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REVIEW ON SUSTAINABLE BUILDING MATERIALS FOR LOW COST HOUSING

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Abstract:

One of the persistent challenges faced by the emerging countries like India is an adequate shelter for all the people. The need of low cost housing have increased due to the incredible rise in population, size and shortage of dwellings in many cities, which resulted in high rents, overcrowding, low infrastructure services, poor urban living conditions and also high construction cost. Therefore, particularly for middle and low income families, their dream of owning the house becomes more difficult. So, it is important to adopt innovative, environment-friendly, cost effective housing technology for the construction of buildings and houses for enabling the common people to build the houses at a reasonable cost. The low cost housing can be built by using various methods and materials. This review paper is based on sustainable materials, which is used for low cost housing.

1. Introduction:

Considering the welfare, health and productivity of man, housing plays an important role. It reflects the social, economic and cultural values of a society and it is the greatest physical and historical evidences of civilization of a country. The need of housing to the people cannot be over emphasized. The person spends most of their time in the house. Now a day, the construction cost is at high range due to the high cost of materials and the wages. Due to the high cost, the poor person has to spend his complete life in the construction of a house [1]. So the low cost housing will be suitable for low income people, if they can spend 30% of their household income. India is a developing country, which has 20% of high income people that can pay for a house [2]. The low cost housing means is not to sacrifice with strength or build with some operational materials, but it defines effective use of local techniques and materials that requires less maintenance and also they are durable. The low cost housing will reduce the material cost and techniques used by some alternative methods [2]. The country needs a design for rapid construction and land acquisition. 40-45% are the slum population which is growing day by day [3].

2. Need for Low Cost Housing:

Due to high construction cost, the poor people or the people getting low wages, they can't to own their dream, that is to build own house. So low cost housing is done by some techniques and materials, which is similar to traditional housing, without sacrificing the needs. The cost is reduced only by using the alternative materials and methods, which are sustainable.

3. Techniques Used:

To know the techniques, building is first divided in to various parts like foundation, walls, floors and roofs.

A. Floor and Roof Methods:

Filler Slab: This material is used in South India. It is a waste material used to ensure advantages over RCC slab. Simple techniques used for roof construction. The concrete is tough to remove from tension zone, but can be replaced by means of the filler material. Materials should place in such a way that the strength is not comprised, so remove the unwanted concrete from below, reducing the use of materials and also increasing the economy, minimizing dead load, saving cost. Various materials can be used such as Mangalore tiles, Coconut shells etc. we need to choose a filler material before designing a slab. The space of reinforcement and depth of the slab will be decided by the size of filler. This will provide thermal coefficient, cost effective, 20% reduction in emission of carbon, material recycled and better appealing. Filler must be soaked in water to not absorb water from the concrete [34].

Brick Panel Roofing: Established by CBRI, Roorkee. IS14142:1994, IS 14143:1994 used for its design. This is suited for a rural area. The bricks used in less compressive zone and concrete in high compressive zone. Use 1:3 grade mortar for construction. It is made up of 1st class bricks reinforced with the 6mm MS bars. The length varies from 900mm-1200mm, but the width will be kept 530mm for permitting36-40mm gaps between bricks. The diameter of the bars is increased, if the length of a brick panel to be increased [7]. The advantages are, it saves cost and time, labour, steel, cement, centering cost by 20%-25% and 25%-35% of slab cost. The compressive strength is 150kg/cm^2 [7,8].

L and T Flex Table System: It is a good type of form work, which is used to lay the RCC floor and used up to the height 5.8m. various sizes of prop can be used such as CT – 250, CT–300, CT–340, CT–410. For the adjustments of heights prop nuts are used. Flat slab construction methods are done by using this method. Bracing is not required and smooth finishing of the concrete is obtainable [34].

Flat Slab: The slab is directly supported on the columns without any intermediate beams. The slab spanning 5m-9m, thin flat slab must be preferred. If slab spanning is greater than 9m than post tensioning must be done. Advantages are less construction time, easy form working, easy concreting. We need to use ACI-318 instead of IS-456: 2000 limitations. The disadvantages are, it is susceptible to high earthquakes. Pan et al. studied about flat slab which had the external joints with 27H shape specimens lower than the seismic loading and concluded that the higher dead load, deflection will be higher. egos I A et al. studied related to

deformability of the internal slab column joist and concluded that the study states to the seismic activities of joints and internal drift of multi storey structure [10,11,12,13,14].

