COMPENDIUM OF GREEN TECHNOLOGIES IN MASS HOUSING PROJECTS

for 'Composite' climatic zones of India

Covering Regions of Punjab, Haryana, Delhi-NCR

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1 Executive Summary

The policies and programmes for addressing the growing shortage of housing in cities call for a deployment of low-carbon, green, technologies for construction as well as forms of housing that would be climatically appropriate and energy conserving. It may be surmised that about half of the housing need would be met by self-by owners or by small enterprises as the existing habitations of cities upgrade and redevelop to accommodate more and better homes. The other half may be met by public, private-public partnerships (PPP) and private builders undertaking large group housing projects. These two distinct processes for housing provision require appropriate enabling measures as well as promotion of materials and construction techniques that are affordable for the majority of urban households, scalable and green.

This compendium surveys the contiguous states of Punjab, Haryana, the Union Territory of Chandigarh (UTC) and the National Capital Region (NCR) which fall in the Composite Climate belt. It describes the current construction practices in urban areas, lists materials and construction systems that are manufactured/ available in the region while evaluating their environmental impacts (greenness), suggests other technologies that are not yet available but would be suitable, presents case studies of exemplary projects in the region and lists design practitioners engaged in affordable and green construction. A simple graphic tool for representing greenness has been developed. Its theoretic basis is explained and the tool is used to assess all materials and construction techniques.

The contiguous states of Punjab, Haryana, the Union Territory of Chandigarh (UTC) and the National Capital Region (NCR) have been following similar construction practices based on burnt brick for load bearing walls and conventional reinforced concrete (RCC) for floors and roofs. For multistory buildings RCC frame construction is the norm. Burnt clay brick has been the chief construction material, being abundant and economical. This continues to be the dominant method of construction. For multi-storey buildings in the NCR and UTC lightweight aerated autoclaved concrete block masonry has been replacing burnt clay brick for infill walls as their lighter weight leads to savings the RCC and reinforcing steel for the frame structure. To speed up construction made-to-order aluminium formwork to cast all walls in RCC is being increasingly used, though this is costlier and climatically unsuitable.

Some companies are offering rapid construction techniques – precast RCC, or steel frame with lightweight infill and cladding. Though their advantage is in the sped of construction, they are more expensive and incur considerably higher carbon footprints compared with conventional housing construction. It is the main structural support system and walling materials that accounts for 70% of the carbon footprint.

The real potential lies in adopting ‘intermediate’ technologies. Masonry materials which use recycled materials and reduce the mass of material consumed per unit of construction – such as flyash block, hollow burnt clay block, hollow concrete block, lightweight aerated concrete block. The advantage of hollow block masonry systems is that they can be reinforced partially for economical four to five storey construction and offer the advantage of speed and climate appropriateness. Small scale prefabrication of components such as shades, stairs and floor panels also gives speed with economy. Green materials for sub-components such as doors and windows, flooring and partitioning, based on use of agricultural wastes, secondary timbers, bamboo and ferrocrete have a marginal market presence at the moment and would need promotional incentives. Similarly insulation synthetic materials, which are very advantageous for thermal comfort, especially in roofing, need active promotion – perhaps through legislation.

The most promising green technology for walling in affordable housing would be hollow burnt clay block. This can be readily adopted in the traditional, well developed, clay brick manufacturing region of Punjab and Haryana. Similarly hollow concrete block construction requires wider adoption. A policy of incentives combined with demonstration projects is recommended. The Compendium also lists design professionals practicing in the region who have a professional reputation and competence in designing prototypical solutions for affordable housing. Though only two case-studies of projects in the region are documented here, they are good examples of the way forward.

2 Introduction

2.1 The need for this compendium

The need for this compendium arises from the technology sub-mission under the Government of India's 'Housing for all by 2022' mission. The technology sub-mission targets at faster and affordable technologies for constructing mass housing. The mission also aims to integrate green technologies in execution of mass housing projects to accomplish its objectives in an environment friendly manner and adhere to its local and global commitment towards environment protection.

The National Mission for Sustainable Habitat (*under the National Action Plan for Climate Change*) and MNRE's scheme have supported initiatives that drives the current building practices towards a more sustainable future. These initiatives outline use of solar energy to reduce load on non-renewable sources of energy. This also stresses on use of active and passive strategies to achieve energy efficiency in the built environment.

BMTPC has been tasked to steer the 'housing for all mission' in the direction of sustainable construction and this compendium is one among numerous other initiatives to inform policy to achieve the goals of the mission.

The following statements, quoted from various researches indicates the broader context of the impact of construction activity on the environment and Climate Change and stresses the need for this compendium-

"*Between 2014 and 2050, the urban areas are expected to grow by 404 million people in India, China and India will contribute more than one third of the global urban population increase between 2014 and 2050*". (United Nations, Department of Economic and Social Affairs, Population Division July 2014)

"*Building construction in India is estimated to grow at a rate of 6.6% per year between 2005 and 2030*" (McKinsey & Company Inc 2009)

"*Today, buildings are responsible for more than 40 percent of global energy used, and as much as one third of global greenhouse gas emissions*". (UNEP Sustainable buildings and climate initiative 2009)

"*If only electricity consumption is considered, building sector has 30 per cent electrical energy consumption in India; what's more, its consumption is growing at the rate of 8 per cent per annum*". (Center For Science and Envionment 2012)

The above quoted facts and figures on rising urban population, the anticipated growth of construction industry, contribution of construction activities in environmental degradation, coupled with our commitment at the COP@! At Paris toward environmental protection establish the necessity for low-carbon, sustainable building construction practices. This compendium would guide development of construction practices and supporting policies to this end. In the recent past there has been a considerable hue and cry about the 'Go Green' revolution. Though there has been a growing interest and shared sense of responsibility to adopt ways of living, producing and consuming in which the negative environmental impact is reduced, there remains, in the minds of those responsible for or engaged with the building industry a confusion and lack of clarity on what green construction entails. In the context of built environment, the characteristics that makes a building 'green' have been a

subject of academic debate. For example, a report by Center for Science and Environment (CSE) states a concern that, *'The rating programmes seem to be content with increasing participation of projects and not really looking at making impacts at the planning or policy level by showing 'real' results.'* (Center for Science and Environment 2012). This compendium of materials and technologies incorporates a simple yet effective method to understand and evaluate their environmental impact

2.2 Content and structure of the compendium

The compendium constitutes of ten chapters starting with the executive summary. It is followed by introduction which is the chapter 2. This chapter discusses the context and need of the compendium followed by the content, structure and limitation of the compendium. It also discusses briefly the definition of green and technology. And thereby initiating the discussion on what makes a technology green. It further describes the method of reference for discussing the building technologies.

Chapter 3 titled 'Background' sets the context of selected regions through demographic profile, climatic conditions and traditional building practices. The demographic data for urban development patterns, in the selected states will help to understand the scale and patterns of development, which shall act as indicators to estimate potential for adoption of appropriate building technologies and its associated challenges. Understanding the climatic conditions will help in enlisting the required thermal properties of the building envelope to attain thermal comfort, by choosing the material palette of the buildings appropriately, thereby reducing the heating / cooling load on active systems effectively.

Chapter 4 covers the current state of green building technology in the regions of Punjab, Haryana, Chandigarh, Delhi and NCR. For each state, a city was chosen and visited by our team. The objective was to understand the scaling of mass housing projects currently springing up in and around these cities. The observations were accordingly recorded.

Upon surveying of the current housing projects in the regions, we came across two projects in the region which we were undertaken as case studies. These demonstrated the effective use of green building technologies in the context of mass housing in the region. These have been documented with annotated drawings and analyzed further in Chapter 5. The salient features, learnings and relevance have been summarized at the end.

Chapter 6 attempts to scrutinize various facets of 'green' and dwells further on discussion, which has been initiated in the third sub-section of Introduction chapter. Green technology in the context of this compendium will refer to application of any material, product or system which causes minimum negative impact on the environment. The intended meaning of green is a function of four parameters namely energy, impact on natural systems, resource availability and disposability. The parameters are put together comprehensively to deduce an overall 'net green score'. This is represented in a simple graphical manner. The graphical tabulation proposed here can be adopted for any climatic region.

This compendium's survey is limited to the four states of composite climate zone namely Punjab, Haryana, Delhi, NCR and Chandigarh. The scope of projects being identified and discussed is restricted to housing only.

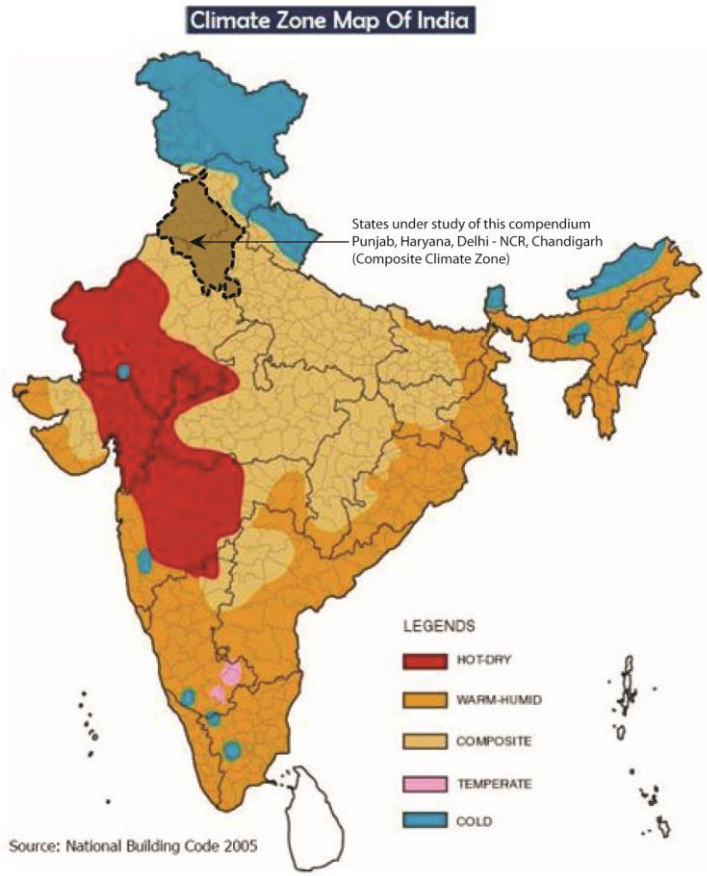


Figure 1 Highlighted composite climate zone of India (National Building Code 2005)

The classification methodology and assessment technique of the 'green' has been derived from the main aspects of environmental sustainability which are discussed and explained in this chapter. A simple graphic method to assess the environmental impact or greenness of a material. Component or integrated structural system has been devised. . This serves as a **guide or reference** for selection of 'green, materials and technologies. It aims to bring a clearer understanding about 'green technologies' especially for non-technical users, enhance their knowledge base and provide leads for further research and development in this field.

Chapter 7 presents 'fact sheets' on some building materials, components and integrated structural systems. The first part of the chapter focusses the technologies which are presently found in region. Each fact sheet is further divided into general, technical and green information on each building technology. The second part of the chapter presents fact sheets for the technologies which are not found in the region but are appropriate for the region.

Chapter 8 entails conclusions and recommendations for low carbon, energy conserving ways of addressing the issue of sustainable mass housing in this region.

This is followed by bibliography and Annexures. These include lists of building product manufacturers, proprietors and practitioners who are associated with green construction methodologies in field of housing. It also identifies proprietors and specialized manufacturers of production machinery for green building materials.

2.3 Method of reference for discussing technologies

As this compendium is directed towards 'Green technologies', particularly for the housing and residential sector, it is therefore important to understand these two terms in context of this compendium.

'Technology' may be defined simply as "the application of scientific knowledge for practical purposes". For the purpose of this compendium, 'green technology' refers to use of any building materials, components or integrated structural system that is resource efficient and causes less harm to the environment as compared to its commonly used counterparts.

A building can be categorized as green on the basis of choice of material, selection of building component and selection of structural system. This is to say that a building can be green by virtue of materials and their green properties- for example by using fly ash to substitute Portland cement, or it can be green due to choice of components like a wall construction using adequate infill insulation so as to optimize on cooling or heating loads of building, thereby saving operational energy costs. Or it can be green because of its structural system design - for example a load bearing construction with brick infill slab system (up to 4 storey construction) will be a greener as compared to a RCC framed structure because the former saves on reinforcement steel and cement, which are particularly high embodied energy materials.

