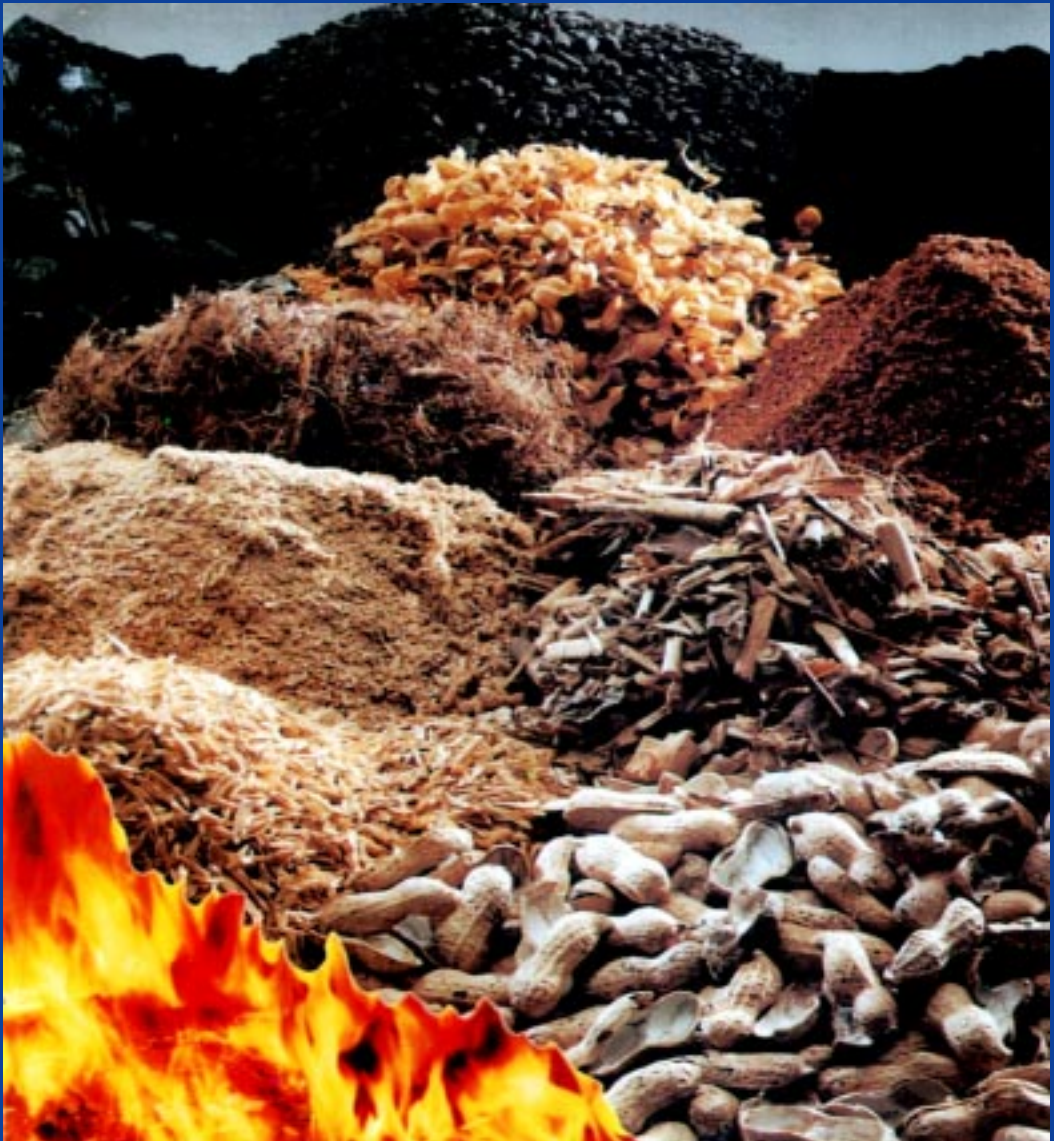
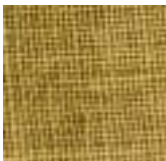


Local
Vegetable
Fibres + Industrial
and Mineral
Wastes
for
**Composite
Materials**



Building Materials & Technology Promotion Council

Building Materials from Local Resources



Historically mankind has been familiar with several applications of composite building materials for their housing and building needs. Most of these were based on timber, bamboo, jute and a large variety of vegetable fibres such as reinforced mud-blocks for walls, panels for partitioning and roofing. In the modern context, the world has seen a total transformation in materials science and technology and a vast variety of industrially produced composites have come into existence.