B. Wall Construction:

Soil Stabilized Block: In crushed block walling, the cement is used as a stabilized soil to attain wet strength. Some other stabilizer may also be used, but it not fulfills with the economic and readily availability. It is uneconomic that to use cement of mortar15kg/$m^2$of walling. The method used for stabilization is, compacting the soil to minimize the voids and there will be increase in compressive strength, density and decrease the access of moisture of block. The ingredients of soil cement stabilization are consisting of 15% gravel, 50% sand, 20% clay, 15% silt and the lime stabilization consist of 30% sand, 15% gravel, 35% clay and 20% silt. Cement and lime are expensive additives, but they are locally available; but if not correctly worked out will give poor results. For sandy soil, cement is used. Compare to fired bricks, the cost of this block is 19.4% less and 47.2% lesser than wire cut bricks. Benefits of this block are thin and high walls are constructed, water resistance, compressive strength, eco-friendly, transferable technology. Disadvantages due to cement stabilization, the curing need to be done for 4 weeks, skilled labour and identification of the soil is required [15,16,17].

Rat Trap Bond: Masonry work, the bricks create a cavity in the wall having similar wall thickness as a convectional concrete. In this, bricks are placed on the edge which forms inner and outer face of the wall with cross bricks. The cement mortar usage in the ratio of 1:6. Advantages are lesser number of bricks are needed and 80% load will have reduced on foundation. This has same strength as compared with others and can built up to 3 storey [8].

Thin Joint Construction: This method is substitute preparation to 10mm sand and cement mortar. They are supply as 25Kg bags of dry-premixed powder which will be applied with the special spreader of 3mm thick. It will be set within 10 minutes and complete strength is attained within 1-2 hours. The approaches are different for sand and cement system. A circular and mechanic saw is used instead of club hammer or bolster chisel that it causes better joint than 3mm. First course will lay on DPC. They are allowed to set over night and also leveled before instigation with a thin joint construction. Often check should be done for line, plumb and level. The sizes available are 610x140x200mm, 610x215mm, 610x270 mm and have different thickness used for the cavity walls. 25 Kg cement and 5.75L of water are mixed in the bucket. To maintain consistency of mortar electric mixing tool is used. 4-hour workability must achieve for mix. To scatter the mortar of 3mm thick, special scoop is used. Mortar must be plastic for 6-9minutes and set within 10 minutes. Advantages can improve by jumbo blocks of 430 mm height and 440mm length. They are used for cavity wall, partition, separating and solid walls. Benefits are accurate dimension blocks, high bond strength, high sound insulation, easy mixing of quantities and fire resistance [19,20].

Fly Ash Sand Lime Bricks: In presence of moisture, the lime and fly ash is mixed, then the fly ash sand lime bricks are made. The fly ash reacts with lime at normal temperature and they form a compound having cementitious properties. After these reactions calcium silicate hydrates are formed and response for a high strength of the compound. These are chemically bonded bricks. Advantages are accurate dimension, use of industrial waste, eco-friendly and reduce shrinkage, does not need plaster, light weight than clay bricks [8,35]. A Sumanthi et al. define best possible mix design, it shall be 15% fly ash, 21% gypsum, 30% lime and 53% quarry dust have compressive strength 7.91N/mm^2 at 28 days. Compressive strength will decrease if increase in fly ash. Water absorption is 10.9% which will be lesser than the standard value of 12%, where a size of brick is of 230x110x90mm [21].

Aerated Concrete Blocks: Aerated concrete is the type of a light weight concrete which neglects the repetitive of coarse aggregates and take in high percentage of void. Before materials are poured in to the moulds, the foaming agents is applied in the mix. Density will reduce to 500Kg/m^3. Size of block is 300mm high, 600mm long, 100–300mm deep. One AAC (Aerated autoclaved concrete) block weighs 12.23Kg and create 1.3ft^2(13.98m^2) of wall area, where the one CMU block will weigh 15.4Kg and creates 0.88ft^2(9.46m^2) of wall area. The 1st course lay in traditional mud blocks and following course lay with a thin layer of jagged trowel. Advantages are low thermal conductivity, high wall area/block, lighter than convectional concrete blocks and less moisture penetration. Disadvantages are, this method is complex, which is unsuitable for small scale production, not appropriate for heavy load bearing circumstances, fragile, not aesthetically pleasant, water absorbent at surface [22].

