Fly Ash Utilisation for Value Added Products
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Ceramic products from fly ash : Global perspectives

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ABSTRACT

This paper gives a glimpse of various emerging global techniques for the production of different value added ceramic materials from fly ash viz. glassy materials, porcelains, refractories etc. The efforts undertaken by CFRI in this regard have also been highlighted.

Key words : *Fly ash utilisation, Ceramic materials, Refractory materials, Insulatory materials*

1.0 INTRODUCTION

Two types of ashes are generated during the combustion of coal in thermal power stations. The lighter one collected at the ESP is known as fly ash and the coarser one collected at the bottom of the furnace is known as bottom ash. The properties of fly ash depend on several factors which include :

a) Nature of coal

b) Temperature of combustion

c) Extent of pulverisation etc.

The ash is composed of tiny and almost spherical particles. Its colour is generally grey and it depends on the proportion of unburnt carbon.

The major constituents of fly ashes are silica, alumina, iron oxides, unburnt carbon etc. The principal group of minerals found in fly ashes are mullite, magnetite, haematite, quartz and glass. The principal group of ceramic products having the possibility of development from fly ash are pottery products like glazed tiles, refractories including insulating materials, glass and ceramics, ceramic fibers and foams, iron exchangers etc. A glimpse of the different technologies developed in different laboratories for the develoment of the above products from fly ash is given in this paper.

2.0 POTTERY PRODUCTS FROM FLY ASH

The basic ingredients of the triaxial pottery products are clay, quartz and feldspar. A judicious blend of fly ash alongwith other suitable ingredients may give rise to the favourable phase composition in the finished products. Hereunder, some of the recent works of different laboratories in this direction is given.

Arpad et al[1] developed glazed ceramic tile from fly ash. The composition (wt. %) of the batch is as below :

Feldspar containing sand	2-49
Fly ash	0-50
Tuff	0-50
Lime free clay	28-70

The raw materials were dry ground using 0.1% sodium tri-poly phosphate to form powders having a mositure content of 5-7%. Sheets were prepared by pressing followed by application of glaze on the surface. Using an optimum composition, a tile body having green strength of·4 MPa, fired strength 30 MPa, shrinkage 5%, water uptake 3% was achieved. The sheets showed good freeze resistance also.

Agarwal et al[2] developed an acid and abrasion resistant fly ash tile. Fly ash was used as a partial substitute of China clay in the economical manufacture of ceramic tile. The firing temperature was unchanged or slightly lower than that of tiles prepared from conventional materials. The fly ash tiles had suitable acid resistance and better abrasion resistance than that of the commercial vitrified tiles.

Abdarkhimov et al[3] developed a glazed tile. One typical composition like the following gave glazed and ungalzed tiles with minimum water absorption of 36 and 14.8% and maximum mechanical strength of 19.7 and 14.8 MPa respectively.

Bentonite	...	5
Plastic Clay	...	45
Pyrophillite	...	25
fly ash	...	22
Ti-Mg Industry Sludge	...	3

Mellenthin et al[4] utilised ash separation products as components of ceramic bodies. Wallastonite- rich residues from alkali leaching of lignite ashes were used for the manufacture of cermic tiles. Tiles of high quality were obtained containing 30-35% wallastonite residues.

Tanabe et al[5] have developed hard ceramic boards and tiles for exterior walls and the lining of furnace using fly ash as one of the constituents. A first powder comprising SiO_2, CaO and an Al compound was mixed with a second podwer serving as aggregate. The mixture was mixed with water glass and subsequently cured. The ceramics are used as exterior wall tiles and furance lining. A mixture consisting of ordinary portland cement 8%, SiO_2 fume 31%, and fly ash was mixed with sand and water glass, moulded and dried at 150^{0}C for 3 hours to give boards with specific gravity of 1.8 gm/cm^3, compressive strength 1120 kg/ cm^2, Moh's hardness 5, water of absorption 9%, immersed in water at 20^{0}C for 72 hours), high heat resistance (at 1050^{0}C for 3 hours) and weather reistance (1,000 hour in weatherometer).

A high strength ceramic composite board for building was developed by Ota et al[6]. They developed a mix composition of flyash 100, wallastonite 5-15, blast furance sludge powder 5-15, silica powder 5-10 and kaolin powder 5-10 parts. The mixture was kneaded with binders and then extruded. The extruded materials with stainless steel mesh sheets on both sides were hot pressed to obtain composite sheets, which were subsequently sintered.

Mukherji et al[7] investigated the feasibility of utilizing flyash in combination with plastic clays and feldspars in the preparation of table-ware and artware and comparing the characteristic properties with stonewares. Trial on fly ash based products showed good freeze resistance and strength.

3.0 GLASS CERAMICS

Glass ceramics or devitrified glasses are products with the addition of a nucleating agent to a molten composition. These materials have got widespread applications in different fields.

These materials can be developed from a suitable composition using flyash as one of the constituents and following suitable process conditions. Here-under, some of the works of different researchers in this direction are given below.

