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Eco-friendly building materials for low cost construction in rural and urban areas

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ABSTRACT

Environmentally friendly building materials are those that make optimal use of resource, produce minimum waste and are safe for the environment and people. This paper includes the variety of building materials as developed and practiced in all countries. The materials included here indicate several options which have been developed in all countries and are being extensively utilized in the construction of low-cost building both in rural and urban areas.

Index Terms: Roof, Floor, Material, Eco-Friendly

1. INTRODUCTION

Building materials from their resource extraction through manufacturing, use and disposal have become a major component of the total human effects on global ecosystem and earth's climate, particularly in two centuries since the advent of the industrial revolution. In the past half-century, with the rapidly advancing pace of urbanization worldwide, finding the raw materials and energy to produce building material, and absorbing the waste from their production use and disposal have become pressing global problems. For example, the production of Portland cement alone represents 8% of total global greenhouse gas releases deriving from human sources. Another highly visible example is the unprecedented degree of deforestation occurring worldwide to produce

wood for building construction. The resulting loss of forest diversity, soil stability, water quality and other long-term ecological and economic values are well known.

Because all manufactured building materials industries are raw material and energy consumers and produce some degree of waste, they are important targets for worldwide for efficiency improvements and environmental pollution reduction.

The search for environmentally friendly building material represents a response from the building sector intended to reduce the environmental cost of making and using building. Eco-friendly building materials may come from traditional sources, such as earth and stone materials, they may come from existing industrial processes, found by life-cycle-analysis to be the most environmentally benign, or they may come from new processes or raw material input such as industrial waste. Whatever their source, the eco-friendly materials are just one part of the necessary range of response required to make building and cities that are more environmentally responsible. Many other factors such as operating energy efficiency, integrated design, reduction of water consumption and waste, reduction of private automobile use etc. are at least as important as eco-friendly materials alone. Furthermore, the way materials are selected and applied in the building is also a very significant component of resource efficiency. For example, a floor system may be as complex as a framing layer, a structural sub floor layer a flooring underlayment, an adhesive or fastening layer and a finish layer. Alternatively, a single material such as a reinforced concrete suspended slab may be finished with a colorant and sealer and serve all these functions.

2. WHAT IS ECO-FRIENDLY BUILDING MATERIAL

Eco-friendly building materials are those that provide appropriate service and life span, with minimum maintenance, while minimizing the extraction of raw materials, the pollution from, and energy consumed by manufacturing and use, and that have the maximum potential for reuse or resource recovery.

3. STRUCTURAL MATERIAL

Pozzolona Material as Blended Material with Cement

Up to 35% of suitable fly ash can directly be substituted for cement as blending material keeping the structural considerations. Addition of fly ash significantly improves the quality & durability characteristics of the resulting concrete. Use of blended cement has now become quite popular world over, from durability and environmental benefits point of view. The advantages achieved with the use of blended cement in concrete are quite well documented: Reduced heat of hydration, improved workability & ease of pumping, superior microstructure leading to lower permeability, higher long term strength, better performance in aggressive environment (Sulphates, Chlorides etc.), reduced risk of alkali silica reaction and higher electrical resistance leading to lesser chances of reinforcement corrosion are some of the benefits of pozzolona material blends. While Portland pozzolona cement saves energy by 20%, lime pozzolona mixture shows up to 70% savings in energy.

Sand and Aggregate from Pulverized Debris

Sand and aggregate from pulverized debris is environment friendly as it is obtained from recycled material, utilizes construction debris, minimizes waste and reduces dependence on virgin natural resources. It is also more economical. In one hour 500 kg of pulverized output can be obtained from the pulverizing machine, which utilizes electricity at the rate of 5 KW/hour.

Sintered Fly ash for Concrete and Mortar

Sintered light-weight aggregate substitutes stone chips in concrete, reducing dead weight. Although fly ash is suitable for production as a light-weight aggregate, it is used only in small amounts for this purpose. The advantage of fly ash over other light-weight aggregates is that it promotes fuel efficiency because the carbon in the ash provides sufficient heat needed to evaporate the moisture in the pellets and bring the pellets to the sintering temperature.

Recycled Steel Reinforcement

Steel reinforcement can be made entirely of recycled scrap iron. This material is salvaged from automobiles, appliances, and steel-reinforced structures, which include reinforced concrete pavements, bridges, and buildings. In general, steel reinforcement bars can be rolled out from either of the following: used scrap rails, automobile scrap or defense scrap, defectives from steel plants, scrap generated from ship breaking or discarded structures, ingots from induction furnaces, tested billets from mini steel plants and main producers.