C. Other Techniques:

Aluminium/ Mivan Formwork: This system has high durability, less maintenance and they can use anywhere. Wall, slab and column can be cast together, which saves time. The panels that made by aluminium are easy to handle, light weight, strong. They can use with repetition of 250 times or more and if not it will be costly. The component is aluminium rail, sheets and section panels. It has thickness of 4mm skin plate and the 6mm is ribbed to stiffen the panels. Advantages are fast construction, custom design formwork, less labour, reuse of panels, less maintenance, seismic resistance, no tower cranes required. Disadvantages are planning must be done before construction, finishing lines can be seen, shrinkage cracks may appear, less modification due to casting is one. It is suitable for low and high rise buildings [23,24].

Tunnel Form Work: It is steel formwork used to cast slab and wall monolithically. It is of various size, modulus and shape. Tunnel formwork are of two types. one is the classical tunnel formwork, which will contain of half or full tunnel formwork. second is a railed tunnel formwork. 1st type is used for construction, it depends on width of a form and the crane capacity. Full tunnel for short span rooms and half tunnel for wide span. Advantages are independent on climate condition, time effective as the floor to floor erection can be complete in one to three days, less error, can be used 800 times, earthquake resistant, high precision of 1/1000 deformation is permitted, no finishing required, saves time by 25% and reduction in frame cost by 15%. Disadvantages are cost of equipment's are high due to requirement of a crane, for small construction there is increase in the formwork cost/m^2, cannot be used for theatre or music halls, minimum thickness of wall is 20 cm, basement cannot be constructed, work cannot be done in high winds, mat or continuous footing needed. Use for house prison, hotels, barracks [25,26].

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Gypsum area Separation Wall: Gypsum walls are easy to construct, lighter in weight, less time consuming. It provides 1-3-hour fire resistance rating, sound isolation. Main content is calcium sulphate dehydrate which consists 21% chemically combined water by weight. If subjected to fire, water will release as steam. This method will protect other side from a high heat. The gypsum board content is metal naming, 1-inch-thick non-combustible type X gypsum liner panel, break away aluminium clips which softens at comparatively low temperature. Advantages are more space available. panel weighs 8 to 9 pounds/ft^2(0.33-0.37kg/m^2), less use of material and labour, scaffolding not needed, easy usage up to four storeys. Disadvantages are, it cannot use in the high humid conditions like saunas, indoor pool etc. and if temperature is more than 52^{o}c [8,27].

GFRG (Glass Fiber Reinforced Gypsum) and (GFRC) Glass Fiber Reinforced Concrete Panel Building System: GFRG is eco-friendly and fire resistant. It is known as gypcrete or rapid wall. They are suited for both load and non-load bearing structure. GFRC Suitable for non-load bearing walls of high rise structures and load bearing structure for 1-2 storeys. GFRG has modular cavities suited for external and internal walls. It also uses in floor/roof slab with RCC. Panel size of 3m high, 12m length, 124mm thick, 1440Kg weight of each panel, in each panel 48 cavities of 230x94x3mm, 10-12% light as related to concrete/brick masonry. Main features of GFRC are high shock resistance, high durability, quick and easy construction, light weight, good heat insulation. Advantages of GFRG are resistant to termite and corrosion, saving in materials, dead load minimized by 50%, 15–20% reduction in construction cost, carpet area increased by 8%, reduction in $C0^2$ emission. Disadvantages are, ten storey can be built, disadvantage also in low seismic zones[33,36].

4. Materials:

Materials are classified in to manmade and natural. Materials like rice and coconut husk, bagasse, banana leaves are naturally available materials from agriculture industry. Materials like Ferro cement, fly ash are manmade materials which is recycled to make new product used for low cost construction.

