Industrial Prospects And New Approaches Of Using Wastes In Building Materials

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Varieties of waste materials are produced from the agro-industrial processes in India causing adverse environmental impact and pollution in closed vicinity of their production. The bulk of this waste remains unutilized. There is increasing shortage of building materials which can be met by producing durable alternative materials from these wastes. The article describes the investigations on the characterization of industrial wastes and their present status and recycling potential in the development of building materials such as cements, cementitious binders, bricks, tiles, boards, precast building components, etc. The findings on the use of industrial wastes may enhance production of alternative building materials desirable to mitigate pollution and health hazards generated by them.

Due to environmental degradation, energy consumption and financial constraints faced by various organizations to get rid of the impurities present in industrial wastes, transferring them into alternative building materials is of national interest.

Introduction

The materials like lime, gypsum, clay, sand, stone, gravels, cement, bricks, pavements, timber and steel are being used as major building components in construction works. Besides this, gaseous and liquid effluents from these industries are degrading the environment and posing hazards to both human and animal life and thus creating serious problems for their effective disposal. Efforts are, therefore, being made to effectively utilize these wastes. In India, over 960 million tonnes of solid waste is being generated annually as by-products during industrial, mining, municipal, agricultural and other processes. Out of this 350 million tonnes are organic wastes from agricultural sources; 290 million tonnes are inorganic waste of industrial and mining sectors and 4.5 million tonnes are hazardous in nature (1-4).

Fly ash, phosphogypsum, fluorogypsum, red mud and slag, cement kiln dust, lime sludge from sugar, paper, acetylene industries, rice husk, bagasse, bamboo, coconut pith and cotton stalk are the important industrial and agricultural wastes of considerable interest. These waste materials contain certain obnoxious impurities which hinder the normal setting and strength characteristics of cement and cementitious materials, and other building materials made from them. Due to environmental degradation, energy consumption and financial constraints, various organizations in India and abroad, apart from the regulatory frame work of United States Environmental Protection Agency (USEPA), have recommended various qualitative guidelines for generation, treatment, transport, handling, disposal and recycling of non-hazardous and hazardous wastes (5-9). Hence, to get rid of the impurities present in these wastes, transferring them into alternative building materials is of national interest.

Extensive research and developmental work has been done at the Central Building Research Institute (CBRI) to develop building materials from industrial solid wastes, particularly, fly ash, phosophogypsum, fluorogypsum, red mud, blast furnace slag, lime sludge, kiln dust, mining dross, etc.(10). The assessment of the industrial and the building materials such as cements, cementatious materials, bricks, tiles, building blocks and boards, partition panels, aggregate and precast building products produced from them, their properties and applications are described in this article.

Assessment Of Industrial Wastes

The availability of industrial wastes in the country are listed in Table 1. Most of the waste materials have identical constituents like SiO_2, Al_2O_3, CaO, Mgo, SO_3, but, they differ in their impurity contents. Intrinsically, the chemical composition of these materials depends on the quality of the raw materials and type of process being adopted in their production.

Fly ash, an industrial waste of thermal power plants causes environmental degradation. Its quality is judged by its lime reactivity.

The lime reactivity of Indian fly ashes varies between 4.0 and 7.0 N/mm^2 and judged as per IS:3812 (Part I, II, III-2003 Specifications for fly ash). Blast furnace slag is produced as a by-product during the manufacture of pig iron. Granulated slag is produced by the chilling of molten slag with excess water, cold air or oil. In addition to blast furnace slag, a number of slags from metallurgical processes such as arc furnace slag, phosphatic slag, low carbon ferrochrome slag, copper and nickel slags are produced in small quantities.