Ferro Cement and Precast Components

Precast Components are 85% recyclable, have low carbon dioxide generation and are energy efficient. They are eco-friendly, cost effective and easy to install. With use of precast components, wastes during operations are minimal, curing is not required, and structures are waterproof due to less water cement ratio, plastering is not required from the inner side of slabs and the components are corrosion proof. The components are also stronger than cast-in-situ structures, have longer life and have better load bearing capacity.

Ready Mix Concrete

The greatest advantage of Ready Mix Concrete (RMC) is its quality. RMC is a water reducer, workability enhancer, has improved resistance, higher strength, lesser possibility of thermal cracking, is economic and has increased durability. Quality of sand, coarse aggregates, cement and water in the concrete mix can be managed better in the factories since there are facilities to check the silt content and bio waste level in the sand. There is little wastage at the RMC plants and less manpower is required in operational phases.

4. BRICKS/BLOCKS

Fly Ash-Sand-Lime Brick

To bridge the huge shortfall of bricks and to maximize reuse of fly ash waste, these fly ash- sandlime bricks should be used. These bricks provide the advantage of being available in several load bearing grades, savings in mortar plastering, and in giving smart looking brickwork. High compressive strength eliminates breakages/wastages during transport and handling, and thus cracking of plaster is reduced due to lower thickness of joints and plaster and basic material of the bricks, which is more compatible with cement mortar.

Aerated Light Weight Concrete Block

These are manufactured by a process involving mixing of fly ash, quicklime or cement and gypsum and foaming agents such as aluminium powder. These are considered excellent products for walling blocks and prefab floor slabs. They reduce dead loads on the super structure, thus indirectly helping cut costs significantly.

Phospho Gypsum based Block

Phospogypsum is generated as a by-product of the phosphoric acid based fertilizer industry. The interaction of ground phosphate rock with sulphuric acid produces 10-40% free moisture along with Phospho Gypsum. Nearly 4.5 million tonnes is generated per year. The fluoride content in Phospho Gypsum causes land and water pollution Phospho Gypsum based blocks are eco-friendly, utilise waste and reduces air, land and water pollution.

Burnt Clay Fly ash Bricks

The fly ash content can be 20-60% depending on the quality of clay. Energy/coal saving in firing up to 30% can be achieved, since fly ash already contains some percentage of un-burnt carbon. These bricks have better thermal insulation, are cost effective and environment friendly. Fuel saving in the range of 15%-35% (coal consumption) can be achieved, resulting in saving of coal up to 3-7 tonne per lakh bricks.

Sun-Dried Brick

It's an eco-friendly technique, energy efficient, reduces air, water and land pollution. It is economic and energy required for firing is saved. In hot and dry and temperate zone countries sun-dried brick have been the most widespread building material through the centuries. One third of mankind still lives in such houses. In spite of the fact that loam is rarely taken into account, it is a plastic material and can be worked easily.

Brick from Coal Washery Rejects

Freshly mined coal is washed to remove impurities prior to its use or processing. This residual waste from the coal washery plants is a hazard to the environment and needs to be disposed or utilized in a manner which lessens its harmful effects on the natural surroundings. With a suitable binder such as cement or lime, bricks and blocks similar to those made using fly ash can be made using this coal washery reject material. These bricks are eco-friendly and waste utilizing. They reduce air, land and water pollution, are energy efficient and cost effective.

Building block from mine waste and Industrial waste

It is eco-friendly, utilizes waste and reduces air, land and water pollution. It is energy efficient and also cost effective. Majority of the large-scale industries and thermal power plants generate solid wastes in bulk quantities. Red-mud, coal ash, slag, fly ash, etc. represent such wastes *unutilized* for several decades.

Stabilized Compressed Earth Block

The Stabilized Compressed Earth Block (SCEB) Technology offers a cost effective, environmentally sound masonry system. The product, a stabilized Compressed Earth Block has wide application in construction for walling, roofing, arched openings, corbels etc. Stabilized Earth Blocks are manufactured by compacting raw material earth mixed with a stabilizer such as cement or lime under a pressure of 20 - 40 kg/cm2 using manual soil press such as Balram. Stabilized Compressed Earth Block (SCEB) Technology helps in offsetting the use of fuel wood as they are sun dried and use cement for stabilization for gaining the required strength.