Continuous progress in metallurgy and materials engineering have remarkably helped in achieving the perfection in behaviour of metals, and other alloys. Multitude of metal composites are now being used with a high degree of confidence for the most intricate structures. Subsequent developments in the discovery of very tough fibres such as glass, carbon, boron and kevlar made it possible to manufacture and use several high performance composites with matrices of synthetic resins such as polyesters, phenolics and epoxies in aircrafts, space ships, machine tools, electronics, biomedical materials etc.

Search for stronger and stiffer fibres and feasibility to utilise widespread inorganic wastes and by-products have provided directions to the production and use of vegetable fibres, such as coir, banana, sunhemp, jute, sisal etc., as quite inexpensive and effective reinforcing fibres, and hydraulic binders as alternative to cements made of industrial wastes like flyash, waste limes, by-product gypsum and mine tailings. These developments have mainly taken place to meet housing and building requirements of ever growing world population, particularly in developing parts of the world.

This brochure provides information on technical properties and availability of a large number of vegetable fibres widely grown in developing countries and broad characteristics of the inorganic wastes and by-products. The information given here is primarily aimed at indicating vast scope and potential for the utilisation of such local resources in the production of fibre reinforced composite building materials for housing and building structures.

The classification of composites into 'advanced' materials or 'low grade' is meaningless as it is the application of a material which decides its class if it is made available in a durable and reliable form at a reasonably affordable cost. Hence the data provided in this brochure should encourage designers to develop low cost, low energy, labour conserving technologies for building materials of required specifications with possibilities for application in housing and building.

Fibres and country of origin

| | |
|----------|--|
| Flax | : Borneo |
| Hemp | : Yugoslavia, China |
| Sun hemp | : Nigeria, Guyana, Sieraleone, India |
| Ramie | : Honduras, Mauritius |
| Jute | : India, Egypt, Guyana, Jamaica, Ghana, Malawi, Sudan, Tanzania |
| Kenaf | : Iraq, Tanzania, Jamaica, South Africa, Cuba, Togo |
| Roselle | : Borneo, Guyana, Malaysia, Sri Lanka, Togo, Indonesia, Tanzania |
| Sisal | : East Africa, Bahamas, Antigua, Kenya, Tanzania, India |
| Abaca | : Malaysia, Uganda, Philippines, Bolivia |
| Coir | : India, Sri Lanka, Philippines, Malaysia |

Annual production of natural fibres and sources

| Fibre source | World production 10 ³ tonnes | Origin |
|----------------|---|-------------|
| Abaca | 70 | Leaf |
| Bamboo | 10,000 | Stem |
| Banana | 200 | Stem |
| Broom | Abundant | Stem |
| Coir | 100 | Fruit |
| Cotton Lint | 18,500 | Stem |
| Elephant Grass | Abundant | Stem |
| Flax | 810 | Stem |
| Hemp | 215 | Stem |
| Jute | 2,500 | Stem |
| Kenaf | 770 | Stem |
| Linseed | Abundant | Fruit |
| Nettles | Abundant | Stem |
| Oil Palm Fruit | Abundant | Fruit |
| Palmirah | Abundant | Stem |
| Ramic | 100 | Stem |
| Roselli | 250 | Stem |
| Rice Husk | Abundant | Fruit/grain |
| Rice Straw | Abundant | Stem |
| Sisal | 380 | Leaf |
| Sun Hemp | 70 | Stem |
| Wheat Straw | Abundant | Stem |
| Wood | 1,750,000 | Stem |



Specific strength, cost and energy contents of synthetic and natural fibres

| Fibre | Sp.gr. | Specific tensile strength (GPa) | Specific tensile modulus (GPa) | Cost US\$/tonne | Energy content GJ/tonne |
|-------------|---------|---------------------------------|--------------------------------|-----------------|-------------------------|
| Plant Fibre | 0.6-1.2 | 1.60-2.95 | 10-130 | 200-1000 | 4 |
| Glass | 2.6 | 1.35 | 30 | 1,200-1,800 | 30 |
| Kevlar | 1.4 | 2.71 | 90 | 7,500 | 25 |
| Carbon | 1.8 | 1.71 | 130 | 12,500 | 130 |