In preparing this compendium the list of building technologies is organized under the categories of a) Materials b) Components and c) Integrated Structural Systems

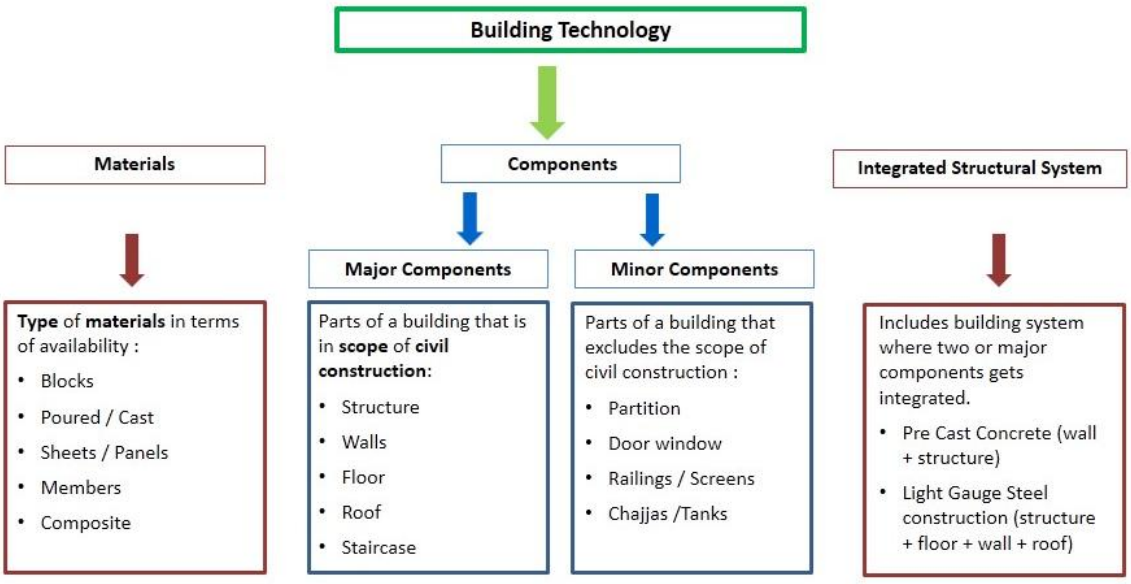


Figure 2 Organization within building technology (Lall 2016)

Materials have been classified in the form of their availability i.e. whether they are available in form of **blocks** like red clay bricks, fly ash bricks, AAC blocks or **poured in place** like concrete and Ferrocement or are available in form of **sheets or panels or tiles** like various forms of insulation boards and cladding materials or available in form of **members** like timber and mild steel sections. **Composite materials** are those which utilize two or more different kinds of materials like thermo insulated blocks use concrete as outer covering which is poured and it has infill of EPS (Expanded Polystyrene) which is available in form of boards.

Components have been classified into major and minor components. Major components are those which come under the scope of civil construction and concerns with either structure, or walling materials or staircases etc. This category forms the major mass of building construction. The minor components are either the ones which falls in the scope of civil construction but are used in very small quantity as compared to the major components like chajjas, water tanks, railings or the building components which are to do with carpentry, metalwork like windows, shutters, screens, shading devices or miscellaneous items.

Integrated structural system are those which simultaneously provides for structure in combination with one or more of the major components. Structure, staircase and walling is one of the most common combination of integrated structural systems. Other combination includes the possibility of structure with roofing and flooring. Construction systems using composite shuttering materials (made up of either Aluminium or plastics) cast structure and walls together.

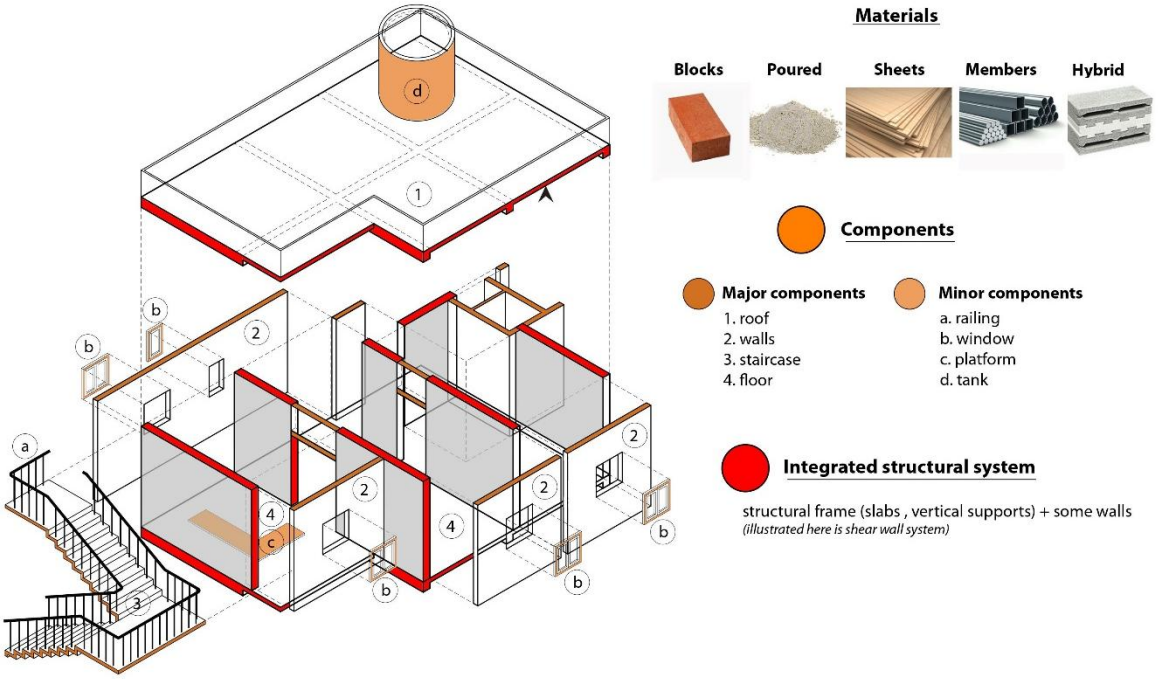


Figure 3 Illustration explaining the organization within building technology (Lall 2016)

Through the next chapters, where we discuss building technologies and present its fact sheets, we shall refer back to this hierarchical nomenclature for technology classification.

3 Background

3.1 Demographic and Urban Development scenario

According to census 2011 the urban population of India has risen from 27.7% in 2001 to 31.1% in 2011, around 2,774 towns have been added and growth rate of urban population in most of the towns with population of 1lakh plus have shown a decline. The percentage rise in urban population which is more than the rise in rural population is attributed majorly to the rural-urban migration and increase of 'census towns'. The census statistic and their reasoning is an indication that thrust of development will now be seen in the new big cities and existing smaller cities. These cities (new and existing small ones) provides us with the opportunity to implement green technologies for its housing needs along with the opportunities that is provided by current housing shortages in existing cities.

In the regions selected for this compendium, McKinsey's (Mckinsey&Company 2010) report has predicted that Punjab and Haryana will be in the top 6 urbanized states with urban population reaching up to the 50% mark (refer figure 5) while the capital cities of Delhi and Chandigarh will have urban population almost tending towards hundred percent.

The trend described above is evident in the selected state of Punjab, where the regions around Chandigarh have shown the highest growth rate in 2011 census. The newly created district of Sahibzada Ajit Singh Nagar (55.17%) emerges as the second most urbanized district in Punjab and urban centers have increased to 217 from 157. The Urban Growth rate (25.72%) is reported to be more than 3 times rural growth rate (7.52%) (Sharma, Sandhu and Teotia 2012)

In the state of Haryana, the cities forming part of national capital region has already witnessed an exponential growth in terms of urbanization and new housing construction. Faridabad and Gurgaon have already crossed the 50% urbanization mark with construction activities filling up the horizon.

	Delhi-NCR	Haryana	Punjab	Chandigarh
Area (Sq. km)	1483.00	44,212	50,362	114
Population 2011	1,67,53,235	2,53,53081	2,77,04,236	10,54,686
Population growth (%)	47.0	28.4	20.1	40.3
Urbanization % (2011)	97.50	34.79	37.49	97.25

Table 1 Population pattern of selected regions for the compendium

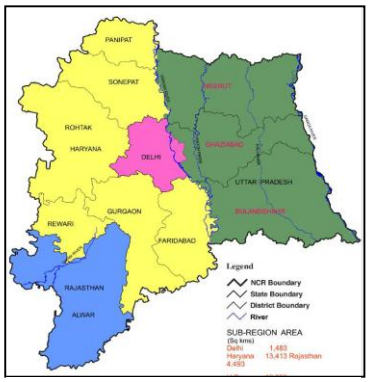


Figure 4 Delhi and NCR

Figure 6 Punjab and its districts

Figure 5 Haryana and its districts

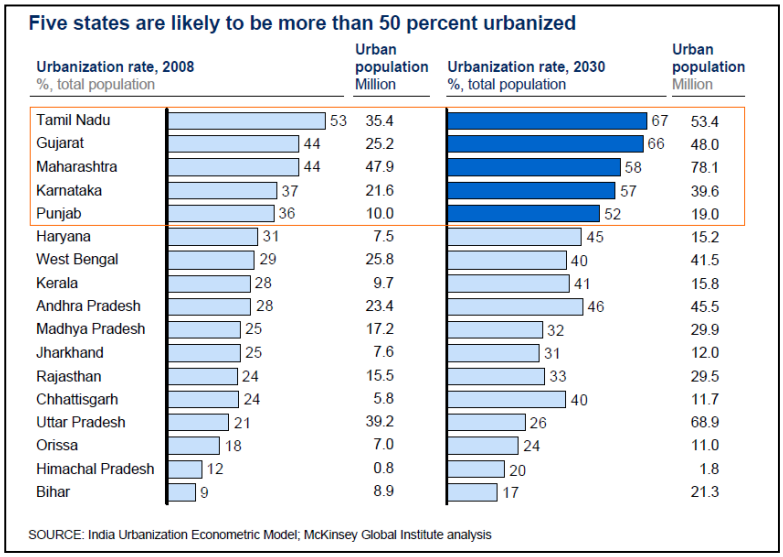


Table 2 Predicted Urbanization for Indian states
(Mckinsey&Company 2010)

The compendium covers regions of capital city Delhi, Chandigarh and states of Punjab and Haryana in Northern Plain. The 'National capital region' (NCR) for Delhi and surroundings areas like Mohali, Panchkula, Greater Mohali around Chandigarh have been covered with their capital cities. In Punjab, the most populous city of Ludhiana has been looked at along with the regions around Chandigarh, while in Haryana, Panipat has been looked at besides the cities that are already included in NCR.

The capital city of Delhi is one of the most populous city as well one of the fastest growing ones. The regions around Delhi have also grown exponentially due to their proximity to the capital city. The population statistics project in-migration as one of the major reasons for population growth in the capital and it is projected to grow further and further, which in turn will further increase the housing demand in the NCR. Thus Delhi was selected. The states of Haryana and Punjab share climatic similarities with the capital city and a geographic proximity as well, thereby bringing into selection Haryana and Punjab.

Similar to the regions around Delhi, the regions around Chandigarh have also witnessed a fast pace of population growth as compared to other cities of Punjab. The regions of Greater Mohali/New Chandigarh are undergoing new development activity. The regions of Zirakhpur etc. tops the list in terms of growth rate.

According to census 2011 the city of Ludhiana is the most populous and urbanized city in Punjab, and is in the need of housing redevelopment due to growing slum conditions in the old city precincts. Ludhiana is not only the most populous city, but also the most urbanized as well.

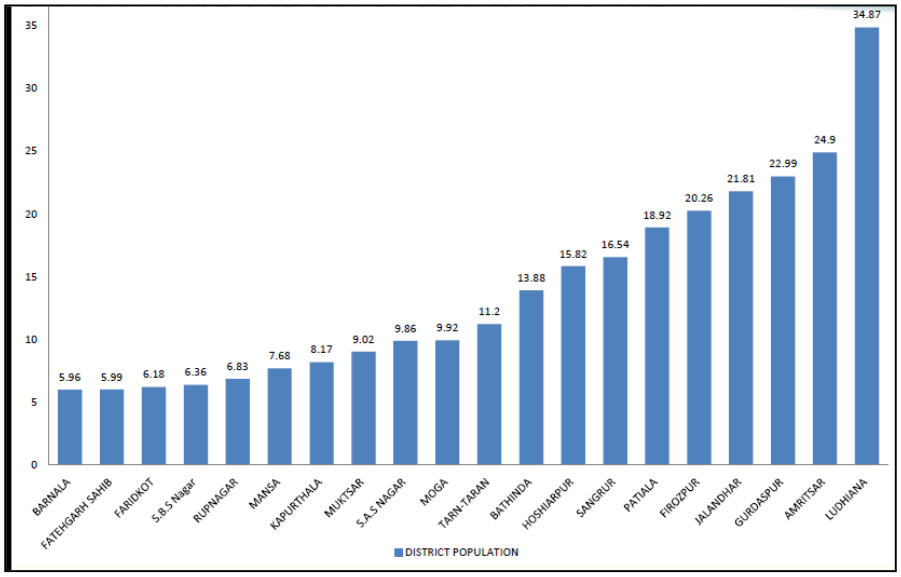


Table 3 District wise Urban Population (2011) –Punjab
(SECTORAL DISCUSSIONS ON HOUSING & URBAN POVERTY ALLEVIATION n.d.)

In Haryana, the most populous and fast growing cities like Gurgaon, Faridabad are covered under 'NCR', leading us to Panipat, which is a growing industrial town with upcoming new industries and housing projects along the Punjab Delhi corridor.