Table 1 - Annual Production of Industrial And Agricultural Wastes In India

Wastes	Industry	Production (Million Tonnes)
Fly ash	Thermal Power Stations	130.0
Blast Furnace Slag	Iron & Steel	12.0
By-product gypsum	Phosphoric acid, fertilizer, hydrofluoric acid plants	6.0
Lime sludges	Paper, sugar, fertilizer, acetylene, tannery, chromium, soda ash industries	5.0
Red Mud	Aluminium industries	4.0
Mine tailings	Zinc, copper, gold, iron ore beneficiation plants	5.0
Cinder	Thermal power plants and foundries using lump coal	3.0
Water works silts	Water works	12.0
Lime kiln rejects	Lime kilns	Large quantity
Coal washery rejects	Coal washeries	Large quantity
Rice husk	Rice Mills	> 25.0

Phosphogypsum, a by-product of phosphoric acid fertilizer industry, is hazardous to health. It contains impurities of P2O5. F, organic matter, alkalies, quartz, etc. P2O5 and F exist as water soluble, lattice bound or as insoluble forms in gypsum. These impurities adversely affect the setting and hardening characteristics of cements/plasters produced from it. Extensive investigations on beneficiation of phosphogypsum have been conducted at the Central Building Research Institute (CBRI), Roorkee. IS:12679-1989 covers the chemical requirements of byproduct gypsum for use in plaster, blocks and boards.

Red mud, a by-product of aluminium plants is toxic (pH 10.5 - 12.0) and rich in alkalies, iron and titanium and are free from detectable radioactive elements. Besides these, lime sludges are the by-products of paper, acetylene, sugar, chromium, fertilizer and soda ash industries. The main impurities in these sludges are sugar, P2O5 and alkalies which have the beneficial effect of lowering the burning temperature. $CaCO_3$ is the main component of these sludges except in the case of acetylene sludge in which it is present as $Ca(OH)_2$.

Considerable mine tailings (siliceous dolomitic in nature) are produced in the beneficiation of ores of zinc, copper, iron and gold. Large quantities of silts are obtained from the water works. Major applications of these materials are in the manufacture of bricks and as a starting material for making lightweight aggregate. Rice husk is agro waste which contains cryptocrystalline silica, a pozzolanic material, for making lime-pozzolana binders.

The building materials developed from various industrial wastes, their science and technology are discussed below.

Fly ash

Portland - Pozzolana Cement: Portland-pozzolana cement conforming to IS: 1489-1976 can be manufactured using fly ash either by intergrinding Portland cement clinker, fly ash and gypsum, or by intimately blending the Portland cement and fly ash in suitable proportions. It is suitable for use wherever ordinary Portland cement is usable under normal conditions. But is more suitable for marine and hydraulic structures and mass concrete constructions.

Ready-Mixed Fly ash Concrete: Portland cement concrete in which a part of the cement has been replaced with fly ash is termed as fly ash concrete. When it is prepared in plastic, unhardened, ready for use state, it is known as ready-mixed fly ash concrete. It has 28 day compressive strength equal to that of corresponding plain cement concrete (11). Batching and mixing of different ingredients is done at a central batching and mixing plant. The ready mixed concrete has the advantages of better quality control, reduction in wastage and pilferage of materials, labour and supervision, which are normally associated with concrete prepared at site.

Precast Fly ash Concrete Building Units: Work done at CBRI has shown that fly ash concrete with 20 percent less cement (by weight), having 1-day strength equal to the corresponding plain cement concrete building blocks, flooring and roofing units such as cored units, channel units, cellular units have been produced using fly ash concrete (12).

Sintered Fly ash Light-weight Aggregate: The sintered fly ash lightweight aggregate (SFLA) is produced by (i) pelletization of the fly ash, and (ii) sintering the fly ash pellets at 1100-1200°C in a vertical shaft kiln or a moving grate sinter strand. The production of SFLA from the Indian fly ashes has been successfully carried out on a pilot plant moving grate sinter strand at CBRI (Power: 12500 kwh/t, fuel: 10 per cent (13). The aggregate is suitable for use in the production of structural light-weight concrete (B.D. 1376-1776 kg/m^3, 28 days C.S. 15.2-40.0 N/mm^2, B.S. 2.5-5.4 N/mm^2, drying shrinkage 0.059 - 0,084 per cent) and precast building units. A model house constructed from lightweight SFLA aggregate concrete still exists after 40 years of construction in excellent condition in CBRI premises. The fly ash is suitable for making lime fly ash cellular concrete (2-3 storey) of density 440-1442 kg/m^3 having wood like properties such as sawing, chiseling, nailing, etc. (14).

