CENTRAL BUILDING RESEARCH INSTITUTE, ROORKEE-247667 (INDIA)

BUILDING RESEARCH NOTE

B.R.N. 14

GYPSUM AS A BUILDING MATERIAL

Gypsum is a common mineral of immense commercial importance. Some of its well known uses are (a) retarder to regulate the setting of various types of hydraulic cements, (b) raw material for the manufacture of ammonium sulphate fertilizer and sulphuric acid, (c) dental, surgical & orthopaedic plaster and (d) filler in paper, rubber, medicines and insecticides. However, its most important use is as a building material. Chemically, it is the sulphate of calcium with two molecules of water ($CaSO_4.2H_2O$). It is a white crystalline substance. Its solubility in water is 2g/litre. It is soluble in dilute hydrochloric acid but insoluble in sulphuric acid. It contains 79.1 percent calcium sulphate and 20.9 percent water. Main gypsum producing regions in India are Bikaner, Jodhpur, Jaisalmer and Barmer districts of Rajasthan which supply about 90 percent of the annual produce of the country. Some other gypsum producing areas are : Trichurapalli in Tamil Nadu; Nellore in Andhra Pradesh; Porbander, Hallar, Bhavnagar and Kutch in Gujarat; Dehradun and Garhwal in Uttar Pradesh, and Uri, Assar, Ramban etc. in Jammu & Kashmir. Besides, mineral gypsum, large quantity by-product gypsum is also produced in the country.

Use of Gypsum in Building Industry

Among the products of gypsum, gypsum-plaster and gypsum-plaster boards find utmost application in buildings. Common impurities in gypsum are sand, clay, calcite, hornblende, illeminite and gypsum anhydrite. Gypsum containing up to 70 percent of calcium sulphate dihydrate content can be used for building purposes. A less pure material needs beneficiation use.

Gypsum Plaster

Gypsum on heating between 120-180°C, loses about 14.7 percent of the water of crystallization in the form of steam, giving an appearance of boiling of the whole mass. Technically, it is called the first boil, resulting in the formation of calcium sulphate hemihydrate containing 5 to 6 percent water of crystallization. This is known as plaster of Paris.

On heating it further, the remaining water is also expelled. This is called the second boil resulting in an anhydrite of calcium sulphate, also known as second settle plaster. Plaster of Paris with small amount of a retarder such as, glue, phosphate, citric acid or hydrolysates of horns and hoofs, which delay the setting period, is known as retarded hemilhydrate gypsum plaster. Gypsum heated to remove all its combined water results in anhydrous gypsum which is ground with a suitable accelerator to make anhydrous or Keene's gypsum plaster. This plaster when mixed with water, sets with little change in volume and with negligible shrinkage on drying. It is practically unaffected by bacteria and is light in

weight, thus ideally suited for use in multistoreyed buildings. Since it dries up quickly, the finishing coat can be applied soon after the undercoat has set, usually the same day. The plaster also shows good adhesion and bond to fibrous materials.

A porous gypsum plaster is an important sound absorbing material while dense and hard plasters are efficient reflectors of sound. They reflect upto 90 per cent of sound energy incident at their surface.

Manufacture of Gypsum Plaster

Manufacture of gypsum plaster involves grinding of raw gypsum, calcination and finally regrinding and mixing it with suitable retraders. The raw gypsum is crushed and ground to 60 per cent passing 150 micron 1S Sieve. Various processes are employed for calcination of gypsum to convert it into plaster of Paris. Kettle process is the foremost among them, and 80 per cent of the gypsum plaster is manufactured by this method, worldwide.

A Kettle for Improved Calcination of Gypsum

The open pan process generally used in India, for the manufacture of plaster of Paris does not permit close temperature control. Quality and performance of the plaster are not consistent. Fuel consumption and dust losses during calcination are high. This Institute has designed, fabricated and set up an enclosed Kettle (Fig. 1) for calcining ground mineral gypsum or by-product gypsum under controlled conditions of temperature.