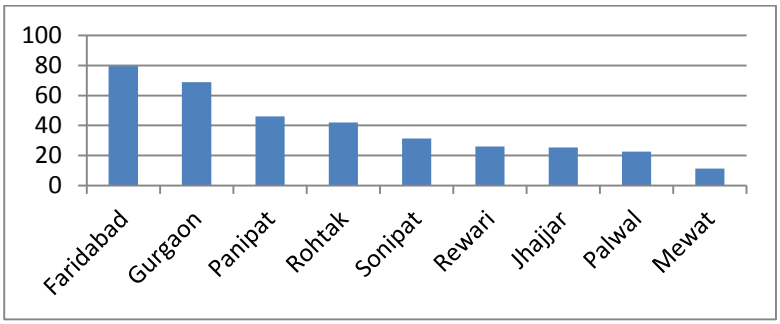


Table 4 Urban Population in Districts of Haryana for 2011
(Primary Source: - Census of India 1991, 2001 & 2011)

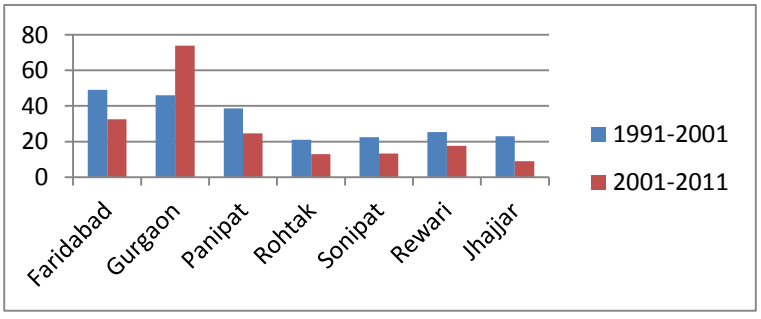


Table 5 Population Growth Rate for Districts of Haryana
(Census of India 1991,2001,2011 n.d.)

3.2 Climatic and geographical parameters

Traditionally climatic conditions have been one of the major determinants of the way we build. The selected regions for the compendium fall under the 'composite' climate zone. The zone covers substantial part of Indo-Gangetic plane which also falls under seismic zone IV.

A status is assigned to any climatic zones only when the defined climatic conditions prevail there for more than six months. In cases where none of the defined categories can be identified for six months or longer, the climatic zone is called composite. The composite zone covers the central part of India.

It is characterized by a very hot and dry summer, followed by a humid season of monsoon rains. With the departure of the monsoon it gradually becomes comfortable in autumn, followed by a short winter. This winter is generally accompanied with cloudy and wet as well as sunny periods. Before the summer returns there is a comfortable but short spring season. (CLEAR Low energy architecture n.d.)

The intensity of solar radiation is very high in summer with diffused radiation. In monsoons, the intensity is low with predominantly diffused radiation. The maximum daytime temperature in summers is in the range of 32 – 43°C, and night time values are from 27 to 32°C. In winters, the values are between 10 to 25°C during the day and 4 to 10°C at night. This region receives strong winds during monsoons from the south-east and dry cold winds from the north-east. In summer, the winds are hot and dusty.

Generally, composite regions experience higher humidity levels during monsoons than hot and dry zones. The relative humidity is about 20 – 25 % in dry periods and 55 – 95 % in wet periods. The presence of high humidity during monsoon months is one of the reasons why cities like New Delhi, Chandigarh, Ambala and Ludhiana are grouped under the composite and not hot and dry climate. Otherwise most of their characteristics are similar to hot and dry climate except that maximizing cross ventilation is desirable in the monsoon period. (Ministry of New and Renewable Energy n.d.)

Based on the climatic conditions, the physical manifestation of built environment is enlisted below. These objectives can act as a guide towards selection of materials and creating building assemblies which aid thermal comfort with minimal external heating or cooling loads. Energy efficiency is one of tenets of green building.

5)Composite Region

OBJECTIVES	PHYSICAL MANIFESTATION
1)Resist heat gain in summer and Resist heat loss in winter	
• Decrease exposed surface area	Orientation and shape of building. Use of trees as wind barriers
• Increase thermal resistance	Roof insulation and wall insulation
• Increase thermal capacity (Time lag)	Thicker walls
• Increase buffer spaces	Air locks/ Balconies
• Decrease air exchange rate	Weather stripping
• Increase shading	Walls, glass surfaces protected by overhangs, fins and trees
• Increase surface reflectivity	Pale colour, glazed china mosaic tiles, etc.
2)Promote heat loss in summer/ monsoon	
• Ventilation of appliances	Provide exhausts
• Increase air exchange rate (Ventilation)	Courtyards/ wind towers/ arrangement of openings
• Increase humidity levels in dry summer	Trees and water ponds for evaporative cooling
• Decrease humidity in monsoon	Dehumidifiers/ desiccant cooling

Figure 7 Physical manifestation of build environment in Composite Climate

Since this compendium is developed with the objective of serving as a reference to those who want to build energy efficient buildings, it might be useful to have a look at 'Design guidelines for energy-efficient multi-storey residential buildings' developed under the Indo-Swiss Building Energy Efficiency Project (BEEP). The guidelines provide comprehensive information on how to design energy-efficient multi-storey residential buildings in the composite and hot and dry climate. The recommendations are

developed based on the climatic conditions of the regions and by modeling different design scenarios for energy efficiency. Thus it is a good guide on how one can build green by design. It serves decision providing indicators to choose appropriate materials and technology.

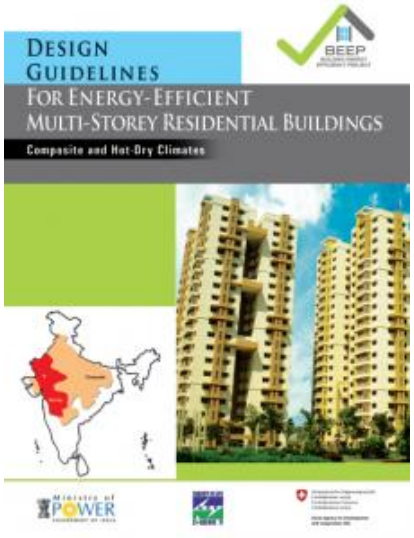


Figure 8 Design Guidelines for energy efficient buildings publication by BEEP

The guidelines can be accessed at http://www.beepindia.org/resource/Residential-Guidelines

3.3 Conventional construction practices

Ever since the advent of reinforced concrete, the default convention of structural system for constructing residential buildings in Haryana and Punjab has become reliant on reinforced cement concrete. For buildings up to three storeys high, the general practice is to use load bearing burnt brick walls for vertical support members and RCC slabs and beams for horizontal members. For taller buildings RCC frame with burnt brick infill is being used. Brick being plentiful and of good quality, it continues to be the economical option. In projects undertaken by government or the ones requiring mandatory Environmental Clearance, burnt brick is being substituted with fly-ash blocks.

Figure 10 Load bearing brick work construction with RCC slab

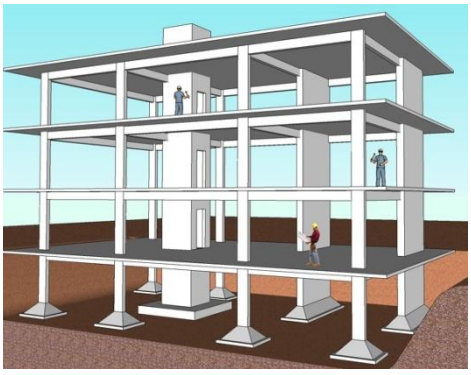


Figure 9 RCC framed construction

For multi-storey projects in the NCR and some projects in the Chandigarh region, there has been a shift from burnt brick to AAC blocks for infill and partition walls. Use of fly-ash blocks is also on the rise. A concern for reducing the consumption of reinforcing steel in RCC construction as a cost-saving measure has led to the use of AAC blocks which reduces the structural loads. In middle income housing, where the use of room air conditioners to meet higher thermal comfort need is increasing rapidly, AAC blocks

in external walls also help in reducing cooling loads. These trends indicate a shift toward green technologies in the high rise residential buildings, prompted by economic advantage combined with the need to meet the prescriptions for Environmental Clearance.

The current trend in the use of floor finishes, doors and windows, especially in residential developments for the middle and upper income groups, are moving away from 'green' paradigm. Natural materials such as stone and timber are being replaced by highly processed and non-bio-degradable materials such as aluminum, UPVC and Vitrified ceramics.

4 Current state of green technology in selected regions

4.1 Chandigarh and its surroundings

A brief review of the housing construction in and around Chandigarh, Panchkula and Mohali leads to the fact that use of green materials/ technologies in mass housing sector is not very evident. Some private housing projects are using AAC blocks. Below is a range of affordable Housing Projects from the tri-city area. This is not an exhaustive list, but captures the latest projects -

Chandigarh Housing Board (CHB) -

Completed projects since the inception of CHB -

Site & Services, EWS & LIG 44065 Units, MIG 10835 Units and HIG 5597 Units giving **Total 60497 Units**

Ongoing Projects-

- Housing for Rehabilitation of slum families living in 18 colonies in the city.
- Construction of 2108 Flats in Sector-63, Chandigarh-
- Construction of 160 Cat-II Flats in Sector-51 A, Chandigarh

Forthcoming Projects-

- Housing Scheme for Sector-53, 54
- 128 Cat-II Flats in Sector 51
- Other General Housing Schemes
- 464 Flats of various categories at Maloya-II
- 1400 Flats of various categories at Dhanas
- 600 EWS Flats in Sector-26 (East)
- ***Construction of Block 'B' in CHB Office Complex, Sector-9, Chandigarh as Intelligent & Green Building***

Materials/ Technologies being used by CHB

- In all projects from EWS to HIG, basic construction is being undertaken in bricks with RCC structure. Fly ash, blocks and other green technologies/materials are not being used.
- In EWS, angle iron frames and shutters are being used, in HIG -MS pressed steel frames.

•In all projects, Coba brick bat work is being done on roof terraces for thermal insulation.

GMADA (Greater Mohali Area Development Authority) -

Ongoing Projects-

Each of these projects includes area for EWS. The list does not indicate the use of green materials.

•IT city/ Knowledge Park , Mohali

•Larsen & Toubro

•Eco City, New Chandigarh , Mullanpur

•Aerocity, Mohali

•M/S Simplex infrastructure-

•Purab Premium Apartments , Mohali

PUDA (Punjab Urban Planning & Development Authority) -

Each of these projects includes area for EWS. The list does not indicate the use of green materials.

•Wave Estate

•Pearl City

•Golf Links – I

•Golf Links II

•EMAAR MGF Integrated Township – Sector 98, 109 , 110 , Mohali

•Preet City – Sector 86 , Mohali

•Unitech Ltd – Sector 97 , 106 , 107 , Mohali

•Taneja Developers – Sector 110, 111 , Mohali

•PUMA Realtors Integrated Township – Sector 86, 97 , 98 ,99 , 105, 106 , Mohali

HUDA (Haryana Urban Development Authority) -

•Shree Vardhman Green Space – By Shree Vardhman Group under HUDA's 1st Affordable housing scheme in Panchkula.

Housing projects claiming to be green -

•Maya garden avenue, Zirakpur – Claims to be the first green housing in the tri-city area

Materials/ technologies -

•UPVC / hardwood / CFFS PVC - Windows

•Rain water harvesting

•Solar Photovoltaic Panels for electricity

•Recycling water

Other Buildings using green technology -

1. Chandigarh Airport International Terminal – Mohali

The terminal has been built by L&T

Technologies used-

- Fly ash bricks
- Cavity wall construction technique
- Double insulated roofing
- Energy efficient chillers
- Sensor -based plumbing system
- Sewage treatment plant of 600 KLD, which is based on environment-friendly extended aeration technology
- Water treatment plant
- Rain water harvesting
- Re-use of treated water for flushing and gardening.

2. Paryavaran Bhavan – Sector 19 D, Chandigarh -

Materials / Technologies-

- Earth air tunnel forced ventilation system for the lower two floors
- Evaporative cooling for the top three floors
- Terrace has reflective white tiles to reflect back heat
- Water harvesting system
- Green paver blocks in parking area

The two claimed 'green' buildings although do not fall under the residential category, have been scrutinized to understand the current state of affairs in green technologies. It brings out the fact that green technology is limited to the use of few established green building products like fly ash, porous pavers, reflective roofing combined with passive design techniques of insulation, thermal gap, earth air ventilation and cooling combined with 'green' means of water management. It is worth noting that products that have more visible marketing or are backed by government policies (like fly as bricks) are more evidently seen in practice than other products. Similar is the case with services, the more widespread use is seen in water management, for example rain water harvesting has caught the fancy and more visible in projects. Similarly, waste water treatment systems ate more common.

4.2 Ludhiana

Ludhiana is the second most populous city in Punjab after Chandigarh. It also has the highest population growth rate among cities in Punjab. It has been a centre for industry and trade. Housing demand is being met largely by informal construction for the lower income groups and construction of homes on plotted developments for the upper income groups. In the recent past some projects for LIG and MIG have been undertaken by the Housing Board. Presently there is no construction of housing undertaken by the government. Private developers have been building for upper middle income and high income groups, though this is also at a standstill currently due to weak demand.