Chemical composition and moisture absorption of some natural fibres

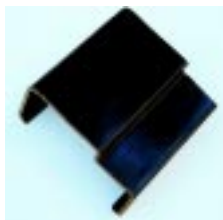
| Fibre % | Cellulose | Hemi-cellulose % | Lignin % | Moisture regain at 65% R.H. | Transverse swelling in water % |
|-----------------|-----------|------------------|----------|-----------------------------|--------------------------------|
| Banana | 60-65 | 6-8 | 5-10 | 10-15 | 16-20 |
| Coir | 43 | <1 | 45 | 10-12 | 5-15 |
| Cotton Lint | 90 | 6 | - | 7 | 20-22 |
| Flax | 70-72 | 14 | 4-5 | 7 | 20-25 |
| Jute | 61-63 | 13 | 5-13 | 12.5 | 20-22 |
| Mesta | 60 | 15 | 10 | 13 | 20-22 |
| Palmirah | 40-50 | 15 | 42-45 | 10-12 | - |
| Pine Apple Leaf | 80 | - | 12 | 10-13 | 18-20 |
| Ramic | 80-85 | 3-4 | 0.5 | 5-6 | 12-15 |
| Sisal | 60-67 | 10-15 | 8-12 | 10-12 | 18-20 |
| Straw | 40 | 28 | 18 | - | - |
| Sun Hemp | 70-78 | 18-19 | 4-5 | 10-11 | 18-20 |
| Wood | 45-50 | 23 | 27 | - | - |

Mechanical properties of some natural fibres

| Fibre | Length mm | Diameter mm | Density kg/m ³ | Young's modulus GPa | Tensile strength MPa | Elongation break % |
|----------------|-----------|-------------|---------------------------|---------------------|----------------------|--------------------|
| Bagasse | NA | 0.2-0.4 | 1250 | 17 | 290 | NA |
| Bamboo | NA | 0.1-0.4 | 1500 | 27 | 575 | 3 |
| Banana | NA | 0.8-2.5 | 1350 | 1.4 | 95 | 5.9 |
| Coir | 50-350 | 0.1-0.4 | 1440 | 0.9 | 200 | 29 |
| Elephant-grass | NA | 0.4 | NA | 5 | 178 | 5.6 |
| Flax | 500 | NA | 1540 | 100 | 1000 | 2.0 |
| Jute | 1800-3000 | 0.1-0.2 | 1500 | 32 | 350 | 1.7 |
| Kenaf | 30-750 | 0.04-0.09 | NA | 22 | 295 | NA |
| Mesta | NA | 0.2 | 1470 | 13 | 180-570 | NA |
| Pineapple | NA | 0.2-8.8 | NA | 14.5 | 413-1627 | NA |
| Sisal | - | 0.5-2.0 | 1450 | 100 | 1100 | - |

Mechanical properties of some fibres other than natural fibres

| Fibre | Length mm | Diameter mm | Density kg/m ³ | Young's modulus GPa | Tensile strength MPa | Elongation break % |
|------------------|-----------|-------------|---------------------------|---------------------|----------------------|--------------------|
| Glass 'C' | NA | NA | 2700 | 70 | 3100 | 4.5 |
| Glass 'E' | NA | NA | 2900 | 72.5 | 3400 | 4.8 |
| Steel | 5-200 | 0.1-0.4 | 7860 | 207 | 700-2100 | 3.5 |
| Boron | NA | NA | - | 410 | 3800 | 2.8 |
| SiC | NA | NA | - | 430 | 240-2400 | - |
| Asbestos Polymer | <15 | <0.2 | 2550 | 159 | 210-2000 | 7-18 |
| (Polypropylene) | NA | NA | 900 | 6.8 | 590 | 210 |