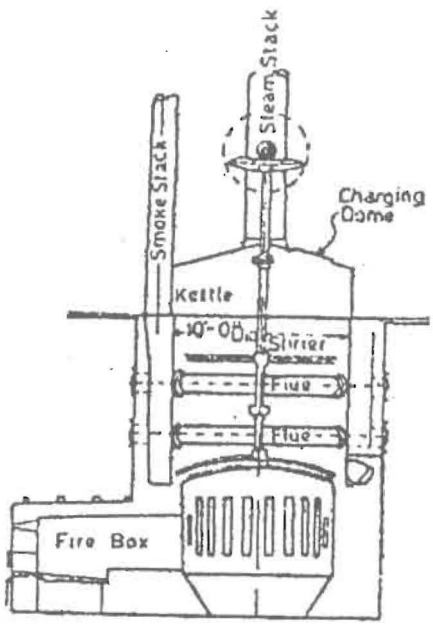

Fig. 1 Calcining Kettle for Plaster of Paris

Salient Features of the Kettle

(1) It has a capacity of one tonne per charge.
(2) Uniform heating of gypsum is ensured through a number of flues and also because of mechanical stirring of gypsum.
(3) The kettle is thermally efficient.
(4) Dust losses during calcination are minimized.
(5) Labour requirement is low and.
(6) Maintenance and operations are easy.

The temperature of calcination is 130 to 170°C. Time taken for first and subsequent charges are five and four hours respectively. Coal consumption is 60 kg. per tonne of gypsum. Approximate cost of kettle including installation charges in Rs. 3,50,000/-.

Energy Efficient Gypsum Calcinatior

A gypsum calcinator which promises further savings in fuel has been designed, fabricated and installed at this Institute. This comprises of a set of two steel pans each of 500 kg capacity, a muffle type furnance fired by coal or wood, oil or gas collapsible metallic lids to cover the pans and power operated stirring mechanism. The main features of the system are :

(1) It has a capacity of 8 tonnes per day.
(2) Average calcination time is 3 hours/charge;
(3) Coal consumption is 50-60 kg/tonne of gypsum as against 150-200 kg in traditional open.
(4) Uniform heating of gypsum is ensured through continuous mechanical stirring;
(5) Dust losses are totally eliminated;
(6) Loading of gypsum charge is manual but hot calcined gypsum is discharged automatically.
(7) Already commercialized in the country.

The cost of the equipment including furnace is about Rs. 2,50,000/-.

This system is recommended for making building, pottery and surgical plasters. Technical know-how is available from Director, CBRI, Roorkee - 247 667.

Limitations of Gypsum Plaster

A great drawback of gypsum plaster is its solubility in water. On continued exposure to damp ness, gradual softening of the plaster and loss of structural properties take place. It cannot, therefore, be used in humid areas for external work.

Storage of Gypsum Plaster

Bags containing gypsum plaster must not be kept in humid surroundings for long periods, as it picks up moisture from the atmosphere. Prolonged storage first hastens the rate of setting and then strength of the plaster is reduced. Storage of gypsum plaster even for more than three months results in deterioration of its quality. It is advised to store gypsum plaster in polythene lined bags.

Gypsum as a Fire Resisting Material

The greatest advantage of using gypsum in building is due its fine resistant quality. Gypsum plaster resists the onslaught of fire by virtue of its 20.9 percent of water of crystallization which it holds. During conflagration, the water of crystallization evaporates in the form of steam, which condenses to water on reaching the cooler part of the plaster slab and the temperature, therefore, may not exceed 1000C until all the water has been driven off in the form of steam. Thus, there is a an efficient barrier between the passage of heat and the combustible material. Gypsum plaster is, therefore, extensively used as an insulating material for protecting the columns and beams of wood or metal from high temperatures.

Fibrous Gypsum Plaster Board

Fibrous gypsum-plaster boards are very popular is several countries. These are produced in 9.5 mm, 12.5 mm and 15 mm thickness. However, 12 mm thick boards of set gypsum plaster reinforced with organic fibre are very popular. Normal dimensions of the board are 120 × 60 cm. The boards are known for its light weight, thermal insulation and fire resistance. Principal uses of such boards are to false ceiling, light weight partitions and as dry surfacing material for walls. Manufacture of fibrous plaster board is feasible on cottage industry scale in India as it does not require high technical skill or costly equipment.

