Research and Industry
Vol. 39, March 1994, pp 55-59

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GYPSUM BINDER 55 ~~1015~~ 0985

1994

# Studies on sisal fibre reinforced gypsum binder for substitution of wood

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Received 3 August 1993

The present paper discusses the use of sisal fibre as reinforcement in the newly developed water resistant binder produced from the industrial by-products such as phosphogypsum, blast furnace slag and chemical additives for the substitution of wood. Laboratory investigations on the characterization of sisal fibre, properties of water resistnat gypsum binder, production of sisal fibre reinforced gypsum binder (SRGB) panels and their use in mild steel and aluminium framed door shutters have been discussed. The 12 mm thick door panels gave flexural strength higher than gypsum board, fibrous gypsum plaster board with impact strength equivalent to GRG and cement bonded particle boards. The energy consumption and economics of SRGB panels vis-a-vis traditional building materials is discussed. The simple fabrication technique of door shutters using these panels makes the technology very attractive.

Brick, stone, clay and wood are predominant building materials being exploited by mankind as common materials of construction since times immemorial. Wood is a forest based product. In India about seventy per cent of the population is rural subsisting on forest resources which are depleting at a tremendous pace. Estimates of deforestation rates vary widely, but according to Food and Agriculture Organisation Report (1980-81), the rate of deforestation in the tropical countries is estimated as 6.0 million hectares per year[1]. This is so alarming that in another 50 years, the natural forests would be significantly inadequate to cater to the ever growing requirements.

Presently about 26 million cubic meters of wood is produced per annum from the forests in India. About 34.0 percent is deployed as industrial wood and the remaining part is generally consumed as fuel[2]. Demand for wood in the housing sector including furniture is about 25.0 percent of the total requirement of timber, presently being fulfilled by cutting trees resulting in ecological imbalance and loss of natural resources and habitation. Wood is also being imported leading to the loss of scarce foreign exchange reserves. It can be recorded here that price of wood consumed in building varies from 10.0 to 30.0 percent of the cost of building depending upon the extent of its utilisation[3].

In order to meet the challange of depleting forests vis-a-vis ever increasing requirement of wood for construction, it is essential to develop material alternative to wood. Some alternative materials e.g. boards/panels such as particle boards, block boards made from wood wastes, products from plantation timber like eucalyptus, rubber sheets, and yet others manufactured from agro wastes like cotton stalks, rice husk, bagasse and similar materials. Besides, these innovative materials, many more products like glass fibre reinforced gypsum (GRG), cement (GRC) and plastic (GRP) have been reported as the panelling materials[4]. These materials have yet to be used on large scale not only in India as well as abroad. Absence of complete information on the durability and high cost of these materials may be a deterrent in their wide use. Moreover, GRG boards currently available in the market are produced from the expensive high strength gypsum plaster. The latter is not easily available due to lack of high purity gypsum. A water resistant binder has been developed by blending the ground granulated slag or flyash and portland cement with the calcined phosphogypsum (β-plaster). The details of this binder are reported by Singh and Garg elsewhere[5]. With a view to keeping pace with development of wood alternatives, sisal fibre reinforced panels based on the water resistant gypsum binder were developed at the Central Building Research Institute, Roorkee. The present paper entails the characterization of gypsum binder, sisal fibre reinforced gypsum binder boards (SRGB) vis-a-vis economic concerns. Production of door shutters using sisal fibre reinforced gypsum binder panels encased in the mold steel and aluminium frames is highlighted.

## Materials

*Industrial By-Products*

Phosphogypsum, granulated blast furnace slag and portland cement conforming to

Table I—Properties of sisal fibre

| Chemical Properties | Content (per cent) |
|---|---|
| Cellulose | 77.00 |
| Lignin | 7.00 |
| Wax | 4.0 |
| Carbohydrate & pectin | 10.00 |
| Ash | 2.00 |
| Physical Properties | |
| Diameter, mm | 0.12 |
| Density, g/cm$^3$ | 1.30 |
| Water Absorption, (per cent) (24 hr) | 150 |
| Tensile Strength, GN/m$^2$ | 0.60 |
| Modulus of elasticity, GN/m$^2$ | 39.0 |
| Elongation at break, (per cent) | 3.0 |
| Aspect ratio | 335 |

