

Energy Optimization through Open-Industrialised Building System in Mass Housing Projects

Ar. Uttam K. Roy¹, Dr. Madhumita Roy², Prof. Subir Saha³

¹ Assistant Professor, Administrative Training Institute & Research Scholar, Jadavpur University, Kolkata, uttamkroy@hotmail.com

² Reader, Department of Architecture, Jadavpur University, madhumi_r@yahoo.co.in

³ Professor and former Director, School of Planning and Architecture, New Delhi, subirsaha5@rediffmail.com

Abstract:

Construction of buildings and production of building materials contributes hugely in environmental stress. To minimize this stresses and to achieve sustainable developments, concepts of green building evolved since building construction activity accounts for major exploitation of natural resources that leads to environmental stresses. From 2001, the buildings started to adopt the credit worthiness for environment protection. Various national strategies resulted in a huge momentum of investment in mass housing projects in India in recent years to achieve affordable housing to all. This paper examines the effectiveness of open industrialized buildings systems in mass housing projects using environment friendly building materials. For this, it first appraises such system-built housing in the credit scale for green building developed by the LEED (Leadership in Energy and Environmental Design)-India and TERI (Tata Energy Research Institute)-'Griha' consecutively. Finally, it focuses on the energy consumption scenario for a model housing projects developed by this system comparing with similar consequences for using the existing technology.

Key words: Open-industrialized system, energy consumption, Green Building

Introduction

Environmental protection and sustainable development is a widely discussed area in recent years. Construction of buildings and production of building materials contributes hugely in environmental stress. These stresses are mainly 1) soil and agricultural land 2) loss of forests and wild lands 3) air pollution and 4) non-renewable energy sources and minerals (Spence and Mulligan, 1995). Cumulatively these stresses lead to climate changes. To minimize this stresses and to achieve sustainable developments, concepts of green building evolved since building construction activity accounts for major exploitation of natural resources that leads to environmental stresses as above. It has been shown by some authors that use of vernacular, low cost and recyclable materials in building construction involves lesser energy consumption and low CO₂ emission.

On the other hand, various national strategies resulted in a huge momentum of investment in mass housing projects in India in recent years to achieve affordable housing to all. Combining these factors, this paper has been prepared to explore the appropriateness of prefabricated technology for environment protection in housing projects in present perspective. This paper examines the effectiveness of open industrialized buildings systems (herein after referred as System) in mass housing projects using environment friendly building materials. For this, it first appraises such system-built housing in the credit scale for green building developed by the 'LEED India(1)' and 'TERI Griha(2)' consecutively and finally, it focuses on the energy consumption and CO₂ emission scenario for a model housing projects developed by this system comparing with similar consequences for using the existing technology.

Industrialised Building System

Generally, industrialized systems building may be defined as the total integration of all subsystems and components into an overall process fully utilizing industrialized production, transportation and assembly techniques. Irrespective of the definition, the system includes a balanced combination between the software and hardware components. The software elements include system design, which is a complex process of studying the requirement of the end user, market analysis, development of standardized components, establishment of manufacturing and assembly layout and process, allocation of resources and materials and definition of a building designer conceptual framework. Whereas, the

hardware elements are categorized into three major groups. These include (a) frame or post and beam system (components are also used in an integrated way), (b) panel system (2D structural elements), and (c) box system (3D elements). The framed structures are defined as those structures that carry the loads through their beams and girders to columns and to the ground whilst in panel system load are distributed through large floor and wall panels. The box systems include those systems that employ three-dimensional modules (or boxes) for fabrication of habitable units are capable of withstand load from various directions due to their internal stability.

Closed System

A closed system can be classified into two categories, namely production based on (i) client's design and production based on (ii) precaster's design. The first category is designed to meet a spatial requirement of the client's that is the spaces required for various functions in the building as well as the specific architectural design. In this instance, the client's needs are paramount and the precaster is always forced to produce a specific component for a building. On the other hand, the production based on precaster's design includes designing and producing a uniform type of building or a group of building variants, which can be produced with a common assortments of component. Such building includes school, parking garage, gas station, low cost housing, etc.