A. Natural Materials: Fiber is hair like materials which are discrete elongated parts like threads. Attractive, paintable, rot–resistance, cheaper, low density and eco-advantages. Disadvantage is absorption of water; chemical treatments is needed [34].

Bamboo Fiber: Swaptik et al. states, the tensile strength of bamboo was around 650N/mm^2 and steel is 500–1000N/mm^2. Bamboo was more bendable than steel have low modulus of elasticity of 50 GPa (50000N/mm^2) than the steel. Mechanical properties will vary from each specimen. It can use in beams instead of columns, because it will buckle. The corrugated bamboo roofing sheet, which is eco-friendly, durable, strong, light weight and fire resistance when compare with thatch roof and also other roofing materials. These sheets are used for walling, roofing, window shutters and doors [28,35].

Earth: It is oldest material, but due to its limits such as water penetration, high maintenance, erosion, termite attackit is less used, but these limitations can overcome by the, compressed earth block which is from adobe block and/or known as earth block. Contain cement using manual press and also overcome by non - erodible mud plaster have a constituents of bitumen which is mixed with specific mud paste. It has capability to resist the water [35].

Random Straw or Coconut Fiber Stabilized Soil: Its applications are, life extended thatch roof which is environmental friendly, water proof and fire resistance and other is, improved thatch roof that the CBRI have designed a method to make roof water and fire resistant by plastering the layer using mud to make resistant to fire [28]. It improves durability and strength. Result with a silty clay by means of the standard AASHTO compaction process applied with tensile strength rise 3 times than soil with no straw and also the soil-straw mix provides a high ductility behavior [35].

Bagasse Fiber: It was obtained from remains of sorghum stalks or sugarcane. They are pale green to grey yellow colour. They are bulky and non-uniform in size. Advantage is eco-friendly, low energy input, reduces the density of product. Disadvantages are degradation of fiber etc. It can use as biomass power generation, bagasse PVC boards, bagasse panels and cement board [29].

Jute and Coir Fiber: It was obtained from husk of coir and coconut. Due to presence of linin it is durable. It has diameter of 12–25 microns and length is 35cm. It affords economic substitute to wood for construction industry. It includes manufacture of coir-ply boards with oriented jute as the face veneer and coir plus waste rubber wood inside [34,35].

Sisal Fiber: D. Chandramohan et al. states these are naturally available fibers, which has high specific strength, low price and recyclable. In reinforced polymer composite they are used as reinforcement. This cannot use in rain, snow and wet spills. It can use for cordage industry, paper production, roofing sheets, tiles, production of ropes and cement flooring sheets [30].

Banana Fiber: This is light weight, highly strong fiber, average fineness is around 2400Nm, with small elongation, environmental friendly and bio-degradable. They are used for production of fire resistance boards, home furnishes, building boards, mats and ropes [31].

Rice Husk: Their constituents are 25% weight of husk is converted to ash, 75% organic matter, 85–90% of silica is present in ash. They are used in the rice husk binder, power plants, fibrous building panels, roofing units, production of activated carbon, low cost sand Crete block, production of building materials [35].

B. Manmade Materials: The byproducts from industrial revolution have best pozzolanic properties and they are used as alternative materials [34].

Fly Ash: Obtain from coal burning and recovered from gasses. The constituents are alumina, iron and silica. They are used as filler in bituminous mix, used in bulk fill, fly ash brick, artificial aggregate [35].

Aerocon Panels: This is inorganic bonded sandwich panels contain two fiber cement reinforced sheets. They are made up of binders, Portland cement and a mix of siliceous and micaceous aggregates. These panels are light weight, sound reduction properties, eco-friendly, fire resistance etc. [34].

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Ferro Cement: It is a versatile cement that based on composite material, they are made by cement mortar and reinforced with a one or more layers of the wire mesh. It's a good strength material, high performance. Disadvantage is high shrinkage and creep. They are used for cycle shed, water tanks etc., that it is easy to construct and can be used in post disaster management [34].