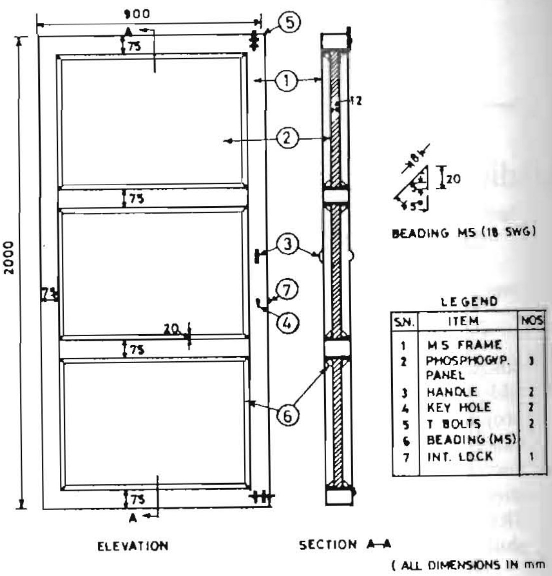


Fig. 1—Sisal fibre reinforced gypsum binder door shutter

BIS:12679-1989, BIS: 455-1967 and BIS:269-1989 respectively were used.[6-8].

*Retarder*

A small quantity of organic acid compound was used to regulate setting time of the gypsum binder.

*Sisal Fibre*

Sisal fibre procured from Nildongri Sisal Estate, Sambhalpur (Orissa) of properties (Table 1) was used for reinforcing the gypsum binder.

**Experimental Procedure**

*Production of Water Resistant Gypsum Binder*

Water resistant gypsum binder was produced by blending the calcined phosphogypsum (produced by heating the processed phosphogypsum at 150°C) of specific surface 3200 cm$^2$g$^{-1}$ (Blaine's) with the ground granulated slag of specific surface 4200 cm$^2$g$^{-1}$ (Blaine's) portland cement of specific surface 3200 cm$^2$g$^{-1}$ (Blaine's) and a retarder followed by grinding together in a ball mill to achieve a material of fineness 3200 cm$^2$g$^{-1}$ (Blaine's). The gypsum binder was tested for physical properties[9,10] as per BIS:4031-1968 and BIS:6909-1973.

*Production of Sisal Fibre Reinforced Gypsum Binder Panels (SRGB)*

Sisal fibre reinforced gypsum binder panels of size 750 × 560 × 12mm were produced by randomly sandwiching the teased sisal fibre of length 5cm in between two layers of gypsum binder at normal consistency (66.0 percent), SRGB panels were cast on the glossy surface. The top edge of the panels was finished with wooden straight edge to provide smooth surface without defects. After one hour of casting, the SRGB panels were demoulded, cured under high humidity (over 90 percent R.H.) upto a period of 28 days and dried at 42°C in the oven. Alternatively drying in the bright sunlight may be adopted. The SRGB panels were tested for free moisture, density, flexural strength, tensile strength, impact strength, swelling, water absorption and surface hardness as per BIS:2542 (Part II/Sec 7)-1981, BIS:2542 (Part I/Sec 12)-1978, BIS:2380 (Part V)-1977 and BIS 8273-1984 respectively[11-14].

*Preparation of Door Shutters using SRGB Panels*

Door shutters of size 2000 × 900 × 30mm were produced by fitting 3 Nos of SRGB panels (size 750 × 570 × 12mm) in the mild steel (18 SWG) and aluminium frames with stiles and rails (Fig. 1). Each door was fitted with two handles, two tower bolts and one dead lock. The SRGB panels were fitted in the mild steel and aluminium frames with the help of mild steel and snap beading on both sides, respectively. The mild steel door shutter was painted in the natural wood colour, the aluminium door shutter was painted with Apcolite white paint. Fig. 2 shows photographs of door shutters produced in mild steel and aluminium frames, respectively.

**Results and Discussions**

*Water-Resistant Gypsum Binder*

The physical properties of gypsum binder are depicted in Table 2.