Portland Cement Clinker and other Cements: Cement clinker can be produced at 1350°C by firing nodules of raw meal containing fly ash in place of clay, normally employed for traditional cement production at 1450°C. Besides a substantial saving in fuel consumption, the use of fly ash in the raw mix has been found to enable production of cement clinker with MgO content of 6 percent without causing unsoundness in the final cement (15). Fly ash is also suitable for making oil well cement (16). A masonry cement based on slag and fly ash of better properties than OPC has been developed at CBRI (17). Masonry cement made from waste phosphogypsum and lime slude of paper or fertilizer industries is equally important.

Clay-Fly ash Bricks: Fly ash can be used with soils yielding good quality building clay-bricks at CBRI (18) conforming to IS : 3102 (Fig.1). These bricks are moulded manually or by an extruded process. The moulded bricks are fired in continuous type Bull's kiln, High draught kiln or intermittent type of kilns at 960°C -1060°C. Addition of 10 to 40 per cent fly ash by weight of the red, black and alluvial soils in the mix is preferred. Most of the fly ashes, contains unburnt carbon in the range of 5 to 20 per cent. Addition of fly ash in optimum proportion to the soil gives fuel saving in the range of 15 to 25 per cent or coal saving up to 3 to 5 tonnes per lakh bricks. The fly ash addition to the plastic red and black soils reduces excessive linear drying shrinkage and drying and firing losses during brick production are checked. The bulk density of clay fly ash bricks is reduced which provides better thermal insulation property to the masonry walls and reduces dead load on the brick masonry structure. Besides above, technologies for manufacture of fly ash - lime bricks (Fal-G) have been claimed by many National Laboratories and private companies.

Fig.1: Clay-fly Ash Bricks

Fly ash - Sand - Lime Bricks: The technology of producing fly ash-sand-lime bricks is based on the process of making sand-lime bricks. These bricks are well known in Germany, U.K., Netherlands, etc. In India, there is one sand-lime factory near Kochi (Kerala). A fly ash-sand-lime brick (calcium silicate brick) is considered to be one of the advanced building materials in India and is made from fly ash, sand and hydrated lime. These bricks are of accurate dimensions,

Table 2: Properties of Fly ash-Sand-Lime Bricks

Property	Fly ash-Sand-Lime Bricks	Burnt-Clay Bricks
Compressive Strength	10.0 - 15.0 N/mm^2	3.5 - 12.5 N/mm^2
Water absorption	15 - 20 %	20% for bricks of compressive strength less than 12.5 N/mm^2
Bulk density	1500 - 1600 kg/m^3	1600-1899 kg/m^3
Thermal Conductivity	0.5 - 0.6 Kcal/m/hr/0C	0.6 - 0.7 Kcal/mhr/0C
Durability	Very good	Good
Drying shrinkage	0.03 - 0.06	0.03 - 0.07
Efflorescence	Slight	Slight to moderate
Fire resistance	Good	Good shape Uniform

sharp edges, no plastering of walls is required, conservation of agricultural land and pollution are attained. Manufacture of these bricks is economically feasible where fly ash, sand and lime are readily available and good quality clay is not found in abundance. A lot of research and development work has been carried out in CBRI (19) to produce good quality fly ash-sand-lime bricks by moulding the bricks in a rotary table press and curing the same by steam at various pressures. A plant of capacity 2000 bricks/hr has been set-up by Damodar Valley Corporation near Calcutta by CBRI sometime back. Properties of these bricks vis-a-vis burnt clay bricks is shown in Table 2.

Blast Furnace Slag

During the process of manufacture of iron and steel in blast furnaces, slag is obtained as a by-product. This is essentially a calcium alumino silicate and contains numerous types of earthen impurities. When the slag is allowed to cool slowly in air, it solidifies to a grey crystalline stone material known as air cooled slag. If the molten slag is poured into large excess of water, or subjected to jets of water or air-water mixture, it cools quickly and is shattered into small particles, known as granulated slag.