Casting

For making fibrous plaster-board, rectangular steel moulds, 120 × 60 cm, and 12 mm deep are laid over a concrete casting table having smooth trowelled surface. The table is brush painted with demousing agent. Gypsum plaster is mixed with 80 to 90 parts of water to form a thin uniform slurry. This is poured and spread in the mould upto 4 mm thickness. Teased sisal/coir fibre is then spread uniformly over the surface. The over hanging part of fibre (4-5 cm) is turned back into the sheet to give extra reinforcement. The remaining slurry is then poured, levelled and allowed to set. The set product is demoulded after about to 2 hours and dried on wooden racks in open sunlight.

Properties

A standard transverse bending test is performed by supporting 30 × 30 cm specimen on 25 cm span and loaded at a rate of 5 kg per minute. Fibrous plaster boards cast using phospho gypsum calcined Mineral gypsum of 75 to 90 percent purities showed average breaking load of 39 and 62 kg respectively.

Thermal conductivity (K) of fibrous plaster board of density 900-1000 kg/m^3 is 0.14-0.17 Kcal/m/hr/^{0}C, as compared to 0.25 Kcal/m/hr/^{0}C for 6 mm thick asbestos cement sheet of density 1700-1800 kg/m^3. The grading period of fire resistance of 12 mm thick plaster board is 30 minutes and is far superior to fibre building boards in this respect. The boards should not be used in persisting dampness as their strength and structural properties are adversely affected.

Gypsum Blocks

Gypsum blocks are very useful in construction of non-load bearing partitions in dry situations because of good thermal insulation and small dead load. This facilitates speedy construction also. These blocks are also utilized for the protection of columns, beams and elevated shafts against fire.

For making lightweight blocks, the plaster is made into slurry in water. To the slurry either small quantity of saw-dust, organic foaming agent or inorganic gassing agents are added to reduce the final weight of the set product. Lightness may also be achieved by creating hollows in the set product. In experiments carried out at this Institute, lightweight blocks were prepared by the addition of a solution of aluminium sulphate ($Al_2(SO_4)_3.18H_2O$), which produces carbon dioxide gas by reaction with calcium carbonate present as impurity in gypsum. Some portion of the liberated gas gets entrapped in the setting mass of gypsum plaster thus causing lightness. The foamed slurry produced was cast into moulds of 50 × 20 × 10 cm size. The material after setting was demoulded, dried to constant weight and then tested for bulk density and compressive strength. The results are reported in Table 1. For comparison, the results of lightweight blocks prepared without the addition of gassing agent are also reported.

TABLE 1

Physical Properties of Lightweight Gypsum Blocks :

Percent Water Used	Percent Reagent Used (Al2(SO4)3.18H2O)	Bulk Density Kg/cm³	Compressive Strength MPa
80	—	980	6.5
90	—	910	5.4
90	2.0	790	2.2
90	3.0	720	1.4

Minimum compressive strength of 0.5 N/mm² (5.0 kg/cm²) has been specified in IS : 2849-1983, specification for non-load bearing gypsum partition blocks (solid and hollow types). The blocks of above mixes comply with the specification. These blocks can be enlarged in size as per need. They are recommended for use mainly for internal partition walls or for inner leaf of cavity construction in external walls. Being lighter than bricks, there is a great reduction in load in foundations and structural members and hence saving in cost can be affected. Like all other gypsum products, gypsum blocks are not recommended for use in external walls whether protected or unprotected. They are not liable to insect or fungal attack and are fire resistant.

Acoustic Tiles

Acoustic tiles are used in large offices and auditoria to reduce the reflected sound by absorbing sound energy. their absorption coefficient increases approximately in proportion to sound frequency. The effectiveness depends on their surface porosity and the extent to which pores are interconnected.

Slotted gypsum plaster tiles 13 mm thick measuring 300 × 300 mm were prepared using calcined gypsum and saw dust mix in the proportion of 65 : 35 parts by weight. The optimum mix was arrived at by casting 5 cm cubes of plaster and saw dust in different proportions and then measuring their bulk density and compressive strength. This mix has bulk density 500-600 kg/m³ and compressive strength 10-15 kg/cm² respectively. These tiles were examined for sound absorption coefficients at different frequencies and compared with coefficients of commercial slotted gypsum plaster tile (U.K.) and Sitatex plain fibreboard tile (India) of similar thickness. Re lts are reported in Table 2.