Industrial, mining and mineral waste having potential for utilisation in the production of composites

| Sl. No. | Type of the Waste | Source | Type of particulate composites | Appropriate technology available |
|---------|--------------------------------------|---|--|--|
| 1. | Flyash/pulverised fuelash | Thermal power stations using pulverised coal as fuel | Portland-pozzolana cement (using upto 20% of flyash) cement concrete, lime-flyash mortar, plaster, cellular concrete, brick and tiles, flyash-sand-lime bricks, stabilised soil bricks (using lime or cement and flyash) | India China UK Russia |
| 2. | Blast furnace slag | Steel Plants | | |
| | (a) Air cooled type | -do- | As dense aggregate replacing natural stone aggregate in concrete. | |
| | (b) Foamed type | -do- | As light weight aggregate in concrete and concrete products | India, China, South Africa, UK, Russia |
| | (c) Granulated type | -do- | As part replacement in Portland cement for Portland-blast furnace slag cement; in super sulphated cement | |
| 3. | By-products gypsum | Ammonium phosphate fertiliser, hydrofluoric acid and boric acid industries | As replacement of natural gypsum in making fibrous gypsum plaster boards, blocks, composite mortar etc. | India UK Russia |
| 4. | Mine tailings | Beneficiation of the zinc, copper, iron, gold, feldspar, fluorspar, bauxite ores and minerals | As part replacement in composite mortar, concretes, masonry cement, cellular concrete sand-lime bricks, as replacement of sand | India China Germany |
| 5. | By-product lime sludges | Sugar, paper, acetylene, tannery fertilizer industries | After calcination used in composite mortar, plaster and lime-pozzolana composites | India Indonesia |
| 6. | Laterite wastes | Cutting and dressing of laterite blocks | For stabilised laterite bricks/blocks using cement or lime as stabiliser and a fibre as reinforcement | Ghana India |
| 7. | Red mud | Aluminium industry | For blended cement, bricks/tiles compositions and fibre-reinforced panel products | India Russia |
| 8. | Basic or acidic metallurgical slags | Metals and alloys industries | Masonry cement compositions and in cement-concrete replacing natural aggregates, cementitious binders etc. | India China UK |
| 9. | Broken glass and ceramics | Glass and ceramic industries | Insulating bricks and tiles, flooring tiles, decorative panels | China India, Russia |
| 10. | Inorganic ashes of plants | Incineration (in boilers) of rice husk type materials | Replacement of natural or clay pozzolana in lime-pozzolana composites, pozzolana cement, bricks etc. | India Sri Lanka Malaysia |
| 11. | Wastes from mica, slate, vermiculite | In the mining of the respective mineral | Utilisation after calcination in lime-pozzolana | India |

Chemical analysis and mineralogical constituents of Indian flyashes

| Constituent | % by wt. |
|--------------------------------------|-------------|
| SiO ₂ | 37.15-66.75 |
| Al ₂ O ₃ | 18.30-28.90 |
| Fe ₂ O ₃ | 3.2-21.90 |
| TiO ₂ | - |
| CaO | 1.3-10.80 |
| MgO | 0.8-5.25 |
| SO ₃ | 0.94-2.91 |
| Na ₂ O + K ₂ O | 0.04-1.30 |
| Loss on ignition | 0.05-16.60 |

General uses of flyash in inorganic composites

| Material | Description |
|---|--|
| Aggregates (for concrete & concrete products) | Production of light weight aggregate of sp.gr.<1 is carried out by palletization and sintering at 1050°-1100°C. The residual carbon content of flyash on burning provides energy for sintering and thus the process needs very little energy. |
| Cement (as Portland-flyash pozzolana cement for concrete and also as raw mix) | Flyash finds a substitute for clay or other argillaceous material in cement manufacture; particularly where high MgO containing limestone is used. In ordinary portland cement, the blending proportion again depends on the fineness, carbon content (low % preferred) and lime-reactivity. These properties also govern flyash application in roads and stabilised blocks. |
| Cellular concrete and other concrete | Flyash is an excellent material as the substitute for ground sand in the manufacture of sand-cement/lime based light weight cellular concrete for structural as well as filler and insulation grades. Flyash is also a replacement for sand in concrete. |
| Bricks (Calcium-silicate sand-lime type - steam cured, and clay-flyash burnt brick type) | Flyash-sand-lime bricks are as good as other sand-lime bricks, in the former flyash replaces sand upto 70%. Flyash is also blended with plastic clays for burnt-clay bricks where it works as opening materials reducing drying shrinkage cracks and providing saving in coal for firing. |

Chemical composition (%) of blast furnace slag

| Source | CaO | SiO ₂ | Al ₂ O ₃ | MgO | Feo | MnO | S |
|---------|-----|------------------|--------------------------------|-----|-----|-----|-----|
| British | 48 | 31 | 10 | 3 | 1.0 | 0.5 | 1.5 |
| German | 45 | 35 | 12 | 4 | 0.5 | 0.5 | 2.0 |
| Indian | 40 | 35 | 18 | 5-8 | 0.5 | 1.0 | 1.5 |