In order to step-up the production of building materials due to enhanced construction activities, transformation of agro-industrial by-products into lucrative building material should be encouraged.

Portland Slag Cement: Portland slag cement can be produced by proper blending of granulated blast furnace (50-60%) slag with Portland cement clinker and small amount of gypsum to regulate the setting time. The hardening of slag cement proceeds by the hydration of Portland cement clinker constituents which are associated with the release of lime and then the slower process of slag activation with lime. The properties of the Portland slag cement prepared from Indian slag conform to the IS:455-1989 "Specifications for Portland Slag Cement". Extensive work has been done at CBRI about the production, hydration and durability of Portland slag cement (PSC) under various climatic conditions (20). PSC has also been produced using high manganese slag (Mn_2O_3 up to 6.17 percent) available from Rourkela Steel Plant (21). PSC can be used in all types of general civil works and water retaining structures. It is eminently suitable for marine and mass concrete construction due to high sulphate-resistance and low heat of hydration.

Super-sulphated Cement: Supersulphated cement (SSC) conforming to the 1S:6909-1990, is an intimate blend of granulated slag (70-80 percent), gypsum anhydrite (20-25 per cent) and small amount of Portland cement (5-10 per cent), which acts as activator. Extensive investigations have been carried at CBRI for the development of supersulphated cement (22-24) using Indian slags. Based on studies, the optimum amount of anhydrite produced by calcining phosphogypsum was found to be 20-25 percent as against the commonly recommended value of 10-15 percent. The initial strength of this cement (1-7 d) is obtained by the formation of ettringite ($3CaO\ Al_2O_3.3CaSO_4.\ 32H_2O$) but the final strength (28 d & onward) is achieved by appearance of calcium silicate hydrates (CSH)/tobermorite similar to those of Portland cement.

Lime Sludges

Large quantities of lime sludge as calcium carbonate ($CaCO_3$) is produced as a by-product from the sugar, calcium carbide and fertilizer industries. Acetylene sludge obtained from carbide plants is, generally $Ca(OH)_2$.These sludges can be used in different ways in the production of cement and cementitious binders.

Cement and Cementitious Materials: Lime sludges can be used in place of natural limestone as a rotary kiln raw feed in the desired proportions in the manufacture of ordinary Portland cement. Based on the studies conducted at CBRI, it has been found that masonry cement can be produced from sludges obtained from calcium carbide, acetylene and sugar industries (25). The products thus prepared possess all the properties of masonry cements (Grades- LP 40, LP 20 & LP 7) conforming to IS:3466-1988.

A hydraulic binder suitable for plastering, masonry and foundation having some of the properties similar to Portland cement has been developed from rice husk and by-product lime of sugar, acetylene, paper industry, etc. (26). Use of rice husk acts as an integral fuel and provides insitu silica for the lime (CaO) produced during firing at 900-950°C. The maximum temperature recorded during firing was 900-950°C. The setting characteristics of the binder are within the time limits similar to those of hydraulic cements (IS:4031-1988). In addition to improved setting and hardening behaviour it also exhibits improved water retention, workability, water tightness, etc. associated with lime based compositions.

Activated Lime-Pozzolana Mixture (ALPM): The ALPM possesses very high water retentivity (70 percent or more) and is slow setting. The final setting time for LP40, LP20 and LP7, as specified in 18:4098-1983, is 24, 36 and 48 hours maximum, respectively (26). To obviate slow setting of ALPM, a rapid setting activated lime-pozzolana mixture based on calcined lime sludges and fly ash surkhi conforming to IS:4098-1983 has been developed.

Cementltlous Binder from Bagasse (27): An attempt has been made to produce quick setting lime-bagasse ash mixture for mortar and plaster as per IS:4098-1967. This was accomplished by intergrinding a mixture of hydrated lime, bagasse ash along with 10 per cent Portland cement and 4 per cent gypsum in a ball mill or tube mill to a fineness passing 90 per cent through 200 mesh.