Open System

In view of the limitations inherent in the closed system, an open system, which allows greater flexibility of design and maximum coordination between the designer and precaster has been proposed. This system is plausible because it allow the precaster to produce a limited number of elements with a predetermined range of product and at the same time maintaining architectural aesthetic value. In spite of many advantages inherent in an open system, its adoption experiences one major setback. For example, joint and connection problem occur when two elements from different system are fixed together. A solid and authentic works in modular coordination can minimize that joint and connection problem.

Earlier Studies in Green Building Materials & Technology

Lot of studies are existing in building materials with respect to environment. Earlier, Suzuki, Oka & Okala (3) has shown that energy consumption in prefabricated light weight building is half of that of steel reinforced concrete (SRC) building in Japan. Energy consumption of wooden building is further low, which is 1/3 of SRC building. CO₂ emission of prefabricated lightweight building is less than half (400 kg/sqm) of that of SRC building (850 kg/sqm). CO₂ emission of wooded single-family house is further low as 250 kg/sqm. In Indian case, it has been shown that most of the energy savings are due to the reduction in cement, bricks and steel-based method of construction (Tiwary, 2001). Further, traditional bricks, which are most widely used for walling in India, prove to be the worst choice with respect to the energy input involved. Moreover, they use precious topsoil, causing serious environmental damage and destruction of prime agricultural land (Chani, Najamuddin & Kaushik, 2003).

On other hand, alternative building materials like clay fly ash and sand lime bricks provide an energy efficient solution for walling. In general, concrete blocks, along with Fal-G, blocks provide the most energy efficient results. Lime comes up as a poor replacement for cement in mortar. Therefore, the conventional cement mortar is the most suitable energy option (Chani, Najamuddin & Kaushik, 2003). Tiwary emphasized for energy tax for the construction in India (2001). Many such study guides the use of appropriate materials in housing construction.

Similarly, technology like low cost technology has been shown as environment friendly options by various authors. However, an integrated system, which suits appropriate materials as well as technology for better environment protection, is yet to come. While industrialized housing (manufactured/modular/prefabricated) is a well-known options in other countries, in India this has to be validated with appropriate materials compatibility for modular construction along with other relevant parameters. There are ongoing research for evolving more environment friendly, light weight, cost

effective building materials which can easily supplement as components(wall, roof etc) for industrialized system.

Emerging Trend in Mass Housing in India

There is around 24.7 million-house shortage in India on an average (National Building Organization, NBO & NHHP 2007). Most of the shortage (99%) is for the lower income group (LIG) and economically weaker section (EWS) as per NBO and NHHP. Housing shortage in absolute number is not decreasing. i.e. existing gap in housing stock from 81, 91 to 2001 could not be filled up by conventional housing supply system. Whereas, housing shortage in urban areas is increasing. i.e. demand for new housing is growing at higher pace in urban areas and supply is not adequate (Fig. 1 below). Since the conventional technology and housing providers (public and private market) could not cater the total need for the housing (backlog and newly created need), there is a need for envisaging an improved system, which will be faster, cost effective and environmentally sustainable. Considering the all-possible barriers, for this non-fulfillment of housing, through five-year plans and programmes in India it will be clear that a faster technology, which can offer affordable module, made of environment-friendly materials is the better option. Accordingly, it is proposed to adopt an open system(see note) for industrialized building for the Indian case (Appendix-I).

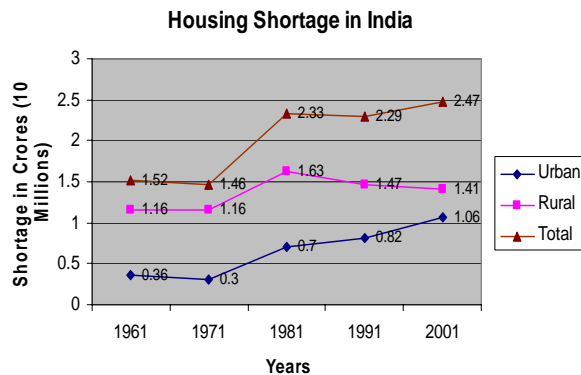


Fig 1: Consistent housing shortage in India

After liberalization and consecutive permission of 100%, Foreign Direct Investment in the large infrastructure and housing projects the investment in housing is also not a big problem. For componentized construction, even smaller manufacturers of building elements can participate. While major real estate projects are meant for higher Income group (HIG) and middle-income group (MIG), recent trend in real estate development shows that developers are keen to invest in housing for MIG and LIG since there is ready demand whereas demand for HIG is in a semi-saturated state in major cities.