Constituents, factor and suitability of slags

| Constituents | Factor | Suitability for |
|--|--|--|
| High SiO ₂ or high Al ₂ O ₃ | Cools to glassy granulated form easily | Slag wool composites |
| High CaO and low Al ₂ O ₃ | Makes suitable composition but tends to dust | Portland blast furnace slag cements but not aggregates |
| High MgO or high MnO | Makes unsuitable composition | Not so good for slag cement |

Ore Beneficiation tailings and their Uses

| Chemical | Zinc Tailings | Copper Tailings | Gold Tailings | Iron Tailings |
|---|---|---|---|--|
| Loss on ignition | 14.75 | 2.24 | 5.31 | 3.58 |
| SiO ₂ | 60.63 | 59.42 | 61.63 | 58.53 |
| Al ₂ O ₃ | 0.54 | 12.06 | 11.63 | 9.21 |
| Fe ₂ O ₃ | 3.02 | 19.82 | 9.85 | 21.08 |
| CaO | 12.68 | 2.11 | 10.36 | 4.08 |
| MgO | 7.27 | 1.86 | 2.32 | 2.76 |
| Na ₂ O+K ₂ O | - | - | - | - |
| Physical Properties | | | | |
| Fineness modulus | 0.342 | 0.637 | 0.103 | 0.416 |
| Sp.gr. | 2.85 | 2.95 | 2.85 | 3.04 |
| Bulk density (kg/l) | 1.51 | 1.45 | 1.56 | 1.60 |
| Specific surface (Blaine's)cm ² /g | 3500 | 3500 | 4000 | 3500 |
| Mineralogical constituents | Quartz and Dolomite | Quartz and Biotite | Quartz and Calcite | Quartz and Haematite |
| Recommend utilisation in building materials | Cellular concrete Calcium silicate bricks Masonry cement Mortar Fine filler in concrete Filler in bitumen mastics -- -- | Cellular concrete Calcium silicate bricks Masonry cement Mortar Fine filler in concrete Filler in bitumen mastics As opening material in brick making Filler in acid resistant cement | Cellular concrete Calcium silicate bricks Masonry cement Mortar Fine filler in concrete Filler in bitumen mastics -- -- | -- Calcium silicate bricks Masonry cement Mortar Fine filler in concrete --- Burnt clay bricks Filler in acid resistant cement |

| Chemical | Feldspar Tailings | Fluorspar Tailings | China Clay Waste Tailings | Coal Washery Tailings Burnt | Unburnt |
|---|---|---|---|--|---------|
| Loss on ignition | 1.30 | 0.85 | 11.20 | 01.8 | 16.90 |
| SiO ₂ | 63.84 | 73.00 | 50.30 | 57.60 | 60.40 |
| Al ₂ O ₃ | 18.32 | 5.70 | 32.70 | 31.30 | 18.10 |
| Fe ₂ O ₃ | 1.42 | 7.00 | 2.37 | 3.86 | 7.03 |
| CaO | 1.45 | 1.30 | 0.07 | 0.36 | 0.66 |
| MgO | 0.50 | - | 0.35 | 0.92 | 0.44 |
| Na ₂ O+K ₂ O | 12.13 | - | 0.59 | 2.73 | 2.35 |
| Ca ₂ F ₂ | - | 12.80 | - | - | - |
| Physical Properties | | | | | |
| Fineness modulus | - | 0.4-0.8 | 0.56 | - | - |
| Sp.gr | 2.53 | 2.75 | 2.85 | 2.66 | 2.40 |
| Bulk density (kg/l) | 1.45 | 1.8 | 2.63 | 1.32 | 1.25 |
| Sp. srface (Blaine's) cm ² /g | 2550 | 2500 | 2800 | 2200 | 1900 |
| Mineralogical constituents | Feldspar Quartz | Calcium fluoride Quartz | Quartz Feldspar | Quartz, Albite, Feldspar | |
| Recommend utilisation in building materials | Burnt-clay brick, Calcium Silicate bricks, Ceramics concrete blocks | Calcium silicate bricks Aerated concrete, Concrete blocks | Ceramics tiles, bricks, calcium silicate bricks | Burnt clay bricks, sintered light - weight aggregate, concrete blocks. | |

