Building Materials from Agricultural and Industrial Wastes

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THE present trends in increased agricultural products and rapid industrialization in the country have created a problem of utilization of a agricultural and industrial wastes. Millions of tonnes of wastes are being discarded by various industries, not only causing serious problem of disposal but creating health hazards to the habitants by way of environmental pollution. This has necessitated research to find out ways and means of utilization of wastes.

Recovery and conservation of some useful scarce materials from Agricultural and Industrial wastes have already been established as sound propositions. The authors here describe some of the building materials developed from Agricultural and Industrial wastes at the Central Building Research Institute, Roorkee. The materials developed are being grouped under five main heads viz. Cementitious materials, Concrete and mortars, Boards and roofing sheets, Brick and tiles, and Aggregate and joint filler.

(A) CEMENTITIOUS MATERIALS

High Slag Masonry Cement

A masonry cement consisting of 30 parts of cement clinker ground with 70 parts of granulated slag, a requisite amount of gypsum and a small amount of an indigenous-air-entraining agent has been developed. The masonry cement thus produced complies with all the physical requirements stipulated in IS:3466-1967 for masonry cement.

Properties of masonry cement: sand mortars (1:6) compare very well with the composite cement, lime, sand mortar (1:1:6). Masonry cement developed higher compressive strength and its use can be recommended for higher design load of brick masonry. The water retention was many times greater than the corresponding cement sand mortar. Its use will reduce cracking tendency and increase water tightness of masonry. Extend of bond of masonry cement-sand mortar with bricks was found to be greater than that of plain or composite mortars. Masonry cement is resistant to sulphate attack and hence its use will prevent efflorescence in brick-work. The mortar produced from this cement would be more economical than the cement-sand or composite mortars.

Lime-sludge based Masonry Cement

About 2.5 million tonnes of waste lime sludge are available every year from sugar, paper, acetylene and tanning industries. Masonry cement can be made by intergrinding waste lime sludge with portland cement and gypsum. A small amount of an air-entraining agent may also be added, if required for any special use.

A mixture of 1 part of this masonry cement to 3 parts (by volume) of graded sand (IS specifications 3466-1967 for masonry cement) shows good workability, water retention value of 72-82 percent, initial setting time 125-138 minutes and compressive strength on 5 cm cubes, 26-28 kg/cm^2 at 7 days and 51-60 kg/cm^2 at 28 days. This process offers a direct utilization and useful means of disposal of waste lime sludges.

Eminently Hydraulic Lime of Natural Cement Type Material

Lime sludge is a suitable material for making eminently hydraulic lime or a natural cement of the composition confirming to ASTM-C-10-64. For producing an eminently hydraulic lime the sludge could be mixed with 5-10 percent of clay of the typical composition before firing it. The mixture after calcination conforms to the composition of eminently hydraulic lime.

Building Lime

Lime sludge is generally in the form of calcium carbonate and it can be calcined at 950°-1000°C to obtain lime. For calcination of sludge in the powder form a rotary kiln, fluo-solid kiln, intermittent clamp type and vertical mixed feed kilns according to the suitability may be used. The process to manufacture bulding lime from sludge is outlined below:

Lime sludge ——— Sun drying ——— Grinding (passing I.S. Sieve No. 60) ——— Briquetting or brick making (with 10-12 per cent water) ——— Calcination in kilns ——— lime.

Cement clinker from flyash

The process enables the production of high strength cement clinker at 1350°C instead of about 1450°C normally employed, thus bringing about a substantial saving in fuel. The use of high strength cement leads to a further economy by reducing the quantity of cement required to obtain desired strength in cement mortars and concrete used in construction works.

Pozzolana Cement

Pozzalana cement can be produced in the factory either by grinding together portland cement clinker and flyash, and adding the requisite quantity of gypsum, or by mixing flyash directly with ordinary portland cement. Mixing of the two in the powder form is rather difficult and so the mode of mixing should be such as would ensure intimate and uniform blending. The specifications of such cement do not differ much from the portland cement.