Gypsum By-product: Phosphogypsum

The by-product gypsum such as phosophogypsum and fluorogypsum possess impurities of P_2O_5, F, organic matter and alkali which adversely affect the hydraulic properties of cements and plasters produced from them. These impurities have been removed / reduced by several processes ranging from washing to chemical treatments evolved at CBRI, Roorkee (28). A plant of capacity of twenty one tonne per day has been developed and installed at M/s Orissa Gypsum Ltd., Cutttack (Fig.2) for the beneficiation of phosphogypsum (29). The plant is functioning well. The beneficiation phosphogypsum and fluorogypsum can be used for the production of following value added building materials. The building materials developed from phosphogypusm waste are detailed below.

Phosphogypsum as a set Controller and Mineralizer in Cement Manufacture: Investigations have been carried out in order to use phosphogypsum as an additive to cement clinker (30) in place of natural gypsum. The adverse effect due to the presence of the impurities of phosphate, fluoride and phosphoric acid adhering to its surface can be removed by washing by-product gypsum with water in the pilot plant (Fig.2).

Thus, produced gypsum conformed to the standard specification for Portland cement and Portland slag cement. Phosphogypsum has been tried as a mineralizer in the production of cement clinker and saving of 200°C has been claimed (31).

As a Raw Material in the Manufacture of Cement and Sulphuric Acid: Phosphogypsum has been used for the simultaneous manufacture of cement and sulphuric acid. The process consists of conversion of gypsum into lime in the presence of carbon with the simultaneous production of SO_2 gas. The lime reacts with SiO_2 and Al_2O_3 to decompose clay to form cement clinker. The technical know-how of the process (250 tp/day) is 'available with M/s Chemie Linz, Austria and M/s Phalobarwa (South Africa) (32). The production of cement and sulphuric acid from phosphogypsum may be adopted in India considering economy of the process in the Indian conditions.

Gypsum Plaster Blocks and Boards from Phosphogypsum: The gypsum plaster produced from phosphogypsum can be used in making blocks and boards suitable for internal partition walls and in false ceiling works. Blocks of different densities (900-1100 kg/m^3) have been prepared by adjusting consistency of the slurry. Fibrous gypsum plaster boards have also been prepared from the gypsum plaster slurry reinforced with sisal/coir/munj/bhabhar/jute fibre. A process for the manufacture of boards of size 120 x 60 x 12 mm has been developed. Gypsum based products are especially known for their lightweight, texture, fire resistance and thermal insulating properties. A high strength hemihydrate plaster (a-plaster) has been developed from the beneficiated phosphogypsum using autoclaved process (33). Recently cementitious binders have been produced using a-plaster for use in boards, blocks, masonry, plsastering works, etc. (34). Fig.3 Shows building materials developed from Indian phosphogypsum waste.

Fig. 2: Phosphogypsum Beneficiation Plant (84 Tpd) Set Up At M/s Orissa Gypsum Ltd., Cuttack, India

Weather Resistant Phosphogypsum Binder: To enhance application of gypsum plaster and plaster products in exposed situations, a water-resistant gypsum binder has been developed by blending ground granulated blast furnace slag or fly ash, OPC and chemical

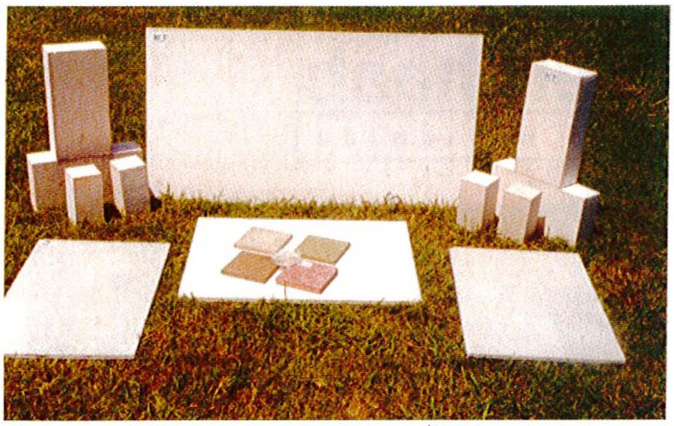

Fig.3: Building Materials (Board, Blocks, Tiles) Developed From Phosphogypsum (M/s RCF, Mumbai) & Fluorogypsum (M/S Navin Fluorine International, Mumbai)

additives with the calcined phosphogypsum (35). The major properties of phosphogypsum binder are shown in Table 3.