Chemical composition of red mud

| Constituent % | Red mud samples from aluminium plants of | | | | | | |
|--------------------------------|--|---------|----------|-----------|----------------------|---------|---------|
| | India | | | Australia | Hungary | Jamaica | Surinam |
| | Hindalco | Indalco | Alcorpon | | Hungary & Yugoslavia | | |
| Loss on ignition | 9-10 | 10-12 | 10-13 | 13-15 | 10 | 13 | 13 |
| SiO ₂ | 6.8-7.7 | 6-8 | 6-8 | 14-18 | 60 | - | 12 |
| Al ₂ O ₃ | 18-20 | 25-29 | 24-26 | 24-28 | 20 | 15 | 19 |
| Fe ₂ O ₃ | 33-35 | 24-27 | 22-25 | 18-22 | 48 | 52 | 25 |
| TiO ₂ | 18-20 | 22-25 | 18-21 | 6-8 | 5 | 5 | 12 |
| CaO | 4-4.5 | - | - | 7-10 | 3 | 5 | 3 |
| Na ₂ O | 5-5.75 | 4-5 | - | 8-10 | 5 | - | 10 |
| Cr ₂ O ₃ | - | - | - | 0.1-0.2 | 0.3 | - | - |
| V ₂ O ₅ | 0.24-0.26 | - | - | 0.07-0.1 | 0.2 | - | - |
| P ₂ O ₅ | 0.26-0.28 | - | - | 0.08-0.1 | 0-2 | - | - |

Hindalco : Hindustan Aluminium Co., Renukoot, (UP) India

Indalco : Indian Aluminium Co., Alwaye, Kerala, India

Alcorpon : Aluminium Corporation, Asansol, West Bengal, India

Physical and mineralogical properties of red mud

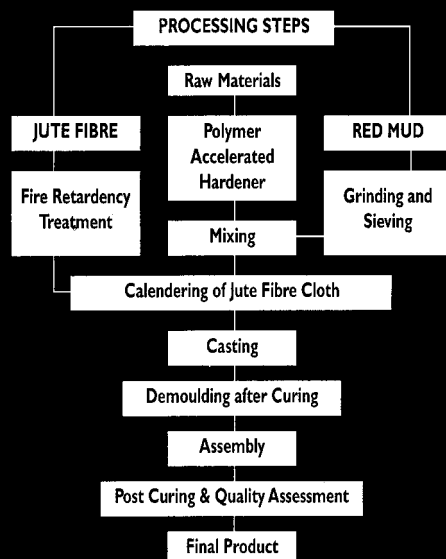
| | |
|-----------------------------------|-------------|
| Sp.gr | 2.6-3.1 |
| pH | 11.7-12.3 |
| Bulk density (g/cm ³) | 1.1-1.3 |
| Initial solids in mud slurry% | 7.8-35.9 |
| Settling rate, cm/kg | 0.014-0.015 |

Mineralogical constituents of red mud

| INDIAN | EUROPEAN | RUSSIAN |
|----------|-----------|--------------------------|
| Quartz | Natrolite | Alkali-alumino silicates |
| Gibbsite | Boehmite | Kaolinite |
| Goethite | Goethite | Halloysite |
| Rutile | Haematite | Feldspar |
| Unatase | Unatase | Limonite |



