# Exploring the use of non-conventional materials for self-sufficient housing as healthy buildings

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**ABSTRACT**
The changing scenario of habitat all over the world is creating chaotic urban areas. These are characterized by rapid migration to the cities and development of slums. The problems of pressurized city services/urban infrastructures, traffic congestion, environmental pollution, inefficient energy systems are compiling in urban conglomerations. The concept of self-sufficient housing is to minimize the pressure on cities in terms of space, energy, traffic, population, etc. The provisions will be made in these housings to enable the inhabitants to produce their own energy, grow their own agricultural produce for food, recycle all the waste. The building will be using renewal energy sources totally. The main objective is to develop suitable architectural designs for self-sufficient housing units incorporating the necessary infrastructures. While the design should be based on the concept of energy efficiency, a careful selection of construction materials and techniques is necessary.

**INDEX TERMS**
Energy conservation; Residential; Air pollution

## THE SCENE

With its present growth rate (about 150 persons/min) the world population will cross 8.5 billion by the end of the year 2025. As per the projections made, 57% of this population will be urban, out of which 95% contribution will be from the developing countries. As a result, the population of many cities in developing countries will cross the figure of 20 million by the year 2025. As per UNCHS, 17 of the 21 mega cities will be in the developing countries. Already there is a global shortage of housing for 2 billion people. This shortage will be become more and more acute if no immediate actions/measures are taken. The rate of urban growth will also increase in the coming years, by building more and more mass housing projects.

## THE PRESSURE

### Land

As of today the land in the urban metro cities has become very dear and costly; also it is difficult to find new land suitable for mass housing. The alternative of housing in high-rise apartments is leading these urban areas towards chaotic development. Claustrophobia, restriction of sunlight/ wind/ open spaces, etc. are the results of such huge developments. They also pose greater pressure on parking and transportation system network.

### Energy

This is a burning problem of the present era. The conventional centralized energy distribution network accounts for high transmission losses (ranging from 9 to 20% at times) The energy consumption in residential structures accounts considerably high than other buildings, and in addition it is a recurring and ever cost increasing phenomenon. It is very difficult to remain in the city and save energy beyond a certain limit without compromising the present day

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materialistic lifestyle by the city dweller households. The factor of polluting the environment by using conventional fossil fuels for energy generation accounts for a disastrous future. Sometimes even providing minimum energy to all households is not possible by the local authorities.

**Utilities**

The present day big cities are growing at a faster speed; the utilities and the availability of basic amenities to urban population is becoming increasingly difficult day-by-day. It is a very complex situation and a major multifaceted problem to cope up with such a huge demand. Lack of finance/civic sense resources are further adding to this precarious condition.

**Environment**

The present day pollution and lack of basic amenities are proving detrimental to future growth of residential nature in metro city areas. The polluted air and water, the toxic wastes, the dangerous fuel emissions from vehicles, are further aggravating this situation. The decreasing green areas are bringing changes in the microclimate of these cities, making it more and more uncomfortable for living.

**Transportation**

The public transport systems of almost all these urban conglomerations are running at a loss and it has become increasingly difficult to maintain their effectiveness, cleanliness and punctuality, because of overcrowding and pressure of daily commuting population.

## ENERGY EFFICIENCY TO SUFFICIENCY

The future of housing design should rely on not only energy efficiency but also towards energy sufficiency. For effectively using these concepts, simultaneous use of various non-conventional energy sources is necessary, which will cover the lean period of generation of energy by one source and will provide designed uninterrupted quantity of energy all the time.

## THE NEW CONCEPT

The concept of 'self sufficient housing' is to develop a self-contained commune with a building unit designed to cater to the needs of approximately 15–20 families. The provisions will be made in these housing to enable the inhabitants to produce their own energy, grow their own agricultural produces for food and recycle all the resources/ waste. These units will be essentially located in rural/countryside areas. The building will be planned in such a way that it will use non-conventional/renewal energy sources totally and will not use any form of external energy source. Studies show that this commune can contain up to 500 families together. The main objective of this research is to develop suitable architectural designs for self-sufficient housing units incorporating the necessary infrastructure, like equipment of energy generation. The major advantages of this concept are:

*Location and site:* These units will be located in rural/country areas and they will be well connected with the possible work centres. The rural natural fresh and unpolluted environment and low cost of land will be the first positive aspect of constructing such dwelling units.

*Energy sufficiency:* The building will be planned in such a way that it will use non-conventional and renewable energy sources totally and will not use any form of external energy source like electrical grid network or fossil fuels, etc.

*Recycling:* The concept of recycling of waste/water/garbage will be applied in such a way that it fulfils the need of dwellers without tapping any external services or utility networks. The garbage will be recycled to produce energy through non-conventional methods and end product will become manure for crops. One example of recycling can be using wastewater from washing in fishponds and from there it can be used in fields/ vegetable farms.

*Space economy:* This building will provide minimum adequate living space for 15–20 families in an economical rural/countryside site. This number of dwellers will depend upon local conditions, extent of the problem and energy sufficiency parameters along with other factors.