It can be seen that the gypsum binder develops

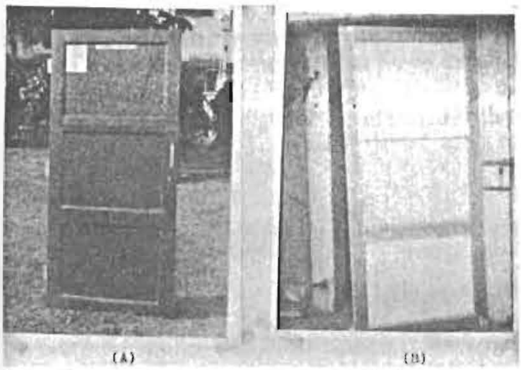

Fig. 2—Photographs of door shutters in (A) Mild steel frame and (B) Aluminium frame

adequate strength at 28 days of curing. The gypsum binder possesses good water absorption as it does not show leaching in water upto 28 days of immersion while the set plain gypsum plaster showed erosion just after three days of immersion in water. The soundness of gypsum binder studied as cold expansion is within maximum specified value of 5.0 mm as given[10] in BIS:6909-1973.

*SRGB Panels*

The physical and mechanical properties of sisal fibre reinforced gypsum binder panels are shown in Table 3. It can be seen that SRGB panels compare well with the free moisture, thickness and density values of other panelling materials. The impact strength is almost similar to GRG panels but is higher than the remaining panelling materials. The flexural strength development in the SRGB panels is enhanced with increase in the curing period from 1 to 28 days. The strength value attained at 28 days curing is higher than gypsum boards, fibrous gypsum plaster board, and is comparable to cement bonded and other particle boards. However, the GRG and asbestos cement boards are superior in flexural strength to SRGB panels but shows higher swelling and water absorption than SRGB panels. The flexural strength and surface hardness values of SRGB panels conform[14] to BIS:8273-1984.

The data on flexural and tensile strength may be utilised by the designers to assess suitability of the material in various applications with respect to load bearing capability, deflection, application of load on horizontal surface, strength characteristics, etc. Thermal conductivity, fire resistance and acoustic properties of SRGB panels are similar to those of gypsum plaster boards (plain/fibrous/laminated).

Table 2—Physical properties of gypsum binder

| Property | Value |
|---|---|
| Fineness, $cm^2g^{-1}$ (Blaine's) | 3200 |
| Bulk Density, $g/cm^3$ | 1.20 |
| Setting Time, Minutes | |
| Initial | 80.00 |
| Final | 140.00 |
| Compressive Strength, MPa | |
| 1-day | 10.00 |
| 3-day | 18.50 |
| 7-day | 26.50 |
| 28-day | 30.80 |
| Soundness, Cold expansion, mm | 0.68 |
| Water absorption, (per cent) | 6.00 |

Table 3—Properties of sisal fibre reinforced gypsum (SRGB) panels

| Property | SRGB | GRG | Gyp board | Particle board | Asbestos cement | Fibrous Gypsum plaster board | Cement bonded particle board | BIS:8273-1976 Limits |
|---|---|---|---|---|---|---|---|---|
| Free moisture, (per cent) | 1.5 | 1.0 | 1.0 | 0.8-1.0 | 2.0 | 1.5 | 1.0 | — |
| Thickness, mm | 12.0 | 10.0 | 12.0 | 12.0 | 6.0 | 12.0 | 12.0 | 12.0 |
| Density, $g/cm^3$ | 1.3-1.45 | 1.8 | 1.0 | 1.8-2.1 | 0.60 | 1.1 | 1.1-1.3 | — |
| Flexural strength, $N/mm^2$ | | | | | | | | |
| 1-day | 3.5 | 17-30 | 4-5.0 | 14.0 | — | 4.0-6.0 | 9-15.0 | Min 3.40 |
| 3-day | 6.5 | — | — | — | — | — | — | — |
| 7-day | 8.0 | — | — | — | — | — | — | — |
| 28-day | 10.0 | — | — | — | 18-23.0 | — | — | — |
| Impact strength $Nmm/mm^2$ (28-day) | 16.0 | 14-18 | 8-10.0 | 4.5 | 2.0 | 10.0 | — | — |
| Swelling (24 h) (per cent) | 0.80 | 0.68 | 3.0 | 14.0 | — | 30.0 | 12.0 | — |
| Water Absorption (24 hr), per cent | 10.0 | 25-30 | 50.0 | 70.0 | — | 30.0 | 12.0 | — |
| Surface hardness, mm | 0.60 | 0.50 | 0.36 | — | — | 0.60 | 0.40 | Max 5.0 |

SRGB panels can be worked with normal wood working machinery and tools to achieve excellent finish, particularly on profiled edges. SRGB panels can be cut, drilled, curved, plained and nailed without chipping, splitting etc.