How Composite Doors and Panels are Made



Commercial products of some companies in India

| Name of the composite | Composition of the composite | Type of building materials | Manufacturer in India |
|---|--|---|---|
| ORGANIC COMPOSITES | | | |
| 1 Red mud-PVC jute fibre | Red mud PVC Fibre | Corrugated roofing sheet, panels | Lotus Roofing Pvt. Ltd Sedurapet P.O. Pondicherry-605 101 |
| 2 Jute fibre-polyester | Polyester jute fibre | Panels | Jupiter Board Industries 93, Pilkhana Road Berhampore, Mushi-dabad-742 101 (WB) |
| 3 Redmud-polyester sisal-glass fibres | Red mud, polyester, sisal | Panels, tiles, roofing sheet | Neolux India Ltd. 75, Altanta, 7th Floor 209, Nariman Point Bombay-400 021 |
| 4 Bitumen bonded paper fibre or pulp | Paper fibre felt, bitumen | Corrugated roofing sheet | Light Roofing Ltd No.2/87, GST Road Chettipunniam 603 200 Chengai, MGR, Distt Tamil Nadu |
| 5 Gypsum plaster-fibre jute/sisal & glass | Sisal/glass fibre gypsum plaster | Partitions, door shutters | Ganesh Agro Industries Pvt. Ltd., 636, Mundka, Delhi-110 041 |
| 6 Borotik | Rubber wood | Door shutter, partition | Borox Morarji Ltd. Jolley Bhawan, No.2, New Marine Lines Bombay 400 020 |
| 7 Coir-oxychloride composite | Coir fibres, magnisium oxy-chloride cement | Ceiling, partition, panels | Anutone Boards (P) Ltd. Bangalore (India) |
| 8 Rice husk board | Rice husk, synthetic resin | Wall panelling, false ceiling, partitioning, door/window shutters, roofing panels, flooring | Padmavathy Panel Boards Pvt.Ltd. 114, 4th Cross 1st, N Block, Rajaji Nagar Bangalore - 560 010 |
| 9 Bagasse board | Baggase, synthetic resin | Wall panelling, false ceiling, partitioning, door/window shutters, flooring furniture | Western Bio System Ltd. ECO HOUSE 65/1-A, Akarshak Opp.Nal Stop Karne Road Pune-411 004 |
| 10 Cement bonded particle board | Cement wood like eucalyptus and casurine | Partitioning, wall lining, false ceiling, roofing, flooring, doors, panelling | NCL Industries Ltd. 7th Floor, Raghava Ratna Towers, Chirag Ali Lane, Abids Hyderabad - 500 001 |
| 11 Medium density fibre board | Cotton plant scantling, wood fibre, resin | Door frame, doors, furniture, partitioning, panelling, | NUCHEM Limited E-46/12, Okhla Industrial Area Phase-I New Delhi - 110 020 |