Phosphogypsum binder has been used for the production of glass reinforced gypsum binder boards (GRGB) of dimensions 400 mm x 750 mm by reinforcing E-type of glass fibres in the gypsum binder matrix by suction process (36). The GRGB boards are characterized by their bulk density 1.62 g/cc, flexural strength 22 MPa tensile strength 18.0 MPa, impact strength 19 Nmm/mm^2 and thermal conductivity 0.09 KCal/m/hr/^{0}C. These boards are recommended as partial replacement of depleting timber in view of their wood-like properties.The phosphogypsum binder has been found suitable for making masonry mortars of properties: mix 1:4 (binder-sand) compressive strength 3.5 - 4.5 MPa, bond strength 0.017-0.018 N/mm^2 and water retentivity 65-67 percent. High water retentivity implies superior workability of the mortars.

Table 3: Properties Of Weather Resistant Phosphogypsum Binder

Property	Phosphogypsum Binder	Plaster of Paris
Fineness m^2/Kg (Blaine)	320-330	300
Bulk density, g/cm^2	1.20 - 1.26	1.00
Setting time, Minutes Initial Final	 75.0 - 90.0 140.0 - 160.0	 30.0 --
Compressive Strength, MPa 1 day 3 day 7 day 28 day	 10.0- 12.0 19.0 - 21.0 27.0 - 30,0 31.5 - 40.0	 13.03 13.18 13.20 13.20
Soundness, cold expansion, mm	0.62 - 0.71	0.50
Water absorption (per cent)	6.00 - 6.80	45.00
Durability (in water)	No leaching in water	Leaching (After 3 days immersion in water)

Gypsum By-product: Fluorogypsum

Fluorogypsum. a by-product of hydrofluoric acid industry contains impurities of free acidity and CaF_2.These impurities are made inert by neutralization with 0.5 - 2 percent lime. High strength plaster and super sulphated cement have been developed from fluorogypsum.

Fluorogypsum as a Plastering Material: A cementitious binder from fluorogypsum (FG) been developed for use in masonry and plastering works (37). Fluorogypsum does not react with water but in presence of accelerators such as K_2SO_4, Na_2SO_4 /Na_2SO_4 + $FeSO_4$, $NaHSO_4$ and $K_2Cr_2O_7$ it forms high strength cementing material. The fluorogypsum binder may be used in plastering (finish and under coat), masonry work and making building units. The hydrated (FG) binder showed typical platy, prismatic and lath shaped habit. A binder containing FG, fly ash/slag and other constituents have also been synthesized for mass use in building sector (38-39). Recently, a technology of 'Making High Strength Plaster from Fluorogypsum and the Flooring Tiles' based on the Indian Patent 'High strength plaster composition and flooring tiles made therefrom' by Manjit Singh & Mridul Garg, CBRI (No.696/Del/2000) has been transferred to M/s Navin Fluorine International, Mumbai.

Super Sulphated Cement from Fluorogypsum: The supersulphated cement has been produced as per the IS:6909-1990. The optimum mix proportion of SSC was - granulated blast furnace slag, fluorogypsum anhydrite and OPC clinker 65:20:15 (by weight) (40). Several high strength binders have been developed using fluorogypsum, fly ash, slag, etc. (41-42). Based on work done by the author and his associates on FG, recently, a sponsored project on Super-sulphated cement has been completed by CBRI for M/s Metadynamics, CC, South Africa.