Hollow Concrete Bocks: Expensive as there are requirement of large quantity of cement and graded sand, that is 12-17% by weight. If correctly dimensioned; can lay on 10mm mortar joint. To settle the mix, vibrating table is required. A heavy lid is slammed many times to compress the material [15]. The raw materials needed for concrete hollow block are sand, cement and aggregates. For fly ash concrete blocks the materials required are fly ash, cement, aggregates. For light weight concrete hollow block light weight aggregate like fly ash, pumice, ceramisite, furnace slag, pearlite, cinder and other waste slags, cement [9]. Hollow concrete blocks are the replacement of convectional bricks and stone. They are lighter than the convectional bricks and easy to place. Standard size of the hollow bricks is 400x200x100mm, 400x200x200mm, 400x200x150mm and have a compressive strength of 39–147KN/m. various machines are used to construct these blocks like stationary block machine, hand held type block machine, standing type block machine. Their advantages are less labour required, good quality, durable and used for exterior and interior walls, compound and retaining walls [8,18].

Recycled Steel Reinforcement: Steel is used as the recycled scrap iron. It is use in steel reinforced structures such as bridges and buildings. The advantages are bond strength, high strength, weathering, resistant to termite [28].

Precast R.C.C: It is door frames using welded reinforcement. Economical, termite, fire and corrosion proof, Durable. No cracks, shrinkage, bending. Stronger than other door frames. Site installationis easy. Great strength to weight ratio than RCC and they give 20% saving on materials and cost [28].

Plaster:

- ✓ **Calcium Silicate Plaster:** The calcium silicate refractories are resulting from calcium silicate. Wollastonite is a naturally arisingform of calcium silicate generally used as filler. Portland cement based on calcium silicate. The calcium silicate plaster is eco-friendly, economic, less wastage, smart finish, wide usage [35].
- ✓ **Fiber Reinforced Clay Plaster:** The clay plaster will achieve best sticking properties by means of reinforcing with fibers. The fibers may be an artificial fibers of polypropylene and natural plant (cellulose). Plant fibers will act as reinforcement in fiber reinforced plaster and create voids, so control's the cracking due to thermal movements and drying shrinkage [35].

Roofing's:

- ✓ **Bamboo Matt Corrugated Roofing Sheets:** In India more number of roof cladding material are used by a people such as Mangalore tiles/burnt clay, corrugated sheets of galvanized iron, thatch, asbestos cement etc. Of these, corrugated sheets are preferred for semi-permanent structures [35].
- ✓ **Micro Concrete Roofing Tiles:** They are durable, inexpensive alternative for sloping roofs and aesthetic. They are made from controlled mix of fine stone aggregate, sand, cement and water [35].

Decorative Concrete Block: The decorative concrete block come with combination of decorative and structural function and used for exterior wall decoration. The raw materials are stone, sand, pigment and admixture [9].

Light Weight Concrete Block (3E) Panel: The light weight concrete block (3E) panel is used for the walling system of steel reinforced concrete and raw materials used are steel wire or glass fiber, fly ash (optional), cement, aggregate (optional: stone, sand, blast furnace slag, pumice, ceramisite, pearlite and other slags [9].

Foam Concrete and Hooking Panel: Foam concrete panel used for partition wall or concrete panel, reinforced hollow floor panel, EPS sandwiched external wall panel, EPS sandwiched roof paneland this are light weight, easily worked and rapid on site assembly, energy efficient (80%), fire resistant, excellent acoustic performance. Raw materials are cement, reinforced materials, fly ash (50-70%), forming agent. Hooking panel used for wall of high and low rise buildings. The features are, the wall is assembled by concrete hooking panel and steel or concrete hook, it is quake and fire proof, no need for bonding or anchoring for the panel. Raw materials are sand, cement, glass fiber (for non-bearing wall), waste slag, steel wire (for bearing wall) [36].

Straw Panel: Used for low rise building walls and partition walls of high rise structure. Features are light weight (33kg/m^2), green building material (70% straw), non-radioactive, low cost: 35-50% of gypsum board, water and fire proof, 10-20% of wood product, crack resistant. Raw materials are sawdust, straw (wheat straw, maize stalk, rice straw), sugarcane pole, reinforced material, anti-burning and bonding agent [9].

Paint for Exterior and Interior Wall: It is used to decorate exterior and interior wall. The main features are convenient maintenance, easy construction, more colour option upon demand. The raw materials are filler, titanium white, additive, polymer emulsion [9].

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