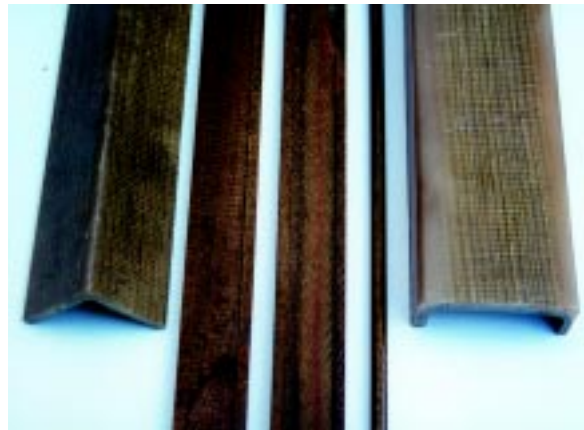
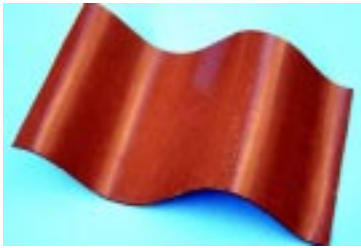
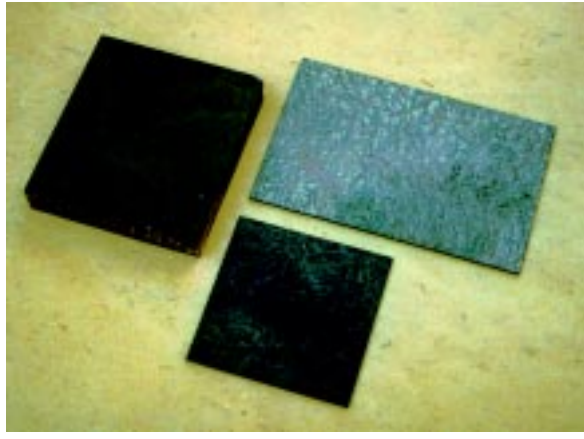
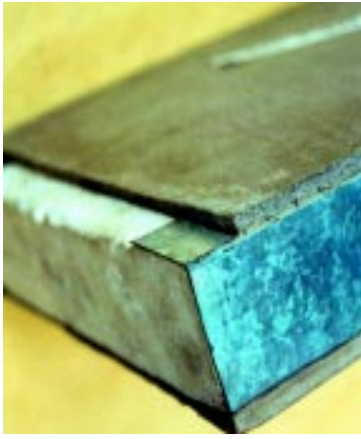
| Name of the composite | Composition of the composite | Type of building materials | Manufacturer in India |
|---|--|--|--|
| 12 Stramit board | Dry un-pulped straw and paper | False ceiling, doors, partitions, non load bearing walls, flooring, roofing, wall cladding | Ballarpur Industries Ltd. Thapar House, 124, Janpath New Delhi - 110 001 |
| 13. Coir Polymer Composite | Coir Fibre, Polymer | Wall Panelling, False Ceiling, Partitioning, Door/window shutters, Roofing Panels | Natura Fibretech Pvt. Ltd No.1/C-7, K.H. Road Bangalore - 560027 |
| Inorganic Composites | | | |
| 14 Elatomation bonding plant | Technology for cement/polymer bonded boards | Roofing sheet, partition, panelling, door shutter & frames | Synergy International B-17, Defence Colony New Delhi - 110 024 |
| 15 Flyash-red mud polymer composite | Flyash, red mud and polyester | Door shutter | Dual Build Tech (P) Ltd. Madras (India) |
| 16 Clay flyash bricks | Flyash 30-40% Clay 60-70% | General purpose bricks | Calcutta Mech. Brick (P) Ltd., Calcutta 700 020 |
| 17 Flyash-sand-lime bricks | Flyash 70% Sand 20% Lime 10% | General purpose bricks | Damodar Valley Corporation, DVC Power Plant, Baria, Durgapur West Bengal (India) |
| 18 Flyash-sand-lime bricks | Flyash 70% Sand 10-20% Lime 7-10% | General purpose bricks | Pulver Ash Ltd. Bundel West Bengal (India) |
| 19 Flyash cellular concrete | Flyash cement/lime gypsum aluminium powder | Light weight blocks and slabs | Ballarpur Industries Ltd. Palval Haryana (India) |
| 20 Fibre reinforced phosphogypsum composite | Purified phosphogypsum plaster & glass fibre or coir | Walling, roofing panels and blocks | IDL Salzbau Visakhapatnam Andhra Pradesh (India) |
| 21 Sand-lime bricks & flyash-lime brick | Sand 90% Lime 10% or Flyash 60-70% Lime 30-40% | General purpose, white & coloured bricks, hollow blocks | Sand Plast India Ltd. Behror, Alwar Rajasthan (India) |
| 22 Flyash-lime gypsum brick (Fal-G) | Flyash 60% Lime 10-20% Gypsum 10-20% | Bricks of medium range strength | Bhadrachalam Paper Board Ltd., Bhadrachalam, Andhra Pradesh (India) |
| 23 Flyash cement brick/blocks | Flyash 80-90% Lime/or Cement 10-20% | Walling, foundation etc. | Gujarat Electricity Board Flyash Company, Ahmedabad, Gujarat |
| 24 Fibre-flyash cement boards | Agro-waste fibre 5% Cement 65% Flyash 30% | Roofing, partition and panels | Everest Roofing 'Eternit' Ltd., Bombay (India) |
| 25 Clay-Flyash Bricks | Clay 60-65% Flyash 35-45% | General Purpose bricks | Kolaghat Power Station Kolaghat, West Bengal |

Recommended equipment* required for research, development and manufacture of natural fibre composites

- Fibre Extraction Equipment
- Fibre Sorting Equipment
- Low Load Fibre Strength Testing Equipment
- Fibre Pretreatment Unit
- Fibre Weaving or Knitting Equipment
- Filament Winding Equipment
- Hand Layup Composite Fabrication Equipment
- Polymer-Fibre Spray Unit for Spray Formed Composites
 - Database on Properties of Fibres and Composites of Different Compositions-Carpet Plots
 - Computers and Computer Aided Design Programs for Design of Composites
- Composite Testing Equipment
 - Optical Microscopes
 - Scanning Microscopes
 - Density Measurement Equipment
 - Moisture Absorption Equipment
 - Tensiometer or Instron or MTS Equipment for Measuring Strength, Modulus and Fracture Toughness
 - Impact Energy Tester, Radiographic Equipment, IR Equipment
 - Weatherability Test Chambers to Test Deterioration Due to Exposure to Elements of Weather
 - Flammability Testing Equipment
 - Dilatometer for Measurement of Co-efficient Expansion
 - Simple Machining Equipment to Shape Composite Components

* All this equipment may not be necessary in all locations. Only a small portion of the equipment, listed may be required where for instance simple pressing or hand layup techniques are being used for manufacture of simple components and where high performance is not required.





Building Materials & Technology Promotion Council

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