Rice-husk Pozzolana Cement

A reactive pozzolana, based on clay and rice husk has been developed. The product when mixed with lime gave a good cementitious material which can be used as a substitute of cement for preparing ordinary mortar and plaster. In this process rice husk and clay are mixed together with water and made into the shape of balls, dried in sun and fired in clamp or in an oval shape brick kiln. The burnet material is soft and can be easily ground to fineness (sp. surface) ranging from 2600 to 9000 cm^2/g, giving pozzolana of various reactivity. The pozzolana, in suitable combination with lime or lime and sand gives economical mortar and plaster materials. The pozzolana mortar thus prepared gives a strength of about 10 kg/cm^2. A more finely ground product (sp. surface 9000 cm^2/g) obtained in a ball mill gave a strength of over 70 kg/cm^2.

The process of making this pozzolanic material is simple. It does not require any costly equipment nor any extra fuel to raise the temperature to the desired level.

Supersulphated Cement from waste Anhydrite

Anhydrite is available as a waste product from the hydrofluoric acid industry. A supersulphated cement has been prepared by intergriding or intimately blending a mixture of anhydrite and granulated slag with small amount of cement clinker or portland cement, which act as activators. The mix proporation used varies as granulated slag 65-70%, Anhydrite 20-25% and portland cement 10-12.5%. The compressive strength of concrete mixes prepared from this supersulphated cement after 28 days of curing varies from 245 to 343 kg/cm^2.

Supersulphated cement from waste Phosphogypsum

Phosphogypsum available as a waste product of the phosphoric acid industry to the extent of 0.8 million tonnes per annum, poses problems of disposal. Phosphogypsum contains impurities of phosphates and fluorides which adversely affect the development of strength of cement if the material is directly used as additive to cement clinker. Investigations have shown that the impurities can be inactivated by heating phosphogypsum to 650-850°C. The phospho-anhydrite thus produced when ground and blended with suitable proportions of ground granulated slag and cement clinker has been found suitable for making supersulphated cement. The cement thus produced has been found to have low heat of hydration and resistant to sulphate action.

Masonry Cement based on slag and Flyash

The industrial wastes like slags and flyashes are available in large quantities and pose problems of disposal. Masonry cement based on the high slag content has been produced in the laboratory and it complies with the requirements of IS:3466-1967 but it has not gained popularity, on account of higher cost of grinding. A portion of the granulated slag in the high slag masonry cement has been replaced with flyash to bring down the cost of grinding at par with that of normal portland cement.

Activated Lime Pozzolana Mixture

Lime, in conjunction with burnt clay (popularly known as 'Surkhi') has been used as a material of construction since times immemorial in India. Lime — Pozzolana mixtures possess good workability, high water retentivity, superior bond and in addition develop high strength with the passage of time. The activated lime-pozzolana surkhi mixtures possess all the original good properties of the lime-pozzolana mixtures. These are rapid in setting and the fairly high strengths can be obtained after 28 days. These mixtures possess high water retentivity, high fineness and the bulk density are 750-800/m^3. They can be converted into mortars and plasters directly through mixing with sand and water, and no special techniques are required for their uses. Such mixtures have been developed from locally available materials of numerous localities.

(B) CONCRETES AND MORTARS

Flyash Concrete Mixes

Systematic and comprehensive investigations prove that flyash produced at various thermal power stations in India passes the specified requirements of chemical and physical properties as per IS:3312-1966. It has also been found that structural concrete mixes, in which 20 per cent of cement by weight is replaced by flyash can be designed to compressive strength, flexural strength and modulus of elasticity equal to those of the plain cement concrete at 28 days. The volume change characteristic of the designed flyash concrete are also similar to those of corresponding plain cement concrete. Use of water reducing admixture was found to increase workability of the flyash concrete mix enabled its proper compaction manually.