RHA based Insulating Block

These bricks are eco friendly, economical, waste utilizing and energy efficient. CG & CRI has developed insulating bricks from rice husk ash, which can be used for insulation of all types of industrial furnaces, particularly ceramic kilns and furnaces in steel and cement plants as well as in non-ferrous and petrochemical industries.

5. PLASTER

Calcium Silicate Plaster

Calcium silicate refractories are usually derived from calcium silicate or silicate bearing minerals such as hornblende, epidote and diopside, often with calcite or dolomite or wollastonite. Wollastonite is a naturally occurring form of calcium silicate commonly used as filler. Portland cements are also based on calcium silicate. Calcium silicate plasters are economic, eco-friendly, produce less wastage, have wide usage, give a smart finish, are less energy consuming, do not emit VOC and other toxic fumes and gases after application and are recyclable. They are safe in handling and usage, do not need skilled man power, are fast drying, durable, and have less water consumption.

Fiber Reinforced Clay Plaster

Clay Plaster can achieve better sticking properties by reinforcing it with fibres. These fibres can be natural plant (cellulose) fibre or artificial fibres of polypropylene. Plant fibres in fibre reinforced plaster act as reinforcement and create voids thus controlling cracking due to drying shrinkage and thermal movements. The dried plaster is less brittle than conventional plasters and can withstand small movements of the substrate. Fibres made from 100% virgin polypropylene fibres are also available and can be used to achieve the similar properties. Use of these fibres can reduce plastic shrinkage, reduce permeability, and provide increased impact and abrasion resistance.

Phospho Gypsum Plaster

Phospho gypsum is the waste generated by manufacturing plants of phosphoric acid, ammonium phosphate and hydrofluoric acid. The fluoride content of phospho gypsum is a source of land and water pollution. It is possible to profitably utilize this pollutant for making cement, gypsum boards, partitions, ceiling tiles, artificial marble, fibreboards etc. Phospho gypsum can be gainfully utilized in the manufacture of expansive and non-shrinking cement, super sulphated and anhydride cement, simultaneous manufacture of cement and sulphuric acid, as a hydraulic binder, as set controller in the manufacturing of Portland cement, as a mineraliser and in making gypsum plaster boards and slotted tiles. This plaster is eco friendly, economic, energy efficient, waste utilising and prevents water and soil pollution.

Non-erodible Mud Plaster

Mud walls are common especially in rural areas. Erosion of mud walls is the most common problem. The plaster requires costly annual repairs. CBRI has developed non-erodible mud plaster, which is non-erodible and water repellent. Mud plaster stabilised with bitumen cutback and kerosene lasts longer, depending upon the intensity of rain and also provides waterproofing, insect and abrasion resistance, hygienic and maintenance free walls. It is easy to prepare and apply on walls. It is economic and durable, thus reducing annual maintenance cost.

6. ROOFING

Bamboo Mat Corrugated Roofing Sheet

Roofing is an essential ingredient of any house and in India several roof cladding materials are in use including burnt clay / Mangalore tiles, thatch, corrugated sheets of galvanized iron, aluminium and asbestos cement, etc. Of these, for semi permanent structures corrugated sheets are preferred. However, one of the major roofing materials, viz., ACCS is being replaced with other alternative materials in many countries.

The sheets have been found to be resistant to water, fire, decay, termites, insects, etc. They are light but strong and possess high resilience and offer better thermal comforts.

Micro Concrete Roofing Tiles

Micro Concrete Roofing (MCR) tiles are a durable, aesthetic and inexpensive alternative for sloping roofs. Micro Concrete Roofing (MCR) tiles are made from a carefully controlled mix of cement, sand, fine stone aggregate and water. MCR tiles undergo stringent quality control at every step. They are put through rigorous tests for water tightness, strength, shape and size. MCR technology is a result of global research and development effort. MCR tiles offer many advantages over other sloping roof materials such as G.I. sheets,

Mangalore tiles, wooden shingles, slate and asbestos. MCR tiles are: highly cost effective, durable-they have the life of concrete, lighter than other roofing tiles-they require less understructure, easily installed, can be coloured to specification, reduce heat gain, do not make noise during rains. Cost of roof varies according to span and roof form.

Clay tiles

These tiles are uniform, more durable, fire resistant, environment friendly, energy efficient and low cost. Due to their low self-weight, the dead loading on the super structure reduces significantly, thus indirectly reducing costs. Tiles made using locally available clay should be encouraged rather than insisting only on the Mangalore pattern clay tile for the purpose of roofing. Fibre reinforced clay tile is a good alternative material, displaying high aesthetic performance and durability. The fibres could be any locally available agro waste.