Our survey team visited Ludhiana. Different stakeholders in the local construction practices were met. Mr. Arjun Khanna a practicing Architect; Mr. S.K Sharma, a contractor; Mr. Sood, brick and clay products manufacturer M/s Khalsa traders, a prominent building materials trader, were contacted. The team also visited five group housing projects that represent the history of group housing along with public and private housing providers.

	Structure	**Sub Components**	**Finishes**	
EWS	Load bearing brickwork	steel grills, brick jalis	exposed brick, IPS floor, whitewash	
LIG/MIG	RCC with brick infill	steel grilles, timber doors/windows	terrazzo, plaster and paint	
HIG	RCC with brick infill	PVC / aluminium single glazed windows, timber doors	Vitrified tile, plaster, Birla putty, plastic emulsion paint, “spectrum” paint.	

Table 6Current construction practices in Ludhiana

Figure 12 EWS/LIG units in Dhubri

Figure 11 Glade height housing society

Figure 13 Housing board EWS houses

Figure 14 High rise housing by Omaxe builders

The construction practices till now are traditional – load bearing brick work with RCC floor slabs for buildings up to three storey and RCC frame with brick in-fill for taller buildings. It appears that a considerable potential for reducing environmental impact of construction lies in the design of structural systems to economize on the consumption of reinforcing steel per unit area of built floor area. Brick continues to be the preferred construction material for walling. It is plentiful and economical. Fly ash blocks are available and AAC blocks can be supplied on order and they are beginning to compete against clay bricks. Some of the traditional brick manufacturers are now planning to modernize brick manufacturing to improve efficiencies of production and fuel consumption, as the raw material for clay products is plentiful and of good quality in this region. An appropriate strategy for greening the local brick industry would be to introduce hollow clay block products as a substitute for the present standard brick. This would optimize the material and energy efficiency for clay based products.

Figure 15 Ireo waterfront development

Figure 16 EWS Housing by ASCC for PHDB

Figure 17 Low rise development by Omaxe builders

In the choice of materials for building sub-components and finishes the trend for upper middle and high income housing is toward higher embodied energy materials – aluminum, stainless steel, glass, plastics etc.

As large projects (built area greater than 20,000 sqm) are statutorily required to be cleared under the Environmental impact assessment regime of the Central Government, they incorporate environmental protection and conservation measures at the campus level. The Ireo Lakeview project was a good demonstration of integrating environmental measures with landscape design and the township layout.

4.3 Panipat, Karnal, Sonipat

Cities of Panipat and Karnal in the state of Haryana, are neither most populated nor the fastest growing regions, yet they have been reviewed for green construction practices in residential sector as they are the representatives of cities where growth is yet to pick up pace like Gurgaon or Noida. These are also the cities where planning for anticipated development is still possible. Such cities provide us with the opportunity to converge sustainable building practices at city level and can also act as testing grounds for emerging technologies to attain better quality of urban living.

Panipat is one of the cities with One Lakh plus population in Haryana and is host to a textile and weaving industry of the country. In addition, Panipat city is the biggest centre of "Shoddy Yarn" in the world. The Samalkha subdivision of this district is famous for Foundry of Agriculture instruments. The city is home for heavy industry, with a refinery of the Indian Oil Corporation, a Thermal Power station (plant)

Corporation (H.P.G.C.L) and a plant of National Fertilizers Limited. The industrial base makes it more vulnerable to pollution impacts and thus needs construction practice to be devoid of on-site pollution.

Housing pattern in the city predominantly comprises of single family dwelling units in a low rise low density composition, with certain areas experiencing high density. The floor heights are mostly restricted to G+3 following conventional system of construction using load bearing brick masonry and RCC slab.

	Structure	**Sub Components**	**Finishes**
EWS	Load bearing brickwork	steel grills, brick jalis	exposed brick, IPS floor, whitewash
LIG/MIG	RCC with brick/AAC/fly ash infill	steel grilles, timber doors/windows, UPVC door, windows	terrazzo, plaster and paint
HIG	RCC with brick/AAC/fly ash infill	PVC / aluminum single glazed windows, timber doors	Vitrified tile, plaster, Birla putty, plastic emulsion paint, “spectrum” paint.

Table 7 Typical material finishes in house types by economic division.

Upcoming housing projects in form of townships ‘in and around’ the city are on the patterns of high rise high density structures, mostly built on framed RCC construction with fly ash /brick /AAC blocks as infill. The pattern is similar to the architectural practices in Delhi and NCR. The individual residences are being constructed in conventional system of load bearing masonry and RCC slab or at times with RCC framed structure.

The regions of Sonipat adjoining borders of Delhi are being developed as North Delhi Extension and a number of housing townships are under construction at the moment. Jindal Global City, Express City, Ansals, TDI, etc. to name a few, all have established their ground. The construction system for all is similar with RCC frame and AAC/flyash/concrete/bricks as infill.

A few upcoming projects are cited below and typical example of material selection in these project is also listed in table 3.

4.3.1 Upcoming Housing Projects

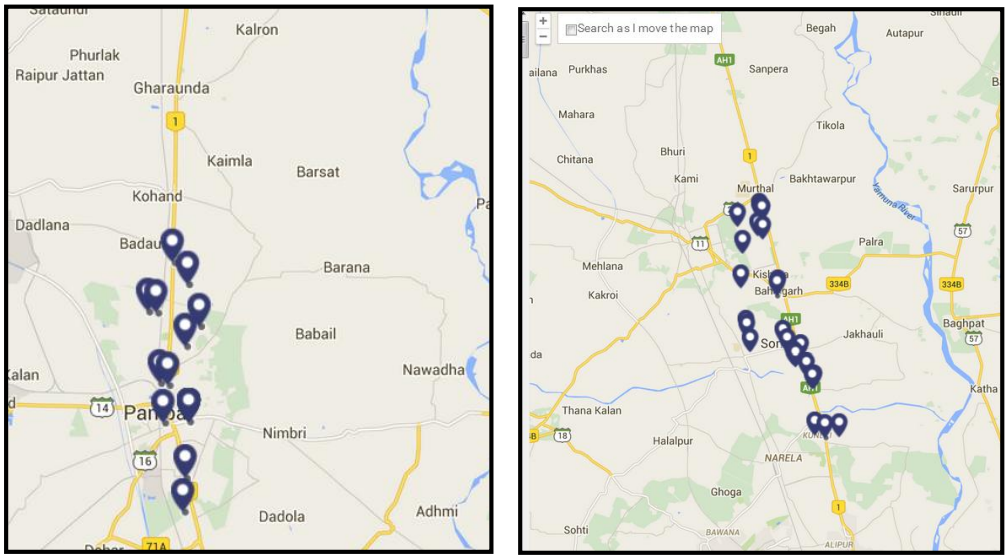


Figure 18 Map showing upcoming housing projects in Panipat and Sonipat
(www.commonfloor.com n.d.)

Some of the upcoming high rise housing projects in Sonipat and Panipat are listed below.
Jindal Global City, Sonipat
Indiabulls Sonepat Township, Sonipat
Ambience City, Sonipat
TDI Kingsbury, Sonipat
TDI Tuscan City, Kundli
Tulip Grand Phase I
Ansal Sunshine County, Sonipat
Splendor Grande, Panipat
Eldeco Estate One, Panipat
Eldeco Savoy, Panipat

TDI Kingsbury Prime

Area	Wall	Floors	Celling	Doors	Windows Glazing
Living room/ dining/ Family room	pop punning with acrylic emulsion paint	vitrified	false ceiling with acrylic emulsion paint & ceiling lights	Internal door- flush door shutters. External door - UPVC/ powder coated aluminum door shutters	UPVC powder coated aluminum window frames and shutters

Table 8 Typical finishes for new high rise housing projects

The construction technology and material finishes in all the upcoming housing projects are more or less similar in nature, throughout the region. Incorporation of sustainable practices is limited to use of fly ash, AAC, etc. at building level and rainwater harvesting and soft paved areas at site planning level. The similarity of building materials, construction technology and imagery is seen throughout Haryana Punjab and Delhi NCR.

Figure 19 Eldeco County, Sonipat

Figure 20 Eldeco Villas, Sonipat

Figure 21 Ansal Sunshine County Sonipat

Figure 22 TDI Kinsbury Prime, Sonipat

Figure 23 TDI City My Floor 2, Sonipat

Figure 24 Splendor Grande, Panipat

Figure 25 Eldeco Estate One, Panipat

One of the emerging technology that was spotted in the region of Sonipat was that of pre-fabricated concrete panels for building components and EPS (Extruded Polystyrene) panels. Jindal group has established manufacturing unit for pre-fabricated concrete panels in Sonipat and are experimenting with other technologies such as EPS panels, Light Gauge structure, speed floor, fly ash aggregate etc.

The prefabricated components have been used for construction of hostel blocks in O.P. Jindal University. The door windows are taken over by UPVC and the rest is all in conventional materials.
The pre-fabricated panel manufacturing plant set up in approximately 9000 Sq. m. space, with imported machinery from Finnish firm Elematic; has production facility for column, wall, Beam, slab and Staircase. The building construction with these panels involves assembly of all components at site and afterwards, a layer of reinforcement with concreting is done on the slabs at site. The electrical conduits and switch boxes are casted in the pre-cast panels itself and plumbing lines are installed on site with core-cutting technology.

- The major advantage of the system is that it saves time. The machinery is capable of producing material for 1 floor in 6 weeks or approximately 3000 Sq. ft. of slab/wall panels in a day. The other claimed advantage is that the technology reduces dust and pollution associated with casting and water requirement associated with curing to certain extent.

- On the other hand the disadvantage is in the comparatively higher cost than the conventional construction system which can be countered with the time saving capabilities.
- The technology demands high accuracy in casting as well as assembly, failure of which leaves gaps in the joinery which needs to be filled/ rectified at time of construction.
- Besides precision in the panels, heavy machinery and skilled labour is also required to attain desired finish.
- Though the slab panels are pre-cast, still one layer of RCC needs to be done in-situ for the desired strength.

Pre-fabricated concrete panel construction is one of the emerging technologies applicable for residential typologies, it reduces construction time and manpower requirements and its management on site; but based on our understanding that concrete and steel both are high embodied energy material that are not biodegradable (could be reusable/recyclable) the technology does not score enough on the green parameters to be classified as 'green technology'. It definitely gives a way for future development of pre-cast components made from sustainable material such as Fly-ash etc.

Figure 26 Pre-cast panel manufacturing unit
(Jindal Power and steel)

Figure 27 Pre-cast panel construction in O.P Jindal University, Sonipat

Figure 28 Pre cast panels for Walls, staircase, columns.
(www.alibaba.com n.d.)

Figure 29 Concrete pouring in pre-cast mould for wall panels

Karnal district is located further north of Panipat. It is even smaller than Panipat in terms of new housing construction. The region has pre-dominantly individual dwelling units, two to three storeys, built in conventional load bearing RCC slab construction. The interesting find in the region is a house with all modern day amenities built in mud and wood construction technology. The house is owned and built by an architect (Savneet Kaur) who is practicing in the region. It is a demonstration project for the technology. The architect claims to have monitored *28* degree Centigrade ambient inside temperature in the month of June when the outside temperature was 40 degrees. Materials used in the house are mentioned below.

- The foundation up to plinth level - Burnt brick. Two steel bars 8mm were used in the plinth beam and junctions to ensure seismic resistance. Burnt brick plinth prevents the harmful effect of ground moisture on adobe.

Service areas - Burnt bricks (to ensure better plumbing).The structural strength of mud bricks and burnt bricks is carefully utilized

- Lintel - Reinforced concrete bands to ensure seismic- resistant safety.
- Flat Slab- Terracotta filler slab in main areas (provides better insulation)

Sarkanda grass (Saccharumbengalense) an insect resistant & fire resistant weed was used in the roof as insulating material.

- Mezzanine flooring: Sal rafters, recycled and bought from old demolished homes
- Sloping roof- bamboo rafters and thatch
- All the furniture, fitting, accessories- crafted from naturally felled trees on the site.
- Plaster - straw, mud, cow dung, rice husk and adhesive

The thick walls of mud bricks with mud plaster provides thermal barrier from the heat outside and during winters certain amount of heating might be required, for which a fireplace is designed inside the house. The openings are oriented for providing cross ventilation which will aid during the humid season. Provision for evaporative/desert cooler is also made in the centre of the house. The technology is very apt for hot humid conditions and the architect claims it to be cost effective as well. The limitation of the technology in terms of longer spans and heights restricts its use to individual plotted houses on the likes of a farm house etc. The thick walls are also less preferred against conventional walls as they take up more space.

The technology is neither new nor replicable at the scale of high rise group housing schemes, yet it can be seen as a revival of old techniques to achieve thermal comfort at a comparative low cost and with the modern day amenities which can be explored further for application in individual low cost houses. More research into traditional materials and their possible use in modern construction should be initiated. The demonstration/prototype house displays use of agricultural waste into construction, which can be taken up further for development at large scale.