*Environment friendly:* The main aim of these self-sufficient housing units is to develop such a housing system in which there will be no generation of pollution by any means. Besides being situated in a rural environment, these houses will be using recycling of water and all the waste materials. Thus, a nature friendly and ecologically balanced surrounding will be created by these dwellers through these housing systems.

*Employment generation:* The commune development activities and maintenance of various energy generation equipment will also generate employment for the dwellers and only a handful (one person per family) may have to go to city areas for sophisticated jobs etc. As this concept provides partial food growing facility/zero energy bill along with other economical advantages; there will be less necessity of a job, and dwellers can engage themselves in an occupation/vocation of their own choice for better income, while living in the commune. This will result in remarkably greater employment in the commune itself (Sanyal, 1997).

*Minimizing transportation:* The dwellers require minimum transportation. Only periodical shopping of merchandise and some other work may require travelling to other areas; any activity which is not possible within the commune would entail travel. Scientific application of knowledge of farming will reduce this need to travel. This in turn will decrease the overall stress on existing transportation systems (Sanyal, 1999)

*Economical effectiveness:* These dwelling units will be only using a one-time investment of building fabrics and land. Though every effort will be made to site these in low priced land areas but it is necessary to invest a sum of capital to install recycling and energy sufficiency systems and their periodical maintenance. The real saving will be in its zero energy bill and utility bill by recycling of water, etc. Availability of maximum essential supplies, like food, energy, etc., near habitation will also bring in much economy.

## ENERGY-RELATED FACTORS IN MASS HOUSING

It is common knowledge that various sources of non-renewable energy sources/fossil fuels are used in procurement/transportation and processing of conventional building materials, sometimes several of them are used at once. The major building materials are termed as high-energy materials, because of quantum of energy required for there manufacturing processes. Presently, this energy usage entails emissions of various dangerous chemicals in the environment. The major characteristics of these emissions are:

| | | |
|---|---|---|
| $CO_2$ | – | of primarily concern as a greenhouse gas. |
| Particulates | – | mainly carbon with a range of associated mineral /metal compounds, primarily a local air pollutant. |
| $SO_2$ | – | air pollutant and precursor to acidic precipitation. |
| $NO_x$ | – | air pollutant, photochemical oxidant and precursor to acidic precipitation. |
| CO | – | local air pollutant. |
| HC | – | VOCs as environmental toxins, photochemical oxidants. |

### The Materials

Over 80% of the embodied energy in housing is the energy required to manufacture the building materials. It has been established that most of this energy is used in only a small number of materials, principally, iron/steel products, cement/concrete products, bricks/ceramic materials. The embodied energy in a housing unit amounts to several times the annual energy consumption of that same housing in use (UNCHS, 1991), see Table 1.

**Table 1** Ratio of embodied energy to annual energy for houses in different locations

| Location | Embodied energy(GJ) | Annual energy (GJ) | Ratio |
|---|---|---|---|
| UK, 1975 | 140 (average) | 71 (average) | 2 |
| USA, 1981 | 190 | 119 | 1.6 |
| Switzerland, 1987 ($m^2$) | 4.6 | 0.8 | 2.99 |
| Pakistan, 1986 | 20–100 | 7.2 | 3–14 |

## THE PROCESS OF DEVELOPMENT

### Procurement of Materials

The development activity starts right from procurement of building materials, which are obtained from various sources. A list of their origins and basic procurement process is given in Table 2.

**Table 2** List of basic building materials and their procurement process

| Materials | Sources | Basic procurement process |
|---|---|---|
| Bricks | Soil | Excavation + moulding + baking |
| Stone | Rocks | Blasting + crushing + sizing |
| Timber | Trees | Cutting + seasoning |
| Lime | Rocks | Excavation + Burning |
| Cement | Rocks | Excavation + processing + mixing of various ingredients |
| Sand | River beds | Excavation |
| Steel | Rocks | Excavation + Burning + Processing |
| Glass | Sand | Processing + mixing of metallic silicates |
| Non-ferrous metals and alloys | Rocks | Mixing of minerals |
| Plastics | | Processing of carbon compounds |
| Paints | | Processing + mixing of various ingredients |

Each of these procurement processes has a long-term negative impact on environment, besides using energy. The procurement of wood and manufacturing of wood-based products requires cutting of trees. The excavation for raw materials and minerals disturbs the existing green areas and changes the proportion of soft cover/hard cover areas, which may lead to changes of irreversible nature in the environment. Sometimes the ground surface is rendered useless because of underground excavations. Further, harmful chemicals/pollutants may adjoin the basic building materials while processing them. There are various process emissions as a direct result of smelting, kilning, distilling, drying, etc., which are generally involved in the manufacture of various building materials. These are characterized as non-energy related emissions and their main characteristic components are:

- Various carbon/ mineral particulates,
- $SO_2$,
- $NO_x$,
- CO,
- HC, etc.