Masonry Mortars using Flyash

A good masonry mortar should have sufficient workability and water retention to provide easy spreading and filling of joints and good bond with bricks. It should develop adequate strength to carry the imposed load. It should also be durable and be able to withstand the action of weathering and efflorescence. In order to have these properties in mortars using flyash, it is necessary to exercise proper control over the quality of materials, preparation of mortar and curing of brick masonry.

Hydraulic Binder from Lime Sludge & Rice Husk

Hydraulic binder has been developed from Rice-husk and waste lime sludge generally available from sugar, paper, tannery, acetylene and fertilizer industries. Rice husk and lime sludge are mixed in suitable proportions with water and made into the form of balls or cakes, dried in the sun and fired in a clamp or in an oval shape kiln. The fired product when ground to fineness of 3000-6000 cm^2/g makes a cementitious material for mortar, plaster, foundation concrete, soil stabilized bricks etc. Compressive strength of the binder after 28 days of curing ranges between 28 to 50 kg/cm^2. The setting characteristics of the binder are similar to that of portland cement, the initial and final setting times being 60 and 480 minutes respectively. The water retention of the binder is similar to those of lime-pozzolaa mixture as per IS:4098-1967.

Cement Coconut Pith Concrete for thermal insulation

Coconut pith is a by-product of coir industry and is a durable lightweight material having very high thermal insulation value. A large quantity of pith is available in the country. However this has no industrial use at present and is going as waste material.

Cement coconut pith concrete, compared to the conventional insulating material 'lime concrete' is much lighter, easier to apply and gives better thermal insulation for equal cost. Pith Concrete compared to modern materials like expanded polystyrene, for equal thermal insulation value, cost only ½ to 2/3 depending upon transporation cost of pith from Kerala where it is available in large quantities. The investigations have been made by laying the material on roofs. The mix is poured on roof and compacted lightly to the required thickness. To check the loss of water from concrete, it is covered for seven days. The cover is then removed and the concrete is left for air drying. Any cracks which may appear on drying are filled by the same material. Water proofing by tiles or bitumen felts is done after this.

Cellular Concrete

Manufacture of cellular concrete involves autoclaving a set slurry consisting of fine siliceous materials and a binder and a high percentage of closed microscopic pores.

The raw materials required for the manufacture of lime-flyash based cellular concrete are lime, flyash and gypsum. Specifications for each materials have been worked out. The grade of aluminium powder to be used for gassing purposes has also been determined. The general properties of lime and flyash based cellular concrete are not much different from those of foamed concrete currently being produced in the country. Cellular concrete is better in overall properties than the foamed concrete currently being produced in the country. It can be cut, sawed and nailed as per requirement. There is a great scope of use of cellular concrete as a precast load bearing and non-load bearing blocks, thermal insulation blocks or slabs, partition walls slabs, roof and floor slabs.

(C) BOARDS AND ROOFING SHEETS

Wood Wool Boards

Wood wool board is used in building as a cladding material for walls and roofs, in partition, permanent shuttering tor concrete and ceilings. This is also used for making flat and pitched roofs and above the concrete and solid floors beneath the screed. Wood wool boards are made from wood fibre (wood wool) and cement. Wood wool is saturated with cement slurry and compressed in the form of a board. After giving strength the board is sufficiently durable material, it is of medium density i.e. 300 to 500 kg/m³ and open texture due to which it is primarily used as a thermal and acoustic insulation material. Being made with fibre, the board also has good flexural properties and can be used as a structural panel material. Other characteristics of wood wool boards are its inherent resistance to propagation of fire and termite attack. Its surfaces can be plastered and all coating material including bitumen can be applied over it. The cost of production (at 1972 rates) is Rs. 3.75/m² and Rs. 5.17/m² for 2.5 cm and 5.0 cm thick board respectively.