Concept of green building is quite new in Indian perspective. In 2001 the building started to adopt the credit worthiness for environment protection. Very few residential projects however has gone through this process since this credit ratings requires some initial compliance criteria, which smaller projects probably cant not afford. However, after 2001 as the Foreign Direct Investment (FDI) was permitted and bigger land parcels are now more available in urban area, big scale housing even for the affordable group (MIG, LIG) are coming up in the cities by even medium and bigger private developers

Adopted Variables for the Present Study

For the present case, a housing project using the above system has been enumerated and secondly a mass housing project consisting Middle Income Group (MIG) & Lower Income Group (LIG) has been modeled to enumerate the energy consumption. To do this, the following assumption has been adopted considering the present Indian context:

Assumptions:

- Component based open system of industrialized building system(see note) has been adopted for the study
- A module of 900 in each axis has been adopted for convenience of the calculation
- Two sub group in the target economic group(MIG, LIG) has been envisaged to address major cross section of the society who do not have housing

- Use of prefabricated blocks in pavements also has been considered
- Use of industrial by products in nonstructural wall system like Fal-G blocks has been considered.
- The model only focuses on the non-structural walling material for the time being for calculation of energy consumption since, data regarding the foundation and roofing materials is not wholly available
- 240 nos of MIG-I (75 sqm), 160 nos of MIG-II (55 sqm), 240 nos of LIG-I(356sqm) & 160 nos of LIG-II units have been considered for accommodate in a plot of 2 hectare with a maximum floor area ratio of 2.0.
- 15 nos of building block for MIG –I & LIG -I each and 10 numbers of building blocks for MIG-II & LIG-II each
- Each building block has four floors and each floor has four similar units

Testing the System and modules

The System

The above system has been enumerated through two different scaling of new construction to become green building. LEED India (1) and Tata Energy Research Institute (TERI) Griha (3). Credit rating for green building is carried out for 100 points for TERI-Griha and 69 points for LEED-India. The enumeration carried out in a comparative base with a conventional construction made of RCC , brick, wood etc. secondly the same project has been enumerated for the energy consumption and CO2 emission.

The Modular Unit

In open system combination of modular components are integrated to form a unit. For this, well-knit dimensional coordination and modular coordination are required. However though the present paper is limited to that study, for convenience of the testing a modular unit (Fig 2 & 3) has been envisaged as below:

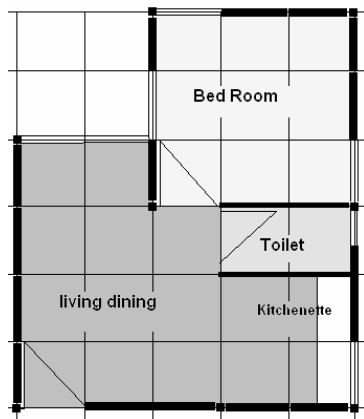


Fig 2: LIG Smaller Unit-25 sqm

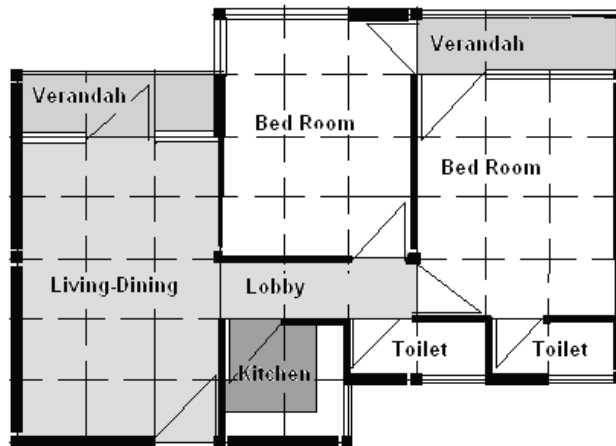


Fig 3: MIG-smaller unit -55 sqm

Now to calculate the walling materials, the following equation has been used

If, $N = n_1 + n_2 + \dots + n_t$

Where n_1 to n_t = type of wall units in Equivalent 8" thk Unit (i.e. 10 numbers of 4" thick wall =5 numbers of 8" thick wall)