**Table 3** Comparative energy requirements of building materials

| Category | Material | Primary energy requirement (GJ/ton) |
|---|---|---|
| Very-high-energy | Aluminium | 200–250 |
| | Plastics | 50–100 |
| | Copper | 100+ |
| | Stainless steel | 100+ |
| High-energy | Steel | 30–60 |
| | Lead, zinc | 25+ |
| | Glass | 12–25 |
| | Cement | 5–8 |
| | Plasterboard | 8–10 |
| Medium-energy | Lime | 3–5 |
| | Clay bricks and tiles | 2–7 |
| | Gypsum plasters | 1–4 |
| | Concrete: | |
| | In situ | 0.8–1.5 |
| | Blocks | 0.8–3.5 |
| | Pre-cast | 1.5–8 |
| | Sand-lime bricks | 0.8–1.2 |
| | Timber | 0.1–5 |
| Low-energy | Sand, aggregate | <0.5 |
| | Fly ash, RHA, volcanic ash | <0.5 |
| | Soil | <0.5 |

**During Construction**

It need not be emphasized here that energy usage is involved in every stage of house construction process, i.e. from the site clearance to finishing stage. There are numerous possibilities of additions of preservatives and hazardous chemicals, while constructing a house. These construction practices have long-term negative impacts on the interiors as well as the occupants. Considerable energy is also consumed in prefabrication/ prestressing of different building components, which also accounts for resultant environmental pollution. Construction should be judged here independently with respect to their negative environmental impacts:

1. *Site clearance:* This leads to topographical changes, disturbing hardcover/soft cover surface proportions significantly, and cutting of trees and plants. General practice is to clean much more site than the actual requirement. This results in further degradation of the natural elements.
2. *Excavation:* Disturbance of subsoil characteristics and local pollution.
3. *Foundation:* Disturbance of deep subsoil, pressure to surrounding subsoil.
4. *Superstructure:* Use of water, creation of environmental barriers (wind flow, shadow, etc.), increase of hard mass.
5. *Roofing:* Reflection of sunlight, resultant glares and increase in local temperature.
6. *Woodwork:* Cutting of trees, artificially treated wood emits hazardous vapours of preservatives.

In the construction process, materials are combined in composite building components such as walls, floors and roofs. Based on the energy intensity of the materials and the quantities used, it is possible to calculate the energy insensitivity of various types of building materials and construction methods (Table 4).

**Table 4** Energy requirements for typical housing components

| Area | Components | Energy (MJ/$m^2$) |
|---|---|---|
| Floors: | Suspended Timber | 733 |
| | Concrete slab on ground | 1014 |
| Walls: | Timber frame, weatherboard cladding | 198 |
| | Timber frame, brick-veneer cladding | 1284 |
| | Concrete block | 755 |
| Roofs: | Galvanized steel | 508 |
| | Concrete tile | 176 |

It is notable that structures can vary up to 60% in capital energy requirement; as a result of the architect's choice of materials. Studies reveal that around 18% of total energy consumption of mankind is in the housing sector. It is necessary to consider energy conservation techniques before, during and after construction, as energy can be saved considerably in each stage. In low-energy housings, i.e. requiring little energy for operation, the embodied energy accounts for a considerable part of total energy use. Therefore, it is important to pay attention to both the choice of materials and to the recycling potential in order to decrease the total energy use of a building. Studies in Lund University, Sweden, show that the embodied energy accounted for about 40% of total energy need over a lifetime of 50 years. By change of materials, the total energy can be decreased to about 10%.

## ALTERNATIVE NON-CONVENTIONAL MATERIALS (Table 5)

**Table 5** Energy saving processes in building materials

| Process | Use of industrial wastes | Approximate % of saving energy |
|---|---|---|
| Portland-Pozzolana and Portland blast furnace slag cement | Fly ash, mining wastes, blast furnace slag | 15–20 |
| Lime-Pozzolana mixtures | Lime kiln rejects, industrial ashes | 30–40 |
| Lime rice husk ash Pozzolana | Rice husk ash/rice husk | 30–40 |
| Lime-sludge, rice husk ash Pozzolana | Rice husk ash/rice husk | 40–50 |
| Sand-fly ash-bricks | Fly ash, mining wastes | 30–50 |
| Masonary cement | Mining mineral wastes, lime sludge | 10–20 |
| Cement-concrete tiles | Mining and mineral wastes | 10–15 |

Source: Central Building Research Institute, Roorkee, 1984.

## STRATEGIES FOR ARCHITECTS/ DESIGNERS

Maximum use of low energy materials. Use local materials, involving less transportation. Selection of lower-energy structural systems, such as load bearing masonry in place of RCC/steel frames. Selection of waste/recycled materials, or manufactured materials which incorporate these, such as Portland Pozzolana cements using slag/fly ash. Optionally smart windows can be also used, which use anti-reflection layers, low emission coatings and switchable films for reducing the heat transmission losses in cold season and overheating in summer seasons. Design with methods of reduction of thickness of walls/finishes/storey heights, etc. Design for recycling, such as using of soft mortars, which allow reclamation of bricks. Design improved housing with lower energy unit demands, using cavity/sandwich walls and roof construction for more insulation. Give insulated foundation walls in cold climates. Use better control of moisture to protect insulation. Use tighter/better sealed joints with higher-performance sealants and better workmanship.

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