Particle Board from Coconut Husk

Particle board prepared from wood, bagasse, etc. are most common, require the normal proportion of adhesive (6 to 9 per cent by weight) for bonding the particles. But coconut husk is unique in that it has considerable self bonding property. Experiments have shown that satisfactory boards can be prepared from the husk of mature coconuts using only 0.5 percent adhesive. Coconut husk particle boards ranging in density from 250-1300 kg/m³ have been prepared. The cost of production of the board (640 kg/m³ is estimated to be about half as compared to wood based particle board. Industrial wood chippers cause the separation of pith and fibre during chipping. To overcome the difficulty a semi-automatic chipping machine for producing clean cut particles with smooth surfaces from coconut husk, has been designed.

Fire Resistant Boards from Coconut Pith

Unretted coconut pith is mixed either with a hardwood pulp or with a pulp prepared from banana stems and water is added to make a 3 to 4 percent slurry. After adjusting the pH to 4 to 5, paraffin wax or resin-paraffin wax (83 : 17) emulsion is added in different quantities, as a sizing agent and mixed thoroughly by stirring for 5 minutes. The size is then precipitated by the addition of alum solution. After a further period of 5 minutes the slurry is transferred to board forming machine (Deckle Box) fitted with removable bottom. When the water is drained off, the felt remaining at the bottom is removed and cold-pressed to remove free residual water. The felt whose moisture content at this stage is about 80-85 percent is dried in an air oven at 80-100°C to a moisture content of 8-10 per cent.

The boards produced at laboratory level of the size 60 cm x 60 cm have shownlow density and satisfy generally the requirements of insulation boards with extra quality of fire resistant.

Corrugated Roofing Sheet from Coir waste/wood wool

Coir waste is the by-product of coconuts, the current production of coconut in India is estimated at 6000 million nuts. About 50 per cent of the husk is used for making coir mat and cushions. The other half, may be considered as potential industrial raw material, is mostly used as fuel. Unlike other cellulosic materials, coconut fibre is free from water soluble polyphenols and make a strong board with portland cement. It is the property of the fibre and the pith which has been utilised in making corrugated roofing sheet.

Corrugated roofing sheet from coir waste/wood wool can be produced by soaking the coir/wood wool fibre in mineralized water for 2 hours. The free water is drained off the fibre and it is then mixed with dry cement. A mat of suitable thickness is next formed on to a corrugated mould and pressed. It is held under pressure for 4 to 8 hours. After demoulding the sheet is cured and dried.

The wood wool/coir fibre corrugated sheet thus produced are light, tough, possess good bending strength, and requires 30 percent less cement as compared to A.C. sheet. These can be layed on roofs like A.C. sheets, do not require any further finishings or water proofing treatment. These are fire resistant and possesses good thermal insulation properties.

(D) BRICKS AND TILES

Clay Bonded Flyash Bricks

The Central Building Research Institute has successfully produced clay-bonded flyash bricks from Delhi and Faridabad flyashes using local clays. In this process, 30 to 60 percent of flyash is mixed with clay by volume depending upon the plasticity of clay. The resultant mix is moulded into bricks which are dried and fired in the usual way. Flyash can also be used as a replacement of sand for demoulding the bricks.

Flyash-Sand-Lime Bricks

The process of manufacture of flyash-sand-lime bricks involves broadly three operation viz. mixing, pressing and steam curing. The mixture of sand-flyash and lime is thoroughly mixed in a semi-dry condition and pressed in a suitable press at the optimum pressure. The pressed bricks may be loaded on small hand driven trolleys and taken into a steam curing chamber/reservoir. The steam is supplied by a boiler. After the steam curing the bricks are dried in the sun for a day before they are ready for use.

The flyash-sand-lime bricks are of light colour, uniform in shape and size, of high strength and low water absorption. The bricks have low coefficient of variation and by having uniforms and smooth surface a variation of about 30 per cent in the mortar and plastering is expected. The bricks are free from efflorescence and stains.