7. FLOORING

Phospho Gypsum Tiles

Phospho gypsum can be used for making gypsum tiles. The use of waste gypsum is recommended for producing value added building materials which would definitely alleviate the pollution generated by the waste gypsum and will provide low cost eco friendly building materials with novel properties of lightness, fire resistance and acoustic effects.

Bamboo board Flooring

Bamboo is a critical renewable raw material resource which is environment friendly, energy efficient, cost effective, and can be used for disaster resistant housing. Bamboo Board flooring is a good alternative to wooden flooring. The flooring blends elegance with toughness, water resistance and ease of installation.

Terrazzo/Marble Mosaic Flooring

Terrazzo flooring is an eco-friendly alternative, made using waste and recycled material. It is primarily made using chips of broken tiles, stones and various other ceramic articles. Cement and epoxy resins are the most widely used binders for such type of flooring. Since this type of flooring can be laid out seamlessly, it helps form a good waterproofing layer on exposed surfaces such as terraces and balconies. Moreover, variations in its component materials by adding polystyrene beads can increase its insulating properties.

8. WOOD ALTERNATIVES

Salvaged Wood

Timber can be salvaged through furniture reuse, railway sleeper wood, construction debris wood or other timber. When using salvaged timber it needs to be treated for any water absorption, UV damage, wood rot, mould and mildew. Based on the source of timber to be used it needs to be treated as follows:

- Wood from furniture reuse needs re-surfacing using laminate or veneer, or polishing, paintwork etc.
- For sleeper wood, chemical treatment is compulsory when human contact persists.
- Reuse also requires surface finishing. The structural strength is very low and it has only decorative value. It also is a limited resource.
- Construction debris wood requires surface finishing, its structural strength varies based on its past usage and treatment. It is also a limited resource and available sizes, shapes and forms are indeterminable.

A. Fiber Reinforced Polymer Plastic

Fibre reinforced polymer plastics are made from plastic components, are cheaper and look elegant and pleasing and compete with wood products. Made from fibre glass, reinforced plastics are characterized by low installation and maintenance cost, high strength, light-weight, translucency or opaqueness, good resistance to weathering and fire and versatility of fabrication methods.

B. Red Mud based Composite door Shutters

Red Mud Jute Fibre Polymer Composite (REPC), this versatile composite, contains ferric oxide, alumina and titanium oxide from red mud and 82.5% cellulose and 11.3% lignin from its jute component. Some of the inherent properties of the product which make it technically superior to other conventional products are - Environment friendly technology, three times stronger than wood, weather resistant and durable, corrosion resistant, termite, fungus, rot and rodent resist ant, and fire resistant. Composite doors & panels possess properties which are comparable to natural wood and thus could be used as a wood substitute for doors, windows, ceilings, floorings, partitions and furniture.

C. Baggase board

It acts as a timber substitute for wood based products. It is strong, light-weight, finds aesthetic acceptance, and controls pollution of environment by minimizing the amount of agro waste. Manufactured with fibrous baggase (sugar cane waste) along with suitable binder under pressure, baggase boards are suitable for making insulation boards, panels, roofing sheets etc.

D. Fiber Reinforced Polymer board

These boards endure high temperature and aging. They are characterised by durability, corrosion resistance, and light-weight and high strength. They can be used in cold-storage and as heatkeeping containers, cold storehouses and so on.

E. Coir Polymer Composite

It is a substitute for wood, metal or masonry and an alternate to tropical timber products. Made using coir fibre, it is eco friendly and economic. It has better stiffness, specific strength, flexibility, reduced wear of processing machinery, strong and rigid, termite and insect resistant, flame retardant, water resistant, smooth surface finish and natural textured design. It has low consumption of paint, varnish and glue, can also be laminated, carpenter friendly, clear cut edges with standard tools, nail and screw holding properties and maintenance free.

F. Jute Fiber Polyester Composite

Such composites can be used as a substitute for timber as well as in a number of less demanding applications. Jute fibre due to its adequate tensile strength and good specific modulus enjoys the right potential for usage in composites. Jute composites can thus ensure a very effective and value-added application avenue for the natural fibre. Recent reports indicate that plant-based natural fibres can very well be used as reinforcement in polymer composites, replacing to some extent more expensive and non-renewable synthetic fibres such as glass.