Besides selection of material, spaces have been oriented according to solar movement and heat gain aspect. The Bedroom is partly sunk in the ground to gain cool of the earth around and has cantilevered balconies acting as shade for the windows since it faces south. West is blocked by toilet and store. The kitchen in the south east enjoys ample daylight and sunlight for the garden while the living space enjoys the north light.

Figure 30 Mud Technology House (Karnal) - Views from North East and South West
(Savneet Kaur 2015)

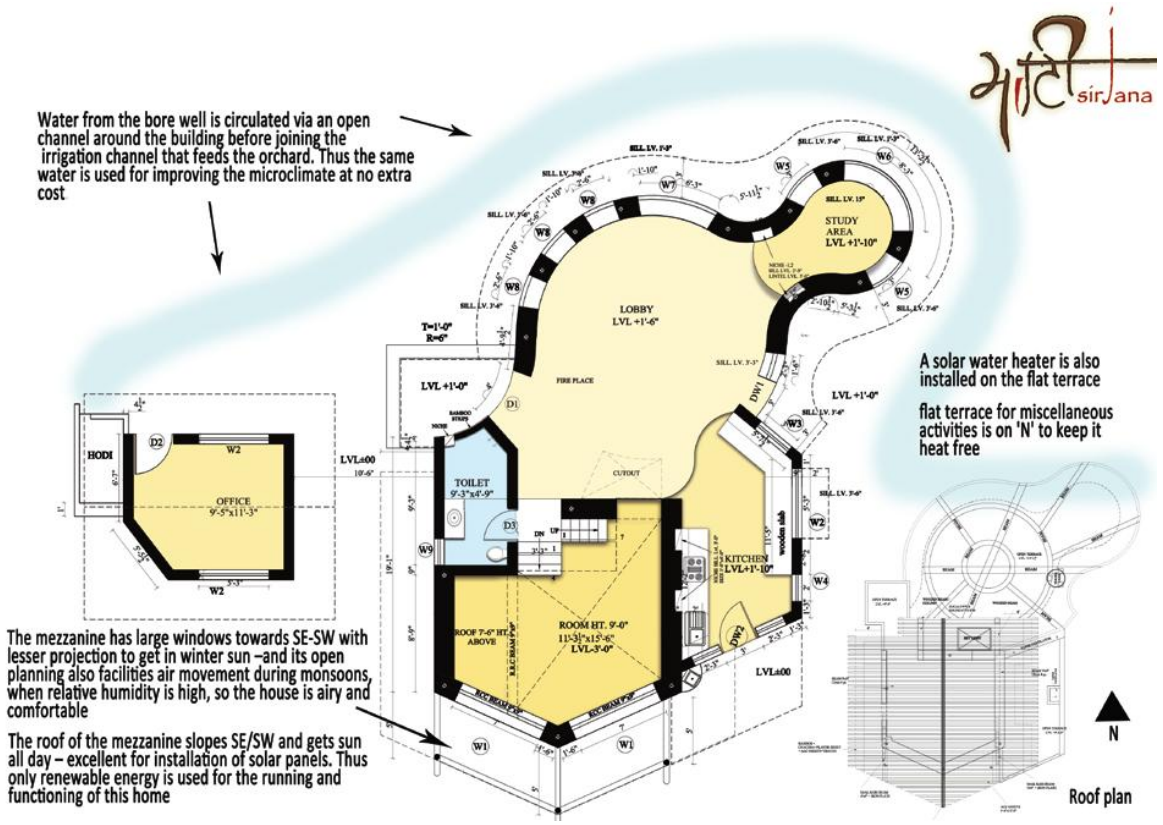


Figure 31 Mud Technology House, (Karnal) - Plan
(Savneet Kaur 2015)

Figure 32 Wooden Staircase

Figure 33 Intermediate floor

Figure 34 Living space with terracotta filler slab

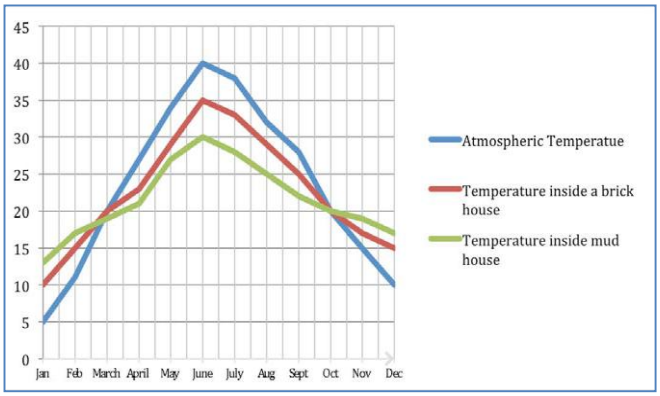


Figure 35 Comparative Temperature chart (Savneet Kaur 2015)

4.4 Noida and Greater Noida

NOIDA (New Okhla Industrial Development Authority) was constituted under the UP Industrial Area Development Act, 1976. It is part of the NCR (national Capital Region) boundary and is well connected to the capital city through road and metro connectivity.

Spread over an area of 20,316 hectares, it is one of the largest planned industrial townships in Asia. According to an article in Economic Times; the new master plan envisions the construction of 2.5 lakh new houses along the expressway and adjacent to Noida Extension in the next three years. Out of this, approximately one lakh houses are being constructed along the expressway under group housing projects. The remaining 1.5 lakh housing units have been proposed adjacent to Noida Extension and in few selected sectors. The densities range from 500 persons per hectare to 1650 persons per hectare, indicating high density high rise development.

The above mentioned figures gives us a picture of massive scale of construction activity in the region, which was further verified by our visit to the Greater NOIDA region. The site visit comprised visiting on-site marketing offices of real estate developers like SAM India, Exotica, Saya Homes, Vaibhav Heritage Heights and manufacturing unit of Supertech's pre-cast concrete products. All throughout the main approach of Greater NOIDA West, one could see construction right and left with heavy movement of truck loaded with construction material. The environmental risks are directly proportional to the amount of construction activity and one could breathe the dust all along.

The dwelling units under construction were from all income and size categories, majority of the chunk is under affordable category. Almost all the mass housing projects were following the conventional RCC framed structure with block work infill as their construction system. AAC blocks, cement blocks, flyash bricks and burnt clay bricks were being used for wall construction. AAC blocks, cement blocks and flyash bricks were mostly used for external walls and to some extend for internal walls, the red bricks were preferred in walls of toilets and kitchens for the ease of chase cutting for services. The building components of door-windows were following the latest market trend of UPVC in most cases while wooden and aluminium frames were also used to some extent in few projects. Flooring materials were conventional tiles and stones. Fly-ash bricks and AAC blocks seemed to be the materials relevant for our study, the ones that fit into the criteria of green materials for mass housing.

At mass housing level, the concept of sustainability is currently limited to site level features like providing green spaces, water/waste recycling, rain water harvesting. It seems that the concept has yet not reached in at the level of material or construction technology.

In Noida not only is the amount of construction massive but also the scale of each housing project is huge; ranging anywhere from hundred to hundred thousand dwelling units. Speed of construction time thus becomes a critical/vital consideration in selection of materials and construction techniques. Big real estate players like Amarpali, Supertech, Jindal have thus started moving towards a speedier way of construction through means of pre-cast concrete components for buildings.

We visited Supertech's pre-cast manufacturing unit called 'Supercast' in Greater Noida West. The unit set up in approximately 7-9 Acres of land is capable of producing 5 million Sq. ft. of pre-cast elements (http://supercast.in/manufacturing-unit.html). The unit manufactures pre cast elements namely -hollow core slab panels, walls, staircases, columns and beam designed to strength as per requirements in their own projects. With advantage of 'speed', Pre-cast elements has become one of the emerging techniques observed in the region.

The details on technical parameters and 'green quotient' of the technique is presented in form of fact sheets in chapter 7.

The scale of construction activity brings along the challenges of environmental risk; which in fact can act as a very apt platform to experiment with emerging 'green' construction technologies for mass housing. The experiment is currently limited to use of flyash or AAC block work (green) and pre-cast components for rapid construction. A scenario like NOIDA has huge potential for application of emerging technologies provided there is adequate awareness and dissemination of requisite knowledge.

Figure 36 Housing construction activity, Noida
(www.indiatoday.in n.d.)

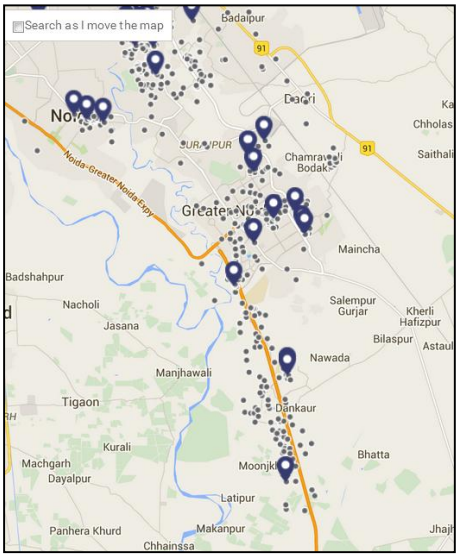


Figure 37 Upcoming Housing Projects in Noida, Greater Noida
(www.coomonfloor.com n.d.)

5 Case Studies in the region

After surveying the state of current green technologies in selected regions, the following case studies illustrate some salient features of how mass housing can be achieved in cost effective and sustainable manner.

5.1 Bhawana Industrial Housing

Name of the project - Bhawana Industrial Housing

Location – Delhi

Timeline- 2007-10

Built up – 1500 units of 31.6 sq. m, 1664 units of 37.7 sq. m, and 1184 units of 40 sq. m (G+3 construction) total: **193012 sq. m**

Cost – INR 850 per sq. m

Client – Delhi State Industrial Development Corporation

Organizations / firms involved – Adhlaka Associates

Figure 38 View of Bhawana industrial housing from central courtyard (Adhlaka 2012)

5.1.1 Relevance

In the geographic context of Delhi, the Bhawana industrial housing demonstrates a sustainable and methodical way of responding to the need of affordable mass housing. It relies on pre-fab technological (structural) innovation and modular planning to achieve sustainability in affordable housing segment. It extensively uses materials with low embodied energy along with high longevity and minimal maintenance. The project capitalizes on ideas of simplicity of execution, speedy construction (pre-fabricated and fixed in-situ) and optimal resource utilization.

Materials used in construction of buildings are as following: 200 mm thick modular load bearing brick wall in super structure (with cement fly ash blended mortar), precast reinforced concrete planks and joist for roofing and flooring, Ferrocement staircase, precast Ferrocement sunshades, precast Ferrocement kitchen platform and precast Ferrocement water tanks. All precast elements are cast on site to save fuel and cost of

transportation. Precast technology optimizes member sizes, plaster thicknesses, dead loads, quality control and effort of on-site shuttering.

The blocks are arranged in a set pattern around centrally shared courtyards. This suffices for ventilation and need for social gathering. The layout is linear to achieve economy in services. The wet areas have been concentrated in and around for minimum length of internal pipes.

5.1.2 Learnings

The spatial configuration of a load bearing structure up to 4 storey is structurally optimal and economical. The overall energy (embodied and active) consumed in producing and running a low rise building is far lower than its high rise counterparts. It rigorously explores the maximum potential of precast Ferrocement elements to cut down on extensive use of steel. Therefore, it can be seen as a system which impacts environment to a lesser extent than conventional counterparts. The construction relies on small precast members which can be man lifted and fixed in place. This negates use of heavy and expensive machinery and makes it cost efficient human scaled construction. It engages local labour and trains them to understand this pre-cast Ferrocement materiality and technology well. With increment in production of this system of building, there is a need to dissemination this knowledge and train work force.