$$A = a_1 + a_2 + \dots + a_n$$

Where a_1 to a_n = area of corresponding unit n_1 to n_n in equivalent area (i.e. area of an window components =area of solid base panel-area of window

Then Gross effective wall area= $\sum AN$

EER of such wall elements = $\sum AN \times$ value of EER for any material per sqm.

Findings

The System

For TERI Griha model, it has been seen that open-industrialized building system has direct advantage for achievement of 10 points due to its in built system and process of construction out of total 100 (i.e. 10%). Further, it has another 27 criteria where open system can facilitate for such credit rating, i.e. by using this system the complying with the parameter will be much easy, cost effective and in some cases minimal intervention. Cumulatively it contributes to 37 out of 100. so using this system only, more than one third of credit for green building is achieved. Complying with remaining credit point has similar situation of conventional method of construction in India.(details in appendix 2)

For the similar model in LEED India, it has been observed that total 26 points can be achieved only by using the system and intervening minimally in site, building or material out of total 69 points. Again, another 38% credit rating is achieved only by adopting the system. Complying with remaining credit points has similar stae like TERI-Griha Model. (details in appendix-3). Excerpts of above findings are as below:

Table 1: Advantage points of Open Industrialized Building system in Green Building Credit worthiness

Parameters	Total exclusive credit points for using the adopted system			
	LEED India		TERI- Griha	
	Total points	Advantage points	Total points	Advantage points
Sustainable sites	13	3		
Water efficiency	6	--		
Energy and atmosphere	17	11	96+4(bonus)	37+4(bonus)
Materials and resources	13	7		
Indoor environmental quality	15	5		
Innovation in design	5	--		
<i>Total marks</i>	69	26	100	41

The Modular Unit

Use of prefabricated wall panels would facilitate timely and cost effective construction. Lightweight, low emitting, agro-waste based building materials can be used for that. However since this is already under research the output using the Fal-G material. Which is quite familiar to technocrats has been shown. The wastage in the adopted system will be lesser. Energy consumption in using conventional technology and materials has not been shown. However if could be shown the efficiency of using adopted system would be further higher.

Comparative EER of only the walling for total 800 of MIG and LIG dwellings in 2 hectare of land is as under

Table 2: Comparative consumption of energy in Open Industrialised system and conventional method

Type of technology used	EER*	Total EER value
By conventional bricks	614 MJ	409X 10 ⁵ MJ
By industrial byproduct made blocks/panels	242 MJ	161X 10 ⁵ MJ

* The EER of walling materials has been adopted from Chani, Najamuddin & Kaushik (6)

Hence, energy consumption optimization is more than 60% than the conventional method.

Conclusion

The present study simply tries to focus on the applicability of open-industrialised building system in mass housing projects with special reference to green building/ environment compliance. The outcome of the study greatly encourages the prefabricated construction made of environment friendly materials for housing projects. The use of the industrialized system alone can achieve 38-40 percent of credit rating for green building in both the system available in India (TERI and LEED India). Further, prefabricated system-built housing embodies lesser (one third) energy compared to conventional technology and materials.

Since the open system involves the integration of various operators in various levels there should be strong and efficient institutional body in national level as existing in other countries for control and compliance. The necessary code revision and adoption must be adhered with the ongoing changes in the industry. The recently published Energy Conservation in Building Construction Code (ECBC) by Government of India is a timely step towards achieving the environment friendly built environment. However, the areas of dimensional coordination and modular coordination need to be addressed before adopting the open system. Bigger developers should take the initiatives further.