Use of Felspar Mineral waste for Improved Bricks

In Rajasthan, Madhya Pradesh and Gujarat, sandy, black cotton and murram red soils are used for brick making, where manufacturers have always faced problem of improvig the quality of bricks. Fortunately in these states there are a number of felspar mines where mine rejects as well as low grade quality of minerals are available which could be utilised as an admixture to clay for improping the quality of bricks. Experiments have been carried out for making bricks from sandy, black and red soils using 5 to 10 percent felspar mining rejects as admixture and firing at 1000 to 1050°C. The processes of high temperature phase formation and glassy state of the clay constituents were favourably accelerated with the increase in the alkalies derived from the felspar and thereby contributing to strength. The bricks made with 10% felspar admixture in sandy soil (70% sand and 30% clay+silt) had compressive strength 55-70 kg/cm^3 against 35-45 kg/cm^2 for the bricks made without any admixture.

Building Bricks and Flooring Tile from Alumina Red Mud

Alumina red mud or bauxite sludge, an organic waste material obtained from aluminium plants can be utilized for developing many building materials like cement, paints, lightweight aggregate, bricks and tiles. In 1973-74, about 0.45 million tonnes red mud was obtained which after the Vth Five Year Plan is expected to be 1.0 million tonnes. Brick and tile industry are perhaps the only industries in India where large amount of this waste materials can be utilized. For the manufacture of red mud bricks the two raw materials red mud and clay are ground and mixed in pan mill grinded or pulvetizer. The mix after wetting can be either used for making hand moulded bricks around the mixer or can be extruded by a pug mill for making wire cut bricks. The process of manufacturing red mud bricks has many advantages like major utilization of waste, decorative and good quality bricks and utilization of inferior soil.

Flooring tiles(22 x 22 x 2.5 cm) have also been made by mixing red mud and clay in the ratio 1 : 1 and fired at 1000-1020°C. The tiles made satisfy the minimum requirement of breaking load 6 kg/cm^2 and maximum water absorption 10 percent.

(E) AGGREGATE AND JOINT FILLER

Sintered Flyash Aggregate

The use of flyash for the production of sintered lightweight aggregate is a potential application that can utilise flyash on a large scale. The fine particles of flyash can be made to cohere by pelletising and heating to about 1200°C, thus forming porous sintered mass having considerable strength. The lightweight concretes made from this type of aggregate possess 28 days compressive strengths upto 350 kg/cm^2 depending upon the mix. It can be used for insitu concrete work, for making load or non-load bearing masonry blocks and other precast concrete products.

Expansion Joint Filler

Cement concrete slabs in service show thermal movement of about 4 cm per 100 metre length. To accommodate this movement, space is provided between slabs and this space is filled up by a composition consisting of a filler and a sealing compound. The filler is known as 'Expansion Joint Filler'. The principal raw materials used for manufacture of 'Expansion joint filler' are coconut pith, cashewnut shell liquid, Phosphoric acid, calcium hydroxide, paraformaldehyde and rubber latex. Commercial cashewnut shell liquid (100 parts) and phosphoric acid (4 parts) are taken in a drum and heated upto 200°C. The polymerized Cashewnut Shell liquid thus obtained (100 parts) is mixed coconut pith (67 parts), calcium hydroxide (8 parts) and paraformaldehyde (12 parts) Now the mixture is filled in steel moulds and consolidated by means of a mechanical press for about 10-15 minutes. Finally the joint filler slabs are cured either by leaving it at temperature for 7 days or in a room maintained at 60-70°C by means of a hot blower in which case the time required is only 24 hours. After this curing the 'Joint Filler' is ready for storage and sale.

Conclusion

The utilization of wastes for development of building materials described here will provide a new direction for setting up ancilliary industries, achieving the goal of self-reliance in the field of building materials. Architects, Engineers, Builders, Entrepreneurs and others interested in having further details of all the processes or regarding the feasibility for setting up bliding material industry, may contact Director, Central Building Research Institute, Roorkee (U.P.).

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