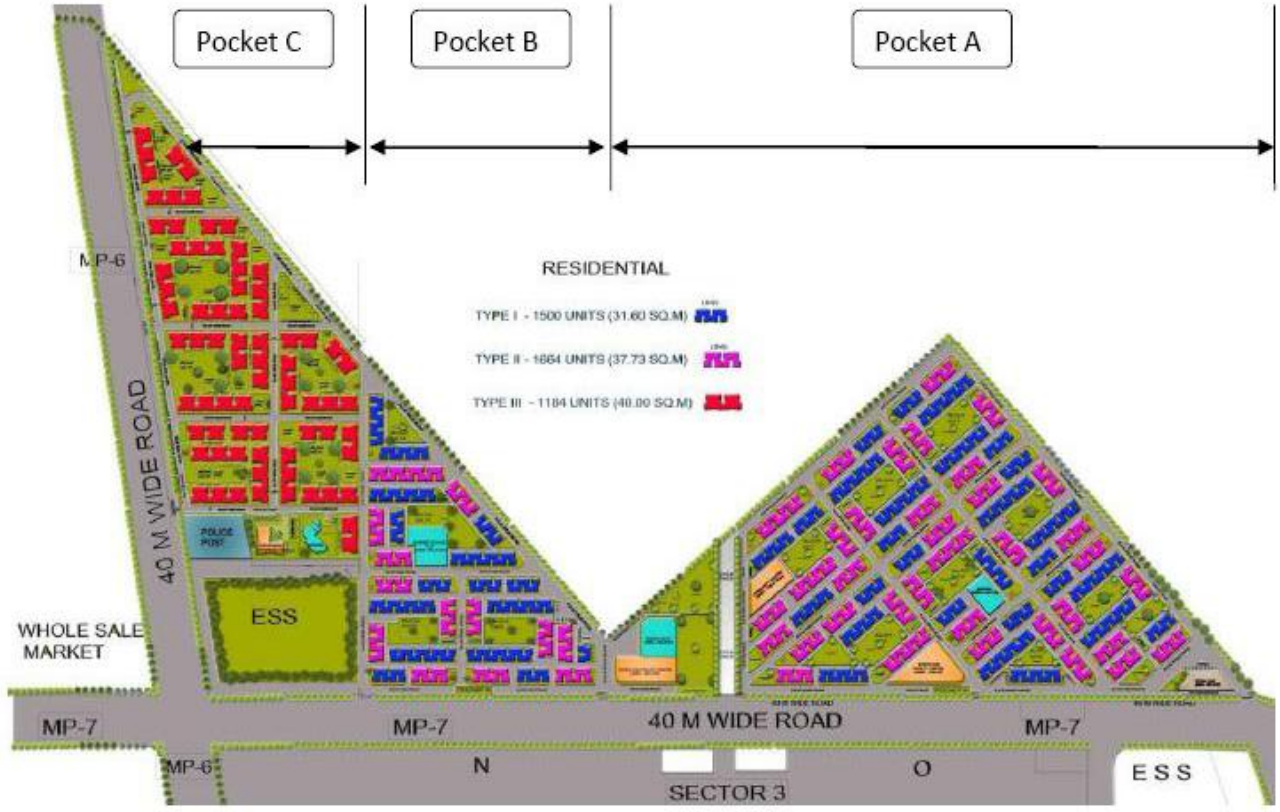


Figure 39 Masterplan of Bhawana Industrial Housing project (Adhlaka 2012)

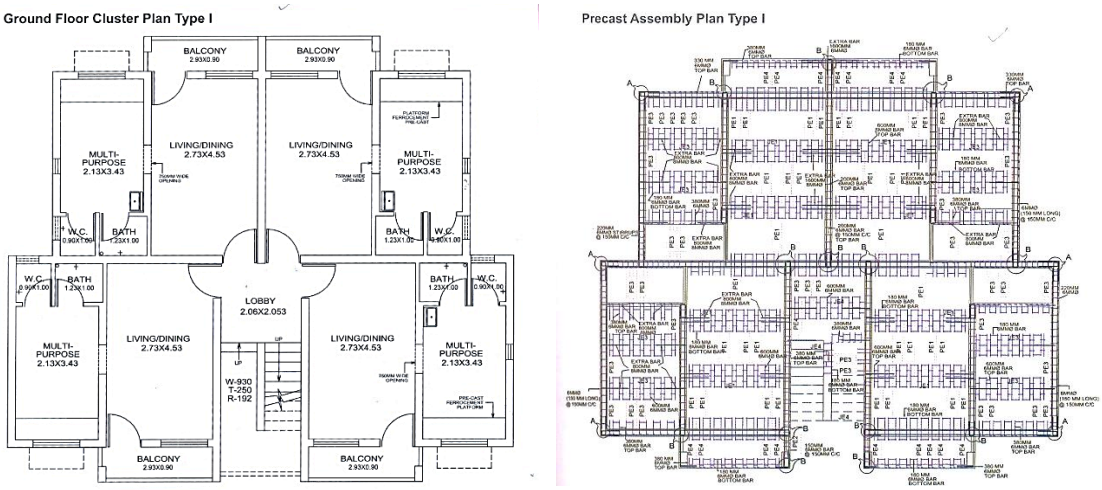


Figure 40 Ground floor cluster plan Type I and its precast assembly plan (Adhlaka 2012)

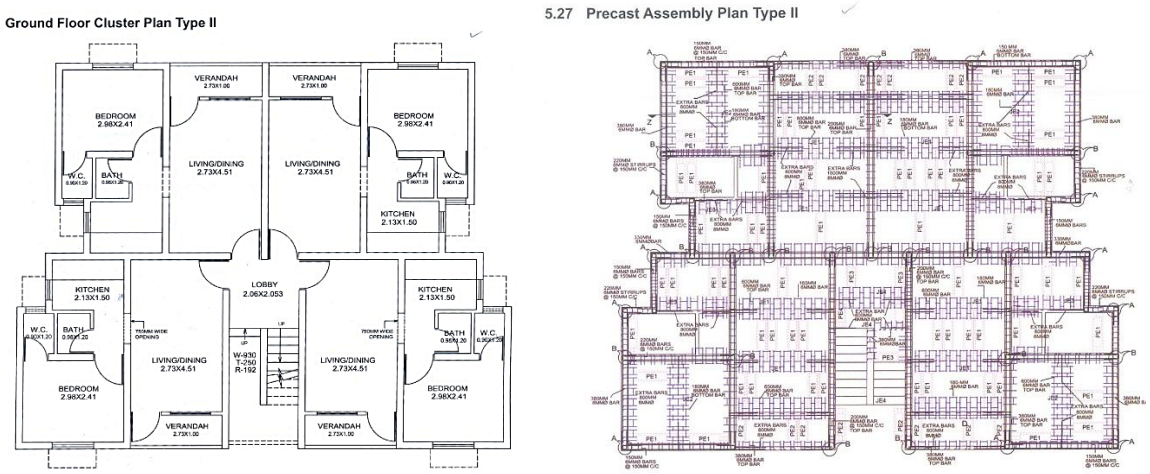


Figure 41 Ground floor cluster plan Type II and its precast assembly plan (Adhlaka 2012)

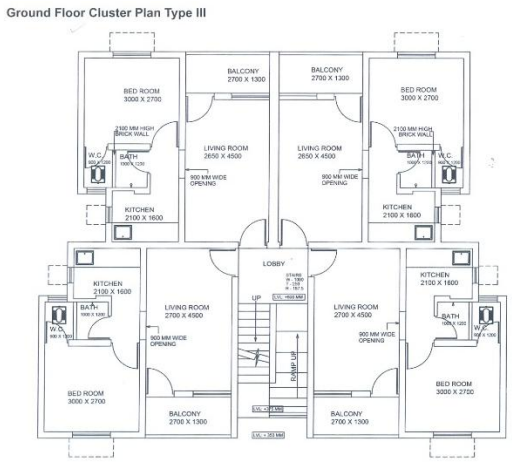


Figure 42 Ground floor cluster plan type III (Adhlaka 2012)

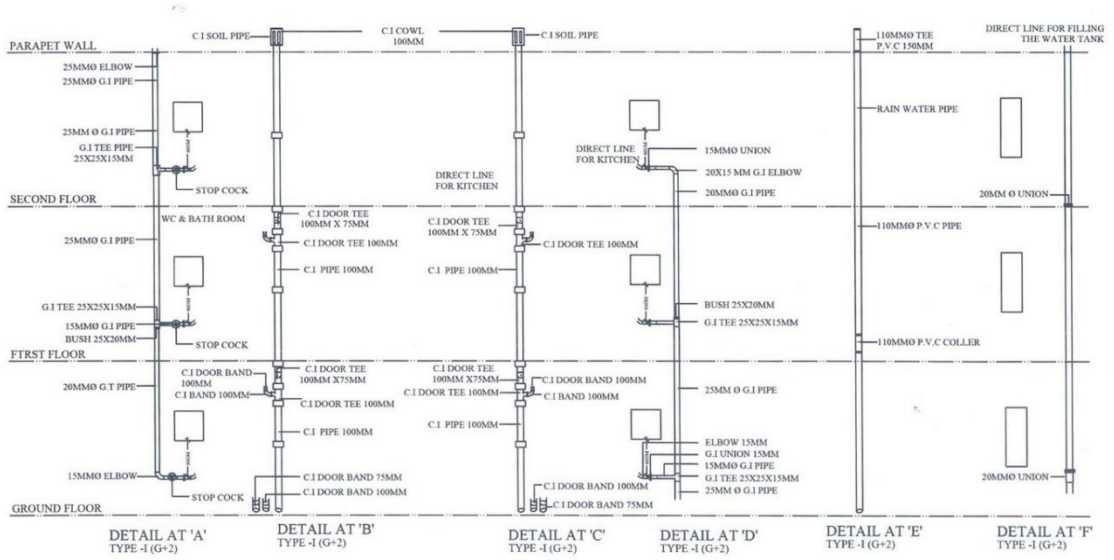


Figure 43 Sanitation and water system (Typical sections) (Adhlaka 2012)

5.2 Model Eco Village housing

Name of the project – Model Eco Village Housing

Location – Village Gaggar, 40km from Bhatinda, Punjab

Timeline – 2008-09

Built up – 129 units 120 sq. m each. Total 15480 sq. m

Cost - INR 4700 per sq. m

Client – Punjab Govt. State Housing Board

Organizations / firms involved – Tara Nirmaan Kendra (Development Alternatives) and Ambuja Cement Foundation under Public Private Partnership

5.2.1 Relevance

In a rural setting, this project demonstrates a climate responsive and sustainable housing for families below poverty line. It appropriately addresses the issues of context and end user lifestyle. It capitalizes on pre-fabricated, energy efficient and low-cost techniques of building. The construction elements have low embodied energy and are recyclable. Climatic responsive nature saves operational energy costs. It addresses affordability by limiting its material and landscape palette to indigenous varieties. Construction debris has been used for earth filling.

Figure 44 view of houses from the central courtyard (DevelopmentAlternatives 2010)

Materials used in construction of buildings are as following: Conventional brick foundation, Fal-G bricks in rattrap bond (with compressed soil stabilized earth block used in alteration to Fal-G for better visual aesthetics), flooring in precast plank and joist and micro concrete roofing tile with MS rafters and purlins. Doors windows shutters and frame are made in local mango wood. Locally made precast Jalis have also been used. The mortar partly uses fly ash mix to cut down on cement quantity.

On operational energy front, the toilets are designed on two pit leach system. The paver-blocks use construction debris mix, which reduces use of fresh aggregates and sand. Rain water is harvested from each house and directed to the harvesting pits located in central parks of the housing.

5.2.2 Learnings

All the materials have been procured through local entrepreneurs. This not only encouraged the local economy to grow but also set up small enterprises on locally available raw materials. Flyash brick manufacturing unit, Ferrocement plank production unit by TARA gram and mango wood door and window shutter production unit being the prominent ones. The TARA gram trained local masons and disseminated the working knowledge for Ferrocement and rattrap masonry.

In affordable housing segment in rural setting, this projects pilots the idea of saving operational energy by two comprehensive means. Firstly, utilizing low embodied energy materials with design build optimizations. Secondly, climate responsive design considerations paired with design build strategies which will further save on operational energy.

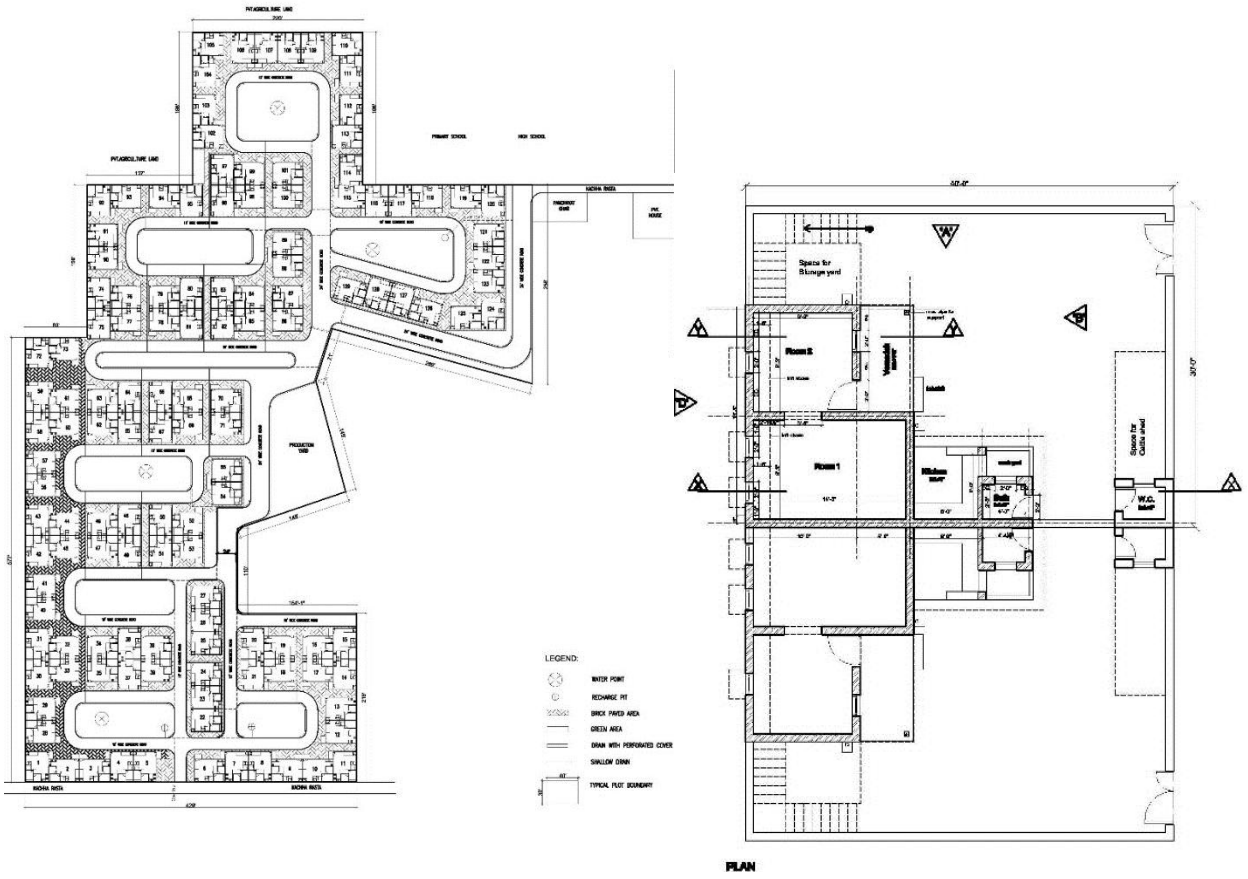


Figure 45 Masterplan of Model eco village and Individual unit plan (DevelopmentAlternatives 2010)

Figure 47 Use of precast Ferrocement elements for first floor slab (DevelopmentAlternatives 2010)

Figure 46 The entrance porch of a house (DevelopmentAlternatives 2010)

6 Scrutinizing Green

'Green' in the context of building construction is understood to be synonymous with 'environment friendly'. However, the idea of a 'green' (either material, component or integrated structural system) intends towards something which causes minimum negative impact on the environment. This being said, a globally accepted definition with definite measurable parameters to assess 'green' is yet to be arrived at.