To summarize, it can be told that the open and Industrialised building system using environment friendly materials will suit for Indian condition for sustainable development. Certainly the prefabricated system can offer an economy in cost, time and environment pro development in the economy of scale and scope.

References

1. IGBC, Abridged Reference Guide For New Construction & Major Renovations (LEED – NC) Version 1.0, 2007
2. <http://www.teriin.org/bcsd/griha/ratingsystem.htm>
3. M. Suzuki, T. Oka, K. Okada, The estimation of energy consumption and CO2 emission due to housing construction in Japan, *Energy and Buildings* 22 (1995) 165–169.
4. NAHB, Green House Gases and Home Building: Manufacturing, Transportation and Installation of Building Materials, Special Studies, September 2008
5. Spence, Robin & Mulligan, Helen, Sustainable Development and the Construction Industry, Vol. 19, No. 3, Habitat Intl, 1995
6. Chani, PS, Najnuddin, Kaushik, SK, Comparative Analysis of Embodied Energy Rates for Walling Elements in India, Vol 84, October 2003, *Journal of Institution of Engineers*
7. Sivam, Alpana, Karuppannan, Sadasivam: Role Of State And Market In Housing Delivery For Low-Income Groups In India; *Journal Of Housing And The Built Environment* 17: 69–88, 2002
8. Tiwary, Piyush, Energy Tax and Choice of House Construction Techniques in India, *Journal of Infrastructure Systems*, Vol.7, No.3, September, 2001, ASCE
9. Sengupta Nilanjan, Use of Cost Effective Construction technologies in India to Mitigate Climate Change, *Current Science*, Vol, 94, No-1, Jan 2008
10. Government of India, Ministry of Urban Employment and Poverty Alleviation, National Urban Housing and Habitat Policy, 2007, National Housing and Habitat Policy 1998

Appendix-1

Comparative weight-age of system of industrialized housing in Indian situation of prerequisites

prerequisites	Weight-age for Suitability of specific system in India condition		
	3D full scale structural elements	2D full scale panelized elements	Componentized construction based on frame structures.
characteristics	Closed	Open/closed	Open
Availability of bigger land	3	3	3
Private Investment Possibility:	1	2	3
building code an inspection mechanism for quality control:	1	2	3
Offsite road infrastructure	1	2	2
Dimensional Coordination and Research in Housing Module:	2	2	3
Skilled manpower requirements	1	2	3
Total score	9	13	17

Note: Scores have been provided as 3-most suitable, 2-suitable, 1-less suitable

Appendix-2

Advantage of Open Industrialized construction for achieving LEED India Credit ratings for Green Building

Category	Total point	Parameter	Why industrialized system is advantageous
Sustainable sites (SS)- 13 points			
Prerequisite	Reqd	Erosion and Sedimentation control	
Credit 1- 4.3	6	Site Selection, Development Density & Community Connectivity, Brownfield Redevelopment Alternative Transportation, Public Transportation Access , Alternative Transportation, Alternative Fuel Refueling Stations, Alternative Transportation, Parking Capacity	Same with conventional system
Credit 5.1	1	Reduced Site Disturbance, Protect or Restore Open Space	Disturbance on the site is minimal as on-site activity is minimized due to use of prefabricated components
Credit 5.2	1	Reduced Site Disturbance, Development Footprint	Building foot print is lesser than conventional method as above (5.1)
Credit 6.1	1	Storm water Design, Quantity Control	Same with conventional system
Credit 6.2	1	Storm water Design, Quality Control	
Credit 7.1	1	Heat Island Effect, Non Roof	Easier as prefabricated blocks are used
Credit 7.2	1	Heat Island Effect, Roof	Same with conventional system
Credit 8	1	Light Pollution Reduction	
Water Efficiency (WE)- 6 points			
Credit 1.1 4.2	6	Water Efficient Landscaping, Water Efficient Landscaping, No Potable Use or No Irrigation, Water Efficiency in Air-conditioning System, Innovative Wastewater Technologies	Same with conventional system
Energy and Atmosphere			
Prerequisite 1-3	Reqd	Fundamental Building Systems Commissioning Minimum Energy Performance CFC Reduction in HVAC&R Equipment	Same with conventional system
Credit 1 -4	15	Optimize Energy Performance, Renewable Energy, Additional Commissioning, Ozone Depletion	
Credit 5	1	Measurement & Verification	More convenient as predesigned and fabricated modular units are used
Credit 6	1	Green Power,	Same with conventional system
Material and Resources (MR)- 13 points			
Prerequisite 1	Reqd	Storage & Collection of Recyclables	Same with conventional system
Credit 1	3	Building Reuse	
Credit 2	2	Construction Waste Management	Less demolition and alteration involved
Credit 3	2	Resource Reuse	Use of minimum waste in hard landscaping and recycling
Credit 4	2	Recycled Content	Component made of agro based recycled components