Hnat et al[8] developed a glass-ceramic tile from flyash. Flyash containing organic materials, metallic contaminants and glass forming materials were oxidized in this process under conditions effective for the combustion of the organic material and partial oxidation of the metallic contaminants and the glass forming materials. The oxidized glass forming materials were vitrified to form a glass melt and the glass melt was then formed into tiles containing metallic contaminants to produce ceramic tiles.

Another variety of glass ceramics was developed from municipal incinerator flyash by Boccaccini et al[9]. A controlled crystallization heat treatment of vitrified incinerator filter fly ashes was used to produce glass ceramics. Glasses were prepared and the samples were quenched in air at room temperature. An optimized heat treatment schedule was developed to yield homogeneous, fine grained glass ceramics of amber brown colour. Resulting materials were evaluated for crystal phase, mechanical properties and toxic potential.

Alfred et al[10] developed another variety of glass ceramics from fly ash. The fusion of fly ashes containing 20% CaO+MgO and Cr_2O_3 as the nucleating agent gave glass melt which solidified to glass ceramics containing pyroxones with very fine (0.1μ m) crystal structure. The linear thermal expansion of these glass ceramics was (60 -120)x 10^{-7} °C (at 20 - 600°C)

Barbieri et al[11] had also developed glass ceramics from flyash. After mixing with other inorganic wastes such as dolomite-slag and glass cullet, samples of fly ash from spanish thermal power plants were vitrified. The relative viscosity and crystallization behaviour of the glasses obtained were investigated by hot stage microsccpy and DTA, from which reheating schedules were choosen for recrystallization. X-ray diffraction analysis showed that diopside (augite and / or wallastonite) could be crystallized from these glasses, giving rise to dendritic and / or acicular microstructures which were observed and analysed by SEM (SEM/EDX). It was shown that the glass ceramics so obtained had improved mechanical properties compared with the untreated glasses.

Cumpston et al[12] studied on the feasibilityof formation of glasses and glass ceramics from fly ash. Glasses synthesized from Utah bituminous coal ash melts were crystallized to form glass ceramics. The use of additives to have glass formation and catalysts to serve as nucleation sites for crystallization was studied.

4.0 CERAMIC FIBERS AND FOAMS

Development of ceramic fibers and foams require the addition of glass forming and combustible additives to the batches and adoption of suitable blowing or drawing techniques. Fly ash has been used as one of the ingredients in the manufacture of these items. Some of the works in these directions are given hereunder.

Mayer-Reiland et al[13] developed a charge for producing a high melting ceramic foam. A composition, like fly ash (0.01-0. 09 mm) 3000, borax 400, and Sic (0.1-0.003mm)5 gm. were mixed and heated in a mould to 1000-1150^{0}C for 1 hour to give a foamed ceramics of density 0.3-0.8 gm/cm^3. Typical bending and compressive strengths were 55-60 kg/cm^2 and 28-32 kg/cm^2 resply.

A composition of mineral wool from fly ash was developed by Ali[14]. The composition (wt%) is like the following : fly ash (SiO_2-52.72, Al_2O_3-21. 17, Fe-Oxide 6.86, CaO-7.18, MgO-0.45, B_2O_3-2.13, Cr-Oxide-0.02, TiO_2-0.90, Na_2O-0. 78, K_20-0.59, $S0_3$-0.55, LOI 6.98 + cement kiln dust (SiO_2-12.48, Al_2O_3-3.21, Fe oxide-1.60, Cao-43.87, MgO-1.16, B_2O_3-1.61, Cr-oxide-0.02, TiO_2-0.27, Na_3O-0.46, K_3O-1.78, SO_3-2.83, LOI-31.18 wt%) and a borate (2CaO, $3B_2O_3$, $5H_2O$)

5.0 REFRACTORIES

Development of refractory materials from fly ash requires the combination of such materials with fly ash which will give rise to the development of refractory phases like mullite, after firing of the body. Some recent works in these directions are given hereunder. Queralt[15] et al used binary mixture of fly ash and plastic clays to manufacture ceramic products with upto 50 wt% mullite and 16 wt% feldspar. The firing behaviour of fly ash and the ceramic mixtures was investigated by determining their change in mineralogy and basic ceramic properties such as colour, bulk density, water absorption and firing shrinkage. To determine the changes on heating suffered by both the fly ash and the ceramic bodies, firing tests were carried out at temperatures between 900 and 1200^{0}C in short firing cycles. The resulting ceramic bodies exhibit features that suggest possibility for use in paving stone ware manufacture, for tile and conventional brick making.

Ni et al[16] studied on the possibility of production of light refractory bricks by using sintered Flyash or coal gangues as raw materials. The addition of a certain level of industrial Al_2O_3 powder to the burnt coal gangues followed by milling to a size with oversize of 800 mesh sieves less than 5%, forming and sintering means, a high quality light refractory brick of mullite can be prepared. During foaming, some easily burned organic materials should be added to the mud. After sintering at 1550°C for 5 hours the bricks produced can reach the German standard JM 28.