Gypsum From Intermediate Dye Industry

Another variety of by-product gypsum popularly known as H-acid gypsum, is produced in India to the tune of 0.75 million tonnes per annum from the dye intermediate by the neutralization of free

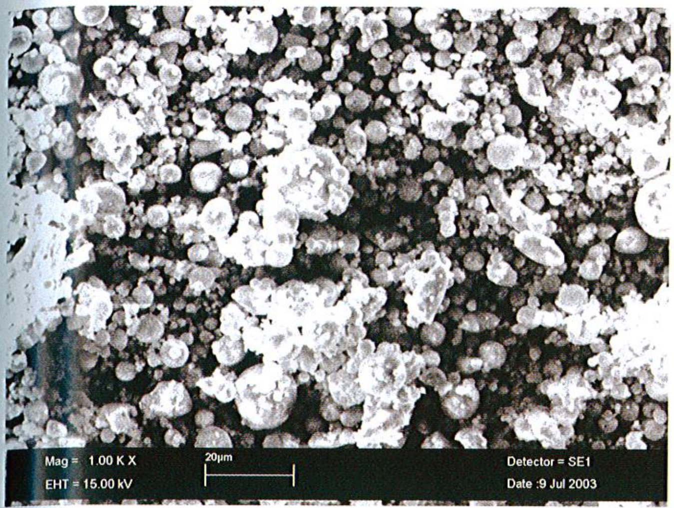

Fig. 4: SEM of H-Acid Gypsum Sample

sulphuric acid with limestone. Very little information is available about the chemistry and utilization of the H-acid gypsum in India or abroad.

Efforts have been made at Central Building Research Institute (CBRI) by Singh, et. al. to find out useful applications of the H-acid gypsum/intermediate dye industry waste through laboratory experiments only (43). The samples of H-acid gypsum were collected from the dye industries from Gujarat and Maharastra regions of the country for chemically examination, differential thermal analysis (DTA) and scanning electron microscopy (SEM). The SEM (Fig.4) showed prismatic crystals in association with lath and twinned crystals coated with the fine gypsum particles. On washing with water, the organic matter is grossly reduced.

The waste gypsum was calcined to - hemihydrate plaster and found suitable for making lightweight plaster boards and building blocks as per relevant Indian Standards. Besides dye gypsum, red mud waste is available from the manufacture of aluminium industry. Several attempts have been made for making useful products from this mud. Red mud is used for the manufacture of burnt clay bricks and tiles. A cementitious binder has been developed from red mud, rice husk, clay and hydrated lime for use in masonry and plastering (44).

Mining Wastes

Efforts have been made to utilize mining wastes obtained from copper, zinc, gold, nickel and molybdenum ore beneficiation processes in the production of masonry cement, sand lime bricks and cellular concrete at CBRI. The zinc tailings, obtained during the beneficiation of zinc, are mainly composed of silica and dolomite. These tailings can be used for making masonry cement conforming to IS-specifications 3466-1988 by grinding with Portland cement and set regulating additives like sucrose to a fineness of over 5,00 m^2/kg (45). The masonry cements have special properties which are essentially required in plasters and mortars. Similarly gold mine and other tailings can also be used for this purpose.

Based on the studies conducted in the laboratory zinc and gold mine tailings have been examined for making sand lime type bricks (46). The tailings and hydrated lime in the ratio of 9:1 were pressed at 24 N/ mm^2 moulding pressure at optimum moisture of 10 percent. The pressed briquettes were autoclaved at a saturated steam pressure of 1.4 N/mm^2 for 6 hrs. The properties of the bricks obtained conform to the relevant Indian standards IS:4139-1976. Besides bricks, cellular concrete (structural and insulation grade) was produced from zinc, copper, and gold mine tailings (47).

Conclusions

In order to step-up the production of building materials due to enhanced construction activities, transformation of agro-industrial by-products into lucrative building material should be encouraged. To promote implementation of developed technologies based on agro-industrial wastes, financial support for setting up new production units as well as expansion of existing units should be provided by Government both in private and public sectors. At the same time facilities for testing and evaluating raw materials and the finished products in various parts of the country should be established to ascertain the right choice of the materials with adequate durability. Demonstration of the new materials from agro-industrial wastes must be undertaken both in urban and rural sectors so that confidence prevails. The alternate building materials such as fly ash, slag, phosphogypsum, fluorogypsum, fly ash - sand lime bricks and wood substitutes may be encouraged as these materials are the futuristic materials which will enhance the economy of the country in addition to affording pollution abatement.

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