Before we identify Green Technologies for the compendium, we would build upon existing definitions and frameworks to decide upon a descriptive framework which will define 'green' for the context of this study.

Most of the existing green material assessment program/certifications and research work follows life cycle assessment as a base methodology to assess environmental impact of a material over its phases from extraction to disposal. They have certain common parameters to assess 'green', like waste reduction/recycling, efficient construction techniques, low carbon emissions, water management etc. The difference in such certifications or researches is that different assessment programs assign different weightages to the parameters and thus making it a subjective comparison rather than an absolute one.

Based on various assessment programs and researches we have shortlisted four (to five) essential parameters (explained below) to outline the idea of green and its parameters for our context. These will tend towards a comparative assessment of 'green'. The parameters will be descriptive and indicative in nature which will be easy to understand in a comparative graphical manner. We have consciously avoided any absolute or numeric or quantitative form of assessment as we believe that such kind and depth of technical evaluation is in scope of only an academic research institution.

As mentioned in the introduction, a technology can be categorized green on the basis of four different constituents of a building, namely – material, building components and integrated structural systems. In order to classify a technology as 'green' under the above mentioned 3 categorizations, we have identified indicators which will depict why a chosen technology is categorized under 'green'. The indicators and their explanation is explained below.

6.1 Assessment of 'Green'

6.1.1 Indicators

The assessment of Green is based on the following 4 parameters, namely: Energy, Impact on Natural Systems, Resource Availability and Disposability. In the wake of the climate change and energy crisis, we think energy is the most primary parameter in deciding whether a technology should be considered green or not. Thus we have given maximum weightage (i.e. 10 points = +5 & -5) to this parameter. We have ranked the Impact on Natural systems next to Energy. We understand that building construction as an activity is inherently injurious to nature (in a context where building material palette is no more limited to mud, wood and biomass produce). It has been given the next highest weightage (i.e. 5 points = -3 and +2). At the best what one could achieve is to reduce the negative impact on the natural systems. Further in the list of parameters, comes the resource availability. We understand that resource availability is a parameter which is affected by various external factors like supply-demand chain, entrepreneurial initiatives, and bureaucratic trade regulations and so on. Therefore, the sustainability aspect is not a primary outcome of this. It has been given 5points also (i.e. +3 and -2).

Our last parameter in assessment of Green is the Disposal. We have yet considered this to gain a comprehensive understanding of the lifecycle of the material for disposability further affects the balance of natural systems. It has a weightage of 4 points (i.e. +2 and -2)

6.1.1.1 *Energy*

The building sector has been projected as one of the largest energy intensive sectors. It is also the single largest contributor of global greenhouse gas emissions. Energy, as a parameter, has two aspects related to it, one being the embodied energy of a material and the other being operational energy. The embodied energy is the measure of the total energy required to produce it. It is a comprehensive measure of energy required to source and collect raw materials, fuel used to power the processing equipments, mechanisms to harvest or mine it and the transportation devices that move raw material to the processing facility. In nutshell, it can be understood as net used energy from raw material stage to finished or usable product stage. This energy typically comes from the burning of fossil fuels, which are (in most cases) limited non-renewable resource. The greater a material's embodied energy, the greater the amount of energy required to produce it, implying higher carbon dioxide emissions and more severe ecological consequences. For example, the processing of wood (harvested in a sustainable fashion) involves far less energy and releases less pollution than the processing of iron, which must be extracted from mined ores. (Qualities, Use, n.d.). The operational energy is the relative measure of energy required to make it functional in an integrated building environment. For example hollow clay block has better insulative properties than concrete blocks and if used as a walling material will decrease the cooling load on HVAC system. Thus while tabulating the energy parameter, we demarcate a neutral axis and on the left (negative) side of it, we measure embodied energy of the material. This parameter is understood to have negative impact on the environment. On the right (positive) side of axis, we measure the operational energy in terms of potential in energy savings. This parameter is understood to reduce the energy consumption, in running of the building. In the context of measuring the green quotient of a building material, we summarize that embodied energy is the sum expenditure of energy from earth's reserve and the operational energy is the measure of possible energy savings as compared to its traditional counterpart

6.1.1.2 *Impact on Natural Systems*

Conversion of raw material to processed construction material involves different techniques and materials that generates waste. The whole process is believed to have a potential to impact the physical, biological and social aspects of the environment. The physical environment of water, air, land/soil etc. is susceptible to pollution by release of gases and waste materials, while the biological environment of flora and fauna is also under threat by the pollution and harmful emissions during the manufacturing and installation of the materials. The social aspect of environment which comprises of the people involved in the production face occupational hazard and safety. Thus this parameter looks at the environmental pollution potential of a technology. The left side of neutral axis measures the severity of negative impact on environment ranging from one to three. The right side of neutral axis measures the potential for reduction in negative impact on natural systems. Building resources which could be harvested sustainably or recycled or have a neutral impact like biomass, would fit on the greener side of parameter scale. On other hand, materials which have severe effect on environment like mining based materials (aluminum, steel limestone) would fit onto the red side of the parameter scale.

6.1.1.3 *Availability on Natural resources*

Globally, the construction sector is arguably one of the most resource-intensive industries and also one of the largest exploiters of renewable and non-renewable natural resources (Akadiri 2011)

Building material or a technology causes impact on natural systems by virtue of the type of raw material selected, for example a material made out of waste products will have a comparatively lesser (negative) impact than the impact caused by a non-renewable scarce material. For the assessment purposes, non-renewable resources fit on the left (negative) side of the axis, depending on how scarce or abundantly available is it. On right (positive) side of axis, lies renewable and recycled resources depending on how abundantly or scarcely are they available.

6.1.1.4 *Disposal*

Disposal is the last stage evaluated in the life cycle assessment methodology, for environment impact. Construction and demolition waste has become a huge cause of concern as landfill sites are reaching their capacities. Thus nature of material in terms of its disposal characteristics has been taken as a parameter to depict green aspect of the technology. Though this has been given the least importance as a parameter. It is known that by recycling materials, the embodied energy they contain is preserved. The energy used in the recycling process for most materials is far less than the energy used in the original manufacturing. (Akadiri 2011). However, when a material is reused or recycled the wider environmental impact of the material is significantly reduced. (UK Green Building Council n.d.) On the left (negative) side of the neutral axis, we measure the toxicity of a material, indicating whether it lands up in a landfill (as a toxic or neutral impact material.) On the right side of the neutral axis, we measure the recyclable or biodegrable attributes of disposability of materials.

One might notice that recycled materials score double plus points, once in resource availability and the other is disposability. This has been done to promote material recycling, as we in our collective understanding believe recycling as an immediate answer to mitigate climate change and energy.

6.1.1.5 *Consumption efficiency factor*

Consumption efficiency factor is the measure of mass of material consumed in producing same built volume or surface area as compared to its traditional counterpart. This concept is valid when comparing either material, component or integrated building systems. However, this is mostly manifested when comparing two different techniques of building or components (minor). For example, in case of building technique, the case of masonry in English bond versus rat trap bond or the case of filler slab versus RCC slab. If the mass of the brick used in former case is 1, the mass of bricks used in rat trap bond will near 0.7. Thus the consumption efficiency factor for rat trap bond with English bond as base case is 0.7. For filler slab, which uses light weight filler material in bottom part of slab, thereby saving steel reinforcement and dead load of concrete as compared to conventional RCC slab.

The iterative hypothesis is that the range of this scale varies from 0 to 2, 1 being the base case (traditional counterpart).

In case of Ferrocement which is a versatile material for making minor components like water tanks, Chajjas, railings and screens etc., it consume far lesser mass of material (cement, aggregate and steel) as compared to their RCC counterpart.

6.1.2 Assessment diagram for 'Green'

A measurement scale has been assigned to the four parameters, where maximum red value refers to maximum negative impact and maximum green value refers to least negative impact. In other words we can say, higher the overall value on green side, better the material, from 'green' perspective.

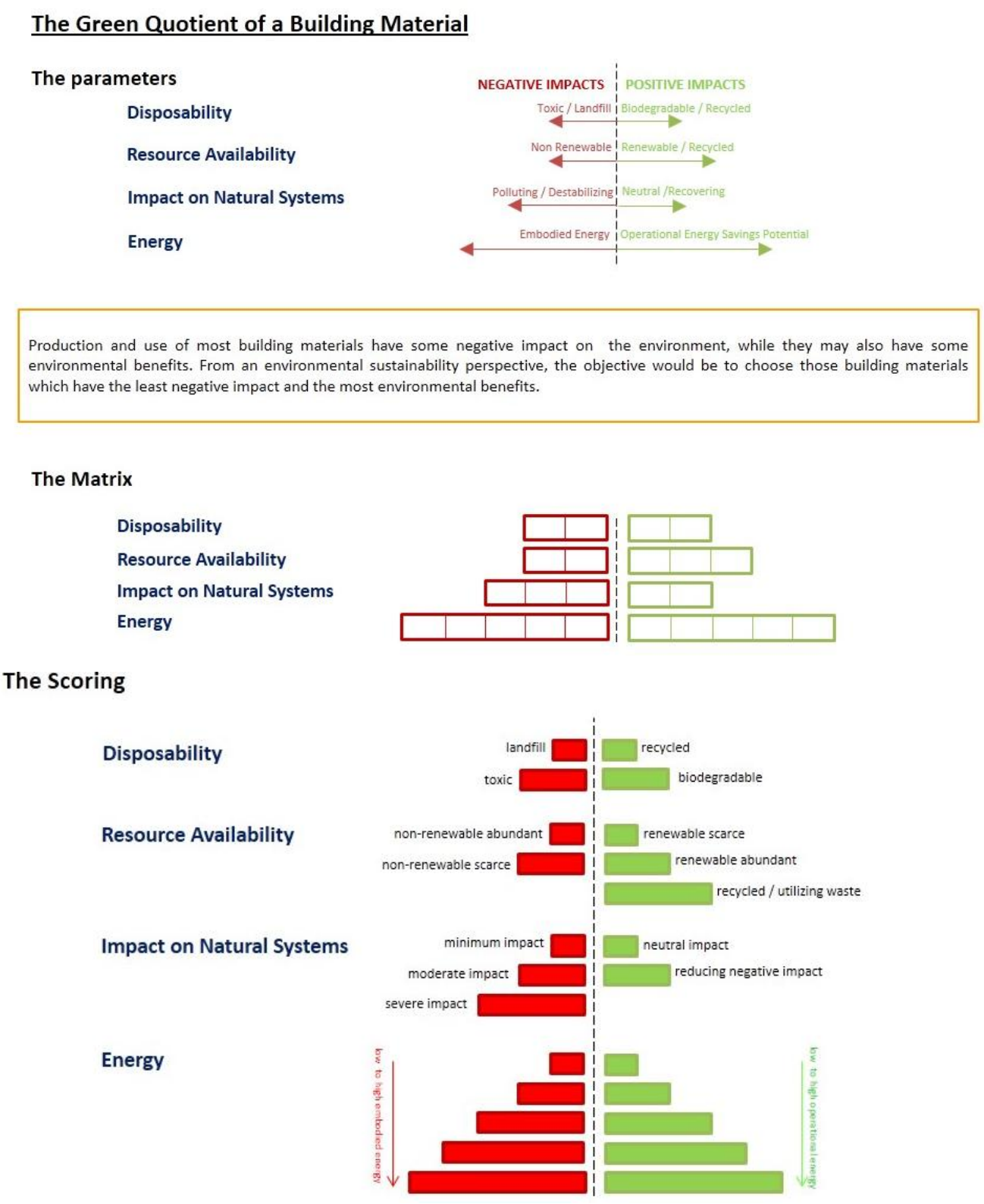


Figure 48 The Assessment matrix of 'Green' (Lall 2016)

Figure 49 Net green score
(Lall 2016)

Depending on the cumulative scoring of the matrix above, each technology receives a net green score namely, High green whose use is highly recommended in mass housing projects in this region; followed by moderately green technology whose use is recommended too. They are followed by a rating of neutral whose use is acceptable, followed by a technology which is rated moderately red and its use is not recommended. The last rating a technology might receive is highly red and the use of such technology is prohibited.