The properties of mullite synthesised from flyash and alumina mixtures were studied by Huang et al[17]. The objective of this study was to determine the feasibility of synthesising mullite from beneficiated flyash and alumina powder mixture. As received and beneficiated fly ash of both class F and C were used to synthesise mullite.

Chiu et al[18] studied on the thermal and mechanical properties of fly ash-calcium carbonate refractory materials. The thermal condition, thermal expansion, heat capacity, room temperature strength (dry and water saturated) and temperature dependence strength for a microwave proccessed refractory prepared from fly ash, $CaCO_3$ and sodium silicate were determined. The results were discused in relation to the utilization of fly ash in the manufacture of low duty refractory material.

Acid resistant refractory material from fly ash was developed by Stanislaw et al[19]. Fire clay was combined with flyash and phenolite and fired at 1200°C for optimum strength and minimum porosity. The compressive strength of the fired samples was a function of its quartz, mullite and glassy phase content.

6.0 INSULATING MATERIALS

Development of insulating materials from a batch with flyash as one of the ingresdients requires the addition of a combustible or foam forming additives to the batch which at an elevated temperature will burn off producing pores in the body. Some of the works in this direction are given hereunder.

An insulating material from flyash was developed by Hokesman et al[20]. They mixed fly ash with a small amount of coal dust and then the mass was humidified, pelletized and sintered. By this process, a strong porous lightweight granulate was obtained. The granulate was used in concretes, prefabricated cements and as a high temperature insulating material.

Masaki et al[21] developed an insulating material from fly ash. Flyash was mixed sewerage sludge and sintered or fused to obtain ceramic material. Clay, silicate minerals, sintering aids, foaming agents and binders were added to the mixture and was coated with a glazing material after shaping. Thus, fly ash 100., dewatered sludge cake containing 65, water 30 and plastic clay 20% were mixed, pressed at 30 kg/cm^2 dried at 70-120°C and fired at 1150°C to obtain insulating brick having an apparent density of 1.62 g/cm^3 and CCS of 355 Kg/cm^2.

An universal insulating material suitable for industrial and domestic structure was developed by Walker et al[22]. The material is installable in molded or unmolded form mixable with water and/ or chemicals by common methods depending on its use. The mix contains brown coal ash 20-90, sand 0-20, cement 5-35, lime 5-20 and blowing agent 0.5-5 wt% (dry). Thus, a dry material containing brown coal ash 70, cement 15, and blowing agent 1 wt% was mixed intensively with addition of a suitable amount of water, stiffened and hardened, molded and mechanically post treated.

7.0 DISCUSSION

Various technologies on the develoment of different value-added ceramic materials have been developed. These technologies now require commercial translation. Research institutes will have to work more intensively to make these technologies cost competitive. Entrepreneures also should come forward for the adopotion of the developed technologies. The government has also a vital role to play by encouraging the entrepreneurs providing fiscal and other benefits for the adoption of the different developed technologies for the commercial production. Then only the mission of 'conversion of waste to wealth' can be fulfilled.

8.0 REFERENCES

1. Arpad R. et al. HU Teljes 40,391
2. Agarwal P. S. and Sen S. K.; Res. Ins. Bull. 1985. 32(4) 103-104
3. Abdarkhimov V. Z. and Rodin A. N.; Kompuken Ipolllz Miner Syrbya, 1986, 12, 63-66
4. Mellenthin U. and Keil I; Freiberg Forschungsh, 1989, 797, 105-109
5. Tanabe K. and Matsure K., Eur. Pat. Appl. EP. 818,428
6. Ota K. and Ota M., Jpn. Kokai Tokkyo Koho, JP.10,25,171
7. Mukherjii S. K. et al, Br. Ceram. Trans. 1993,92 (6), 254-257
8. Hnat J. G. et al. US Appl. 629,558
9. Boccaccini A. R. et al. Am. Ceram. Soc Bull. 1997, 76 (11), 75-78
10. Alfred S., Pr. Kom. Ceram. Pol. Aked. Nauk. Ceram. 1986,35,103-134 (Pol)
11. Barbieri L. et al glass technol. 1997, 38, (5) 165-170
12. Cumpston B. et al, J. Mater. Sci. 1992, 27 (71), 1781-1784
13. Mayer E. M.- Reiland, Ger. Offen. DE 3314796
14. Ali M. A., Ceram Inf. 1986, 21 (247), 59-60
15. Queralt I. et al, Fuel, 76(8), 786-791
16. Ni W. et al, Dizhi zhaokuang Luncong, 1997, 12 (4), 79-86
17. Hangu X. et al. Interceram., 195, 44(210,65-66
18. Chiu C. C. and Case E. P.; Ceram eng. Sci. Proc. 1988, 9(1), 140-152
19. Stanislaw G.; Srch Sineral, 1986, 41(1), 249-258, (Pol)
20. Hoksema H. W.; Energiespectrum, 1987, 11 (5-6), 137- 146
21. Masaki W.; Jpn. Kokai 62,212,260
22. Welker D. et al; Ger, DD 226, 279