Credit 5	2	Local/Regional Materials	Same with conventional system
Credit 6	1	Rapidly Renewable Materials	Agro fibre used
Credit 7	1	Certified Wood	Same with conventional system
Indoor Environmental quality (EQ)-15 points			
Prerequisite 1	Reqd	Minimum IAQ Performance	Same with conventional system
Prerequisite 2	Reqd	Environmental Tobacco Smoke (ETS) Control	
Credit 1	1	Outdoor Air Delivery Monitoring	
Credit 2	1	Increased Ventilation	Appropriate predesigned and simulated ventilation
Credit 3	2	Construction IAQ Management Plan	Same with conventional system
Credit 4	4	Low-Emitting Materials	More possibility
Credit 5-8	7	Indoor Chemical & Pollutant Source Control, Controllability of System, Thermal Comfort , Daylight & Views	Same with conventional system
Innovation and Design			
Credit 1	4	Innovation in Design	Same with conventional system
Credit 2	1	LEEDTM Accredited Professional	

Appendix-3

Advantage of Open Industrialized construction for achieving TERI-Griha Credit ratings for Green Building

List of criteria	Points	Why industrialized system is advantageous
Criteria 1: Preserve and protect landscape during construction /compensatory depository forestation.	5	Minimal disturbance due to use of prefabricated components leading to minimum site disturbance
Criteria 2: Soil conservation (post construction)	4	Minimum disturbance for the above reason
Criteria 3: Design to include existing site features	2	Same with conventional system
Criteria 4: Reduce hard paving on site	2	Hard paving may be well optimizing by using prefab components as required
Criteria 5 to 7: Enhance outdoor lighting system efficiency, Plan utilities efficiently and optimize on site circulation efficiency, Provide, at least, minimum level of sanitation/safety facilities for construction workers	9	Same with conventional system
Criteria 8: Reduce air pollution during construction	2	Reduced air pollution as minimum on-site emitting action
Criteria 9: Reduce landscape water requirement	3	Overall water requirement is low as mixing and other preparation is done at laboratory/factory
Criteria 10: Reduce building water use	2	
Criteria 11: Efficient water use during construction	1	
Criteria 12: Optimize building design to reduce conventional energy demand	6	Since predesigned simulated module is used, energy consumption is minimum
Criteria 13: Optimize energy performance of building within specified comfort	12	Same with conventional system
Criteria 14: Utilization of flyash in building structure	6	Utilization of flyash and other agro based products, which endorse low emission
Criteria 15: Reduce volume, weight and time of construction by adopting efficient technology (e.g. pre-cast systems, ready-mix concrete, etc.)	4	Complies with the system under examination
Criteria 16 -21: Use low-energy material in interiors, Renewable energy utilization, Renewable energy based hot-water system, Waste water treatment, Water recycle and reuse (including rainwater), Reduction in waste during construction	17	Same with conventional system
Criteria 22: Efficient waste segregation	2	Minimal waste generation
Criteria 23 to 31: Storage and disposal of waste, Resource recovery from waste, Use of low - VOC paints/ adhesives/ sealants, Minimize ozone depleting substances, Ensure water quality, Acceptable outdoor and indoor noise levels, Tobacco and smoke control, Energy audit and validation, Operations and maintenance protocol for electrical and mechanical equipment	19	Same with conventional system
Criteria 32: Bonus	4	
	100	