9. PIPES

A. Unplasticized PVC and HDPE Products

Unplasticised PVC is an eco-friendly type of plastic that can be easily recycled. It is cheap and exhibits qualities of good acid and alkali resistance, flame-retardant, stiff and strong, can be transparent, has good vapour barrier properties and good UV resistance. It however, has a limited solvent stress cracking resistance and becomes brittle at (5°C (40°F)) unless impact modified. It is used in applications of pipe and pipe fittings, building products e.g. gutters, cladding, window frames, etc. High-density polyethylene (HDPE) plastics perform similar to the UPVC compound.

10. BOARDS AND PANELS

A. Calcined Phospho Gypsum Wall Panels

These panels are environment friendly, durable, cost effective, water resistant and pest resistant.

They have dry construction, using bonding plaster, are quick and easy to install and have easy workability. They are precise, smooth and there is no need of plastering. They have the ability to take add-ons like wall paper, painting, decorative laminates preferably of 0.6mm thickness with rubber solution or surface texture, can be used in wet areas such as bathrooms/toilets etc, take paint directly without any Plaster of Paris application, are fire resistant and provide easy laying of electrical conduits. Only water soluble primers and paints should normally be applied.

B. Fiber Reinforced Phospho Gypsum Composite

Fibre reinforced phospho-gypsum composites are made up of purified phospho-gypsum plaster and glass fibre and coir. It is used for walling, roofing panels and blocks. These can be easily cut, drilled, screwed and other wood working operations can be carried out with the conventional wood working tools. These boards can be painted, polished and decorated by conventional means. It offers advantage over wood and other conventional board materials, such as: It can be made to the required size and thickness, thereby reducing labour, wastage and jointing cost. Being isotropic in nature, it has equal strength in all directions. Any ornamental design can be incorporated at nominal cost. These panels are about 50% cheaper than teak wood. The cost also compares favourably with plywood and particleboards.

C. Fly Ash Red Mud Polymer Composite

Fly ash red mud polymer composite is made up of fly ash, red mud and polyester. It is used in making door shutters. Composites are able to meet diverse design requirements with significant weight savings as well as high strength-to-weight ratio as compared to conventional materials. Some advantages of the composites over conventional ones are: Tensile strength of composites is four to six times greater than that of steel or aluminium, has improved torsional stiffness and impact properties. It has higher fatigue endurance limit (up to 60% of the ultimate tensile strength). It is 30-45% lighter than aluminium structures designed to the same functional requirements. It has lower embodied energy compared to other structural materials like steel, aluminium etc.

11. WATER PROOFING CHEMICALS, ADDITIVES, SEALANTS AND ADHESIVES

A. Water based Components

Water based compounds have the same performance and durability properties as their conventional solvent based counterparts. All chemicals, water proofing compounds, sealants, paints and adhesives have two basic components – base compound and curing agent. On application, the curing agent evaporates, triggering a chemical reaction that leaves the base compound as a residual layer. These evaporating components have high harmful levels of volatile organic compounds and other pollutants and contaminants. These emissions can be reduced or eliminated through alternative curing agents.

B. Epoxy Resins

Tar felt / paper and pitch have always been associated with water proofing in structures. The bitumen-based products basically have a high energy consuming manufacturing process and use huge amounts of natural resources. An eco-friendly replacement for such applications is through the use of epoxy resin systems. These resins are an eco-friendly alternative, consuming lower energies throughout their lives and are easily disposable or recyclable. Lower occupational hazards and emission levels add to its advantages. The only drawback is the 7-10 times increase in costs. This increase can be justified by the overall life cycle performance of the alternative.

12. PAINTS

A. Cement Paint

This product is environment friendly, has very low VOC, and is easy to apply, while being highly economic. Its applications and uses include, exterior and interior coating for cement concrete, cement plastered walls, A.C. sheets, brickwork etc. It has good water resistance properties and can be used as a decorative element. It also has a good covering capacity, easy mixing character, better resistance to crazing, map cracking and microbial growth. The main components of cement paint are cement, pigments, accelerators, water repellents and hydrated lime.

13. CONCLUSION

Eco-friendly building materials provide appropriate service and life span, with minimum maintenance, while minimizing the extraction of raw materials, the pollution from, and energy consumed by manufacturing and use, and that have the maximum potential for reuse or resource recovery. This paper discussed the variety of building materials as developed and practiced in all countries. The materials included here indicate several options which have been developed in all countries and are being extensively utilized in the construction of low-cost building both in rural and urban areas.

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