Sound absorption coefficients of slotted gypsum tile compare fairly well with the imported gypsum tile and fibreboard tile. Manufacture of these tiles is recommended on cottage industry basis. It can consume a large quantity of saw dust which is also a waste material.

TABLE 2

Sound Absorption Coefficients of Tiles

Characteristics	Frequency (c.p.s.)					
	125	250	500	1000	2000	4000
Slotted gypsum tile (CBRI)	—	0.15	0.18	0.21	0.30	0.36
Slotted gypsum tile (U.K.)	0.5	0.10	0.25	0.30	0.15	0.20
Sitatex plain fibre board tile	0.13	0.18	0.21	0.18	—	—

Gypsum Lath

It is another product of gypsum used in buildings. It is used as a base for plaster. It is made of two types, solid and perforated. The fibrous covering of lath helps in uniform suction and gives a fairly strong and durable bond with gypsum plaster. Lath can easily be nailed to studdings and joints. It also does not stain plaster or create plaster marks.

Keene's Cement

Keene's Cement is produced by judicious mixing of various materials in the original gypsum plaster. Gypsum is calcined to hemi-hydrate stage, soaked in a solution of potash alum, rebaked at higher temperature (500 to 750°C) and ground. Another method of Keene's cement preparation involves the calcination of pure gypsum at 600 to 750°C to anhydrous stage, mixing and grinding it with potash alum or another suitable accelerator. Keene's cement is characterized by high density, hard finish plaster. Its compressive strength is 25-35 N/mm^2 and setting time 20 minutes to 360 minutes. Its main advantage lies in its being less susceptible to moisture, high resistance to cracking, admirable capability of receiving polish. It is used for making ornamental plaster work and imitation marble. Keene's cement may also be used in internal plastering (finish coat) and masonry work in building construction. In finish coat, it is used with lime putty to provide early set and strength.

Prospects of Gypsum Industry in India

The use of gypsum in buildings is known to India from ancient times. However, the mass application of gypsum has yet to start in the country.

By the use of gypsum plaster, problem of shortage of cement can be solved partly. Setting up of gypsum industry needs modest capital and it can also be developed as a flourishing cottage industry which will go a long way in providing employment to many people. Since much cost is involved in the transport of gypsum it is imperative to set up gypsum product industries in the neighbourhood of gypsum deposits. Recently, production of gypsum plaster has started in India at Jind (Haryana) by India Gypsum Limited. The utilization of gypsum plaster boards has also and niented since than. It is interesting to note that many places in Western Rajasthan, where clay is hardly suitable for making good quality bricks and where large gypsum deposits are available, could be developed into good industrial centres of gypsum building materials.

Current production of mineral gypsum in the county stands at about 24.0 lakh tonnes. Bulk of production is of the grade 70-80% $CaSO_4.2H_2O$ accounting for 85% of total production followed by grades 80-85% $CaSO_4.2H_2O$ (7%), 85-90% $CaSO_4.2H_2O$ (6%) and

above 90% $CaSO_4.2H_2O$ (2%). For the manufacture of plaster of Paris, high purity of gypsum, selenite type, containing about 85% $CaSO_4 . 2H_2O$ is required. Different grades of plaster of Paris are manufactured depending upon purity of gypsum. There is a great demand of high purity gypsum for the manufacture of ammonium sulphate fertilizer, ceramic moulds and plaster products like building boards, blocks and acoustic tiles for their diversified uses in the building industry. As the country is in short supply of high grade gypsum, the demand of high purity gypsum may be met by utilizing by-product gypsum which is available to the tune of 5.0 million tonnes per annum in the country from the Wet process phosphoric acid and hydrofluoric acid industries respectively. This variety of gypsum has $CaSO_4.2H_2O$ content between90 to 95% and contains impurities such as phosphates, fluorides, organic matter alkales and free acidity. This by-product gypsum can be converted into a useful building material after removing or minimizing the impurities presents in it (Refer CBRI B.R.N. No. 9). Thus, use of by-product gypsum would be a definite economic advantage in those areas where the production units are located in the neighbourhood of fertilizer plants and also sufficient number of consumers are available in nearby areas.

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