*Economics of the Production*

The basic raw materials for the production of water resistant gypsum binder based SRGB panels are phosphogypsum, slag and alkali or alkaline earth hydroxides. These materials are abundantly available as industrial by-products. The major component of gypsum binder is calcined phosphogypsum or plaster of Paris. The calcination of gypsum needs very less energy as compared to other building materials (Table 4).

The cost of water resistant gypsum binder has been computed as Rs 800/tonne. Table 5 provides the cost of SRGB panels vis-a-vis the conventional sheeting materials. It can be seen that cost of SRGB panels compares well with that of 4mm thick plywood and 1mm thick thermoplastic sheet but are much cheaper than the other major building materials used for construction purposes.

*Sisal Fibre Reinforced Gypsum Door Shutter*

Door shutters (size 2000 × 900 × 30 mm) produced from SRGB panels encased in mild steel and aluminium frames are being evaluated for various properties as per BIS 4020-1967[15]. The cost of door shutters has been worked out and found to be Rs 1350/ for the mild steel framed door shutter and Rs 2700/ for the aluminium framed door shutters respectively. The cost of the SRGB panels used in the door shutters lies in the range of 3 to 6 percent of the total cost of the door shutter. In spite of the high cost of the metallic frames, the door shutters have the following specific advantages over the conventional door shutters.

*Total elimination of timber
*Water proof
*Termite proof
*Fire reistance
*Waste utilization
*Pollution abatement

Table 4—Energy requirement of building materials

| Materials | Total Energy (KWH/T) |
|---|---|
| Steel | 2,700 |
| Aluminium | 17,000 |
| Particle board | 599-721 |
| MDF | 1230-1480 |
| Cement | 130-140. |
| Timber | 430 |
| Calcined gypsum | 246 |

Table 5—Cost of SRGB panels vis-a-vis traditional building materials

| Materials | Approx. Cost in Rs (per sq.m.) |
|---|---|
| Plywood | |
| 3mm, 4mm, 6mm, 8mm | 60,70,90,100, |
| 12mm, 19mm, 25mm | 140,180,230 |
| Roofing Sheets A.C.Plain (4mm thick) | |
| 4' × 4', 6' × 4', 8' × 4' | 120,180,240 |
| Red mud plastic roofing sheet | 80.0 |
| Particle boards | |
| 12mm, 19mm, 25mm | 136.0,165.0,207.0 |
| Thermo plastic sheets | |
| 1mm, 2mm, 3mm, 4mm, | 61.0, 122.0, 183.0 |
| 5mm,6mm | 244.0, 304.0, 365.0 |
| PVC Compact Sheet | |
| 1mm, 2mm, 3mm | 130.00, 198.0, 296.0 |
| 4mm, 5mm | 411.0, 514.0 |
| Gyp board (12.5mm thick) | 95.0 |
| GRG (based on high strength plaster), 6mm | 170.0 |
| SRGB (based on water resistant gypsum binder) | |
| 12mm | 60.0 |

The major thrust on actual utilisation of these door shutters can only be realised if the testing and evaluation of these shutters can be adopted by the standards other than BIS:4020-1967 or equivalent due to brittle nature of the SRGB/GRG panels. The pilot plant studies on the production of glass reinforced gypsum binder boards by spray suction process are in progress at the Institute.

## Conclusions

1 The technology for the production of water resistant gypsum binder from the industrial by-products such as phosphogypsum and slag has been developed.

2 Sisal fibre reinforced gypsum binder panels/boards can be produced at a lower cost than the conventional panelling materials.

3 Sisal fibre reinforced gypsum binder panels have the product potentiality as an alternative to sparsely available timber for use in door shutters in the building sector.

## Acknowledgement

The authors are thankful to Director, Central Building Research Institute, Roorkee for allowing the publication of the paper. Thanks are also due to Shri V N Varma of Sai fabricators and Shri Akshay Kumar of Akshay Enterprise, Meerut for timely helping in the fabrication of the metallic frames and fitting of SRGB panels.

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