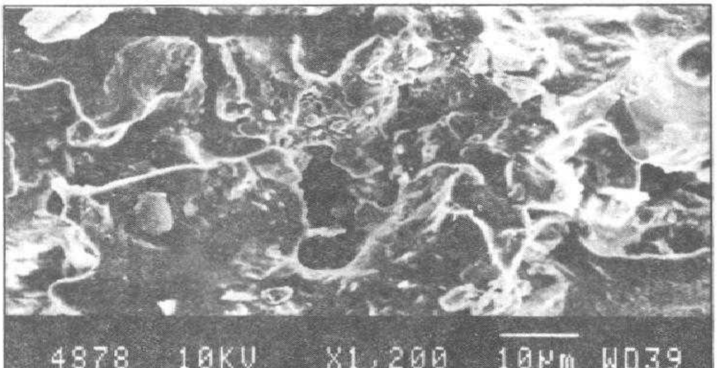

Fig.5 : SEM photograph taken on the fractured surface of the vitrified waste based ceramic tile

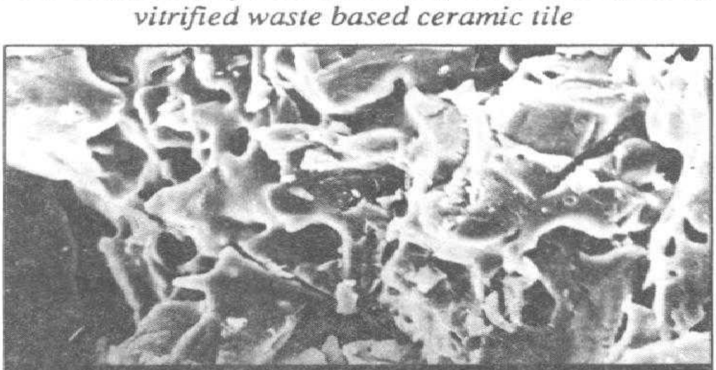

Fig.6: SEM photograph taken on the fractured surface of vitrified commercial tile

strongly bonded together along with corundum grains in between them. This type of microstructures appears to be best for resisting both sliding abrasion and impingement wear.

The physico-mechanical properties of the sintered samples are given in Table-2. The properties are well comparable with high alumina based sintered ceramic materials in respect to its hardness, strength and wear resistant properties[11].

Table-2: Physico-mechanical properties of the sintered sample

a. Bulk density (gm/cc)	:	2.85
b. Hardness (Mohs scale)	:	9.00
c. Apparent porosity (%)	:	0.05
d. Cold crushing strength (kg/cm^2)	:	> 10,000
e. Abradibility index (Morgan Marshall)	:	14.10
f. Erosion rate (Volume loss in cc/kg erodant)	:	0.0151

Fig.3 is a photograph of the wear resistant ceramic products developed at NML in various shapes and sizes.

There can be many more successful applications of these sintered products as lining material in the material handling equipment to protect wear at near room temperature conditions . Some of the specific application areas are chutes, bunkers, hoppers, storage bins, cyclone separator, vibrating feeder in coal yard, P.F. bend pipe, mills , ash slurry pipe lines in thermal power plants and equipments of coal washeries, cement and iron and steel industries.

The sintered samples after crushing and grading to different size fractions were used as refractory aggregate with high alumina cement to produce monolithic castable. The castable briquettes were heated at various temperatures (200°-1500°C) and their compressive strength were determined. The results were compared with castables made with other type of refractory aggregates, synthetically prepared from sillimanite and kyanite. The variation in compressive strength properties in relation to heating temperature is shown in Fig.4. A significant improvement in strength is observed of fly ash based aggregate (FM) at 1400°C which may be attributed to better sintering caused by Fe_2O_3 present in fly ash. This study probably open the scope of using the fly ash based sintered material developed by NML during these studies as refractory aggregate for high alumina cement castable for applications around 1400°C. Further study in this area are under progress and shall be presented in our future communications.

PRODUCTS DEVELOPED BY VITRIFICATION PROCESS AND THEIR RESULTS

Densification with the aid of viscous liquid phase is the major firing process for the great majority of silicate system. In the vitrification process this concept is utilized. A viscous liquid silicate is formed at the firing temperature and serves as a bond for the body. In the present study, iron ore slime, fly ash, B.F slag and other alumino-silicate minerals are used as raw materials in different combinations to produce a vitrified product which find applications as ceramic floor and wall tiles for building industry. The compositions and vitrification temperatures were optimized in such a way that the densification occurs in a reasonable time without the ware slumping and warping under the force of gravity. In the present system, fyalite (2FeO. 2 Al_2O_3 .5 SiO_2) might have formed and the viscous liquid phase serves as bond for the body. The SEM photographs taken on the fractured surface of the vitrified body is shown in the Fig.5. The structure consists of a mixture of glassy and crystalline phases. One of the probable crystalline phase is mullite.

Most of the commercially available ceramic floor and wall tile is a vitrified product of clay, felspar and sand. One of the commercial sample was subjected to SEM study and the photograph is shown in Fig.6. Similar type of structure are observed in commercial sample also. Some amount of small and big tapped pores are seen in the Figs. 5 and 6. The physico-mechanical properties of the presently developed tiles has shown advantages over commercial tiles in respect to scratch hardness and flexural strength values which are better for floor application[12]. A suitable matching glaze

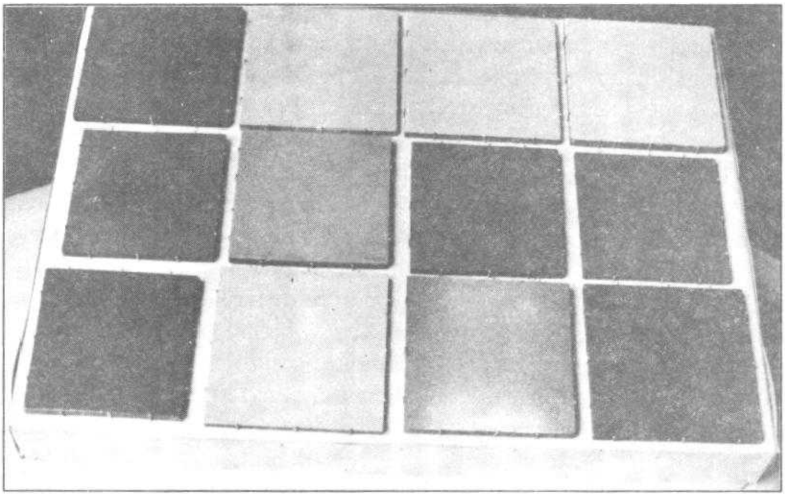

Fig.7 : Photograph of NML developed waste based ceramic floor & wall tiles (unglazed & glazed)

material is also developed for glazing the tiles in various colours. Fig.7 is a photograph of market size (4"x4") tiles developed and produced at NML both in glazed and unglazed form.

CONCLUSION

The present paper describes an innovative approach for the gainful utilization of iron and steel plant solid wastes for high value added ceramic products which finds both engineering and other commercial applications. The successfully developed products are wear resistant ceramic lining materials, refractory aggregate for high alumina cement castables and ceramic floor and wall tiles.

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