7 Fact sheets – Documenting and evaluating green technologies

The fact sheets are a concise graphic tabulation of green building technologies. A building technology has been further classified into material, component and integrated building systems (Refer section 2.3 of chapter 2, for detailed description and classification). The first section of the chapter focuses on documenting and evaluating green technologies that are available in this region of Punjab, Haryana, Chandigarh, Delhi and NCR. The later section covers the green technology that are not available in the region but are appropriate in the region. The factsheets are presented under three sub headings-

i) *General information* - covers a brief description, salient features, cost as surveyed in 2016, how it is used in building, the appropriateness for this climatic region and availability of manufacturers and suppliers in the region.

ii) *Technical Information* - documents the constituents of material, manufacturing scale, whether it is manufactured on site or in mechanized factories, applicable Indian Standard codes, production, scaling challenges and opportunities and limitations.

iii) *Green Information* - deduces a net green score for the material / component or integrated structural system based on the environmental impact of sourcing, utilizing and disposal. It calculates embodied energy, lists down conventional counterparts, green features, green benefits over conventional counterpart and future assessment and potential in building industry.

7.1 Green technologies available in the region

7.1.1 Fact sheets on building material

7.1.2 Fact sheets on building components

7.1.1 Fact sheets on Building Materials

7.1.1.1 Autoclaved Aerated Concrete (AAC) Blocks

General Information

➢**Brief Description:** It is a lightweight, precast building material that is produced by mixing silica rich material fly ash, cement, lime, gypsum, aluminum powder/paste and water.

Fig. AAC Blocks used in wall construction

➢**Features**:

- Use of light-weight AAC Blocks results in reduction of deadweight. The reduced deadweight reduces the use of cement and steel in structure.
- Useful material for external wall for its insulation property.
- The block sizes are relatively large which ensures rapid construction so that more wall area can be laid per man-hour than in conventional brick wall constructions.
- Offers sound attenuation of about 45 dB, blocking out all major sounds and disturbances.

➢**Cost:** 3500 – 4000 Rs/m^3 of wall**

* Test reports of various manufacturers

** Rates as surveyed in January 2016, varies with states according to applicable taxes

➢**Applicability**

•**Use** : All non-load bearing construction

•**Climatic Zone** :Suitable for all climatic zones in this region but a certain caution has to be taken against high moisture.

➢**Availability**

•Manufacturing centered around large cities but supply network is spread across all cities.

➢**Availability**

Available across the region

7.1.1.1 Autoclaved Aerated Concrete (AAC) Blocks

Technical Information

➢**Raw Material :** Fly ash (55-60%), Gypsum (2-3%), Cement (10-12%), Lime (12-14%) and Aluminum Powder (0.03%)*

➢**Manufacturing Scale** : ~ 400 m^3/day **

➢**Manufacturing :** In factory

➢**Applicable Standards/codes:**

- IS 2185 (Part 3) – 1984

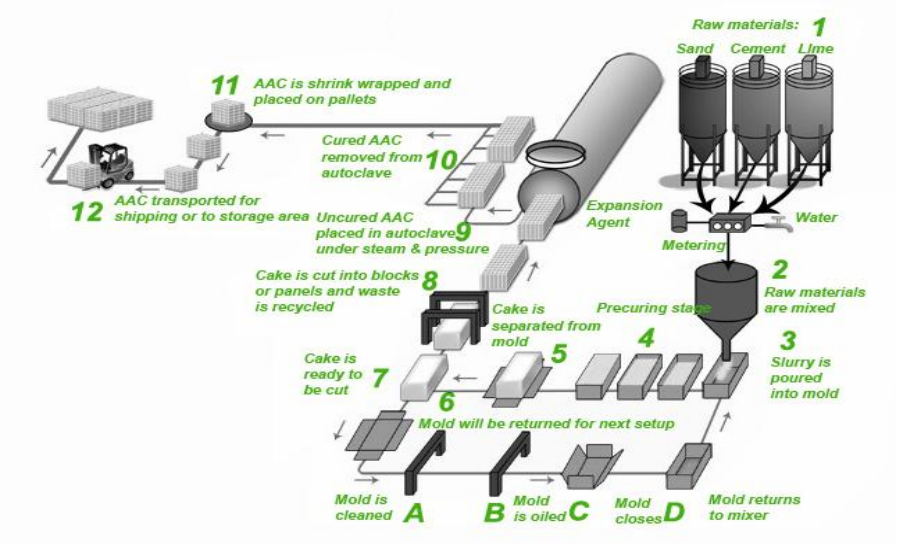


Image Source: http://www.greencon.my/img/production-map.jpg

➢**Production and scaling challenges and opportunities**

Demand has picked up in the high rise building construction market because of fast rate of construction and cost competitiveness; Challenge lies in a) standardizing the product quality b) educating users in proper method/practice for application.

➢**Limitations :** Caution has to be taken against moisture ingress and cracks developed during transportation, storage and application. There is a perception in the market that improper mortar joinery, diurnal temperature fluctuations, etc results in crack development in walls.

➢**Projects where used:**

Multi story high rise housing projects in NCR and around Chandigarh

*Biltech Building Elements Ltd
** 24 hours of work shift at manufacturing plant.

7.1.1.1 Autoclaved Aerated Concrete (AAC) Blocks

Green Information

Environmental Impact

Net Green Score

➢**Embodied Energy***:1200-1300 MJ/m^3

➢**Green Features**:

- Makes productive use of industrial waste (fly ash: 55-60%)
- Low energy consumption and CO_2 emissions in production.
- Good thermal insulation properties.
- Low fraction of mined raw material content.

** Source: Greentech Knowledge Solutions Pvt Ltd analysis*
*** IS 2185-3 (1984): concrete masonry units, Part 3: Autoclaved cellular Aerated Concrete blocks*

➢ **Conventional Counter part/s**:

Solid fired clay bricks (solid red bricks)

➢**Green Benefits* over counterpart:**

- 45-50% energy savings in production
- K value 0.21 to 0.42** W/m-K as compared to 0.52 to 0.85# W/m-k of red bricks.
- CO_2 emissions in production of AAC Blocks is 0.134 t CO2/m^3 as compared to 0.219 t CO2/m^3 for red bricks.
- Mined raw material content in AAC is around 1/8th of its counterpart because of its low density and use of industrial waste material.

Appendix C: Default Values for Typical Construction - ECBC,2007

➢**Future assessment/ Potential**

- With applicability across almost all climates, the acceptance and use is expected to see growth in new constructions across the country. For this to happen issues related with product quality and application needs to be addressed.
- The increase in acceptance has potential to bring down the costs and make it affordable for low cost housing.
- AAC technology can be developed into precast products like wall & roof panels to bring down the construction time.

- http://www.biltechindia.com/biltech-ace-aac-benefits-advantages.asp?links=b3
- http://www.aeratedconcreteblock.com/aac/aac-blocks-waterproof

➢**Machinery Set up** http://www.aac-india.com/aac-blocks-project-consulting-services/
➢**Manufacturing Process**http://www.aac-india.com/aac-blocks-manufacturing-process-raw-material/, http://www.dongyuegroup.com/product/index.asp
➢**Specifications** http://www.godrejconstruction.com/Construction/AACBlocks.aspx?id=8&menuid=774

7.1.1.2 Flyash (Fal-G technology) Bricks

General Information

➢**Brief Description:** It is a blend of fly ash (Fa), lime (L) and gypsum (G) in suitable proportions which yields strength upon hydration. It utilizes an industrial waste, fly ash, which is approx. 2/3rd by volume of the brick.

Fig. Flyash bricks used in wall construction

➢**Features**:

- Produced in standard brick sizes.
- For compressive strength of 12.5-30N/mm^2, water absorption is less than 10%.
- Production process does not involve sintering and thus completely eliminates the burning of fossil fuels.

➢**Cost:** 2500-3500 Rs/m^3 of blocks (Rs.5-7 per brick)*

Distance of manufacturing plants from thermal power plant can affect the transportation cost and thereby significantly increase the production cost.

* Rates as surveyed in January 2016, varies with states acc. to applicable taxes

➢**Applicability**

- **Use** : All stories of load & non-load bearing construction
- **Climatic Zone** : Fly ash (Bricks) have found a wide spread applicability across climatic zones.

➢**Availability**

- Manufacturing facilities found throughout the region, particularly around thermal power plants.

➢**Availability**

Available throughout the region particularly around thermal power plants.

7.1.1.2 Flyash (Fal-G technology) Bricks

Technical Information

➢**Raw Material : Lime Route***: Fly ash 65-70%, Coarse sand or crushed stone 15-20%, Lime 5-10% and Gypsum 3.5-6.5%

Cement Route**: Flyash 70 %, Lime 5 %, Cement 20% and Gypsum 4-5%

➢**Manufacturing Scale** : 650-1600 bricks per hour

➢**Manufacturing :** small scale manufacturing units (Machinery : Pan Mixer, Hydraulic/Vibro Brick Press)

➢**Applicable Standards/codes:**

- IS 12894 (2002): Pulverized Fuel Ash-Lime Bricks, Working specification by BMTPC including manufacturing method -BM 02

**Techno Economic feasibility report on Flyash Bricks by BMPTC*

***The FaL-G Concrete for Housing and Infrastructure, Second International Symposium on Concrete Technology for Sustainable Development*

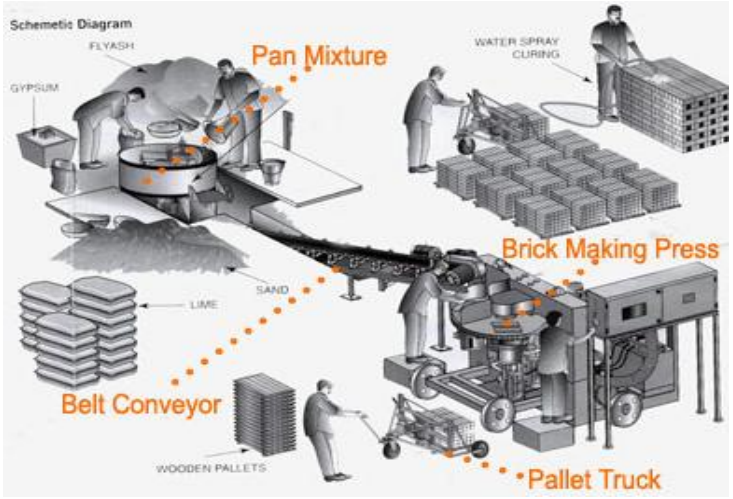


Image Source: http://www.exportersindia.com/

➢**Production and scaling challenges and opportunities**

- Use of Flyash bricks has picked up as an alternate to clay fired brick especially where quality of clay bricks is not good and availability of flyash is not a constraint. Also, flyash bricks are being preferred in government construction and green rated buildings.
- Being manufactured by small-scale producers, a large variation in the quality of flyash bricks is observed. Poor quality in many instances is a challenge in developing the market.
- Flyash bricks are facing challenges in high rise construction, due to its high density i.e. dead weight. In the low rise construction (particularly in rural areas), low consumer awareness is a challenge
- The availability of sand in many parts has been impacted due to the environmental issues related with the mining of sand, and this is having adverse impact on flyash brick production.
- The manufacturing plant should be located in a radius of 100km of the power plant to minimize the transportation charges.

➢**Limitations :** Is available and economical in areas close to power plants.

➢**Projects where used:**

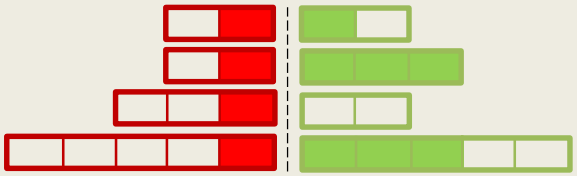
NCR metro station projects, residential complexes, private residences, institutions, government projects.

7.1.1.2 Flyash (Fal-G technology) Bricks

Green Information

Environmental Impact

Disposability
Resource Availability
Impact on Natural Systems
Energy



Net Green Score

➢**Embodied Energy***: 1100-1200 MJ/m^3

➢**Green Features**:

- Makes productive use of industrial waste (fly ash: 60-70%)
- Low energy consumption and CO_2 emissions in production.
- Low fraction of mined raw material content.

➢ **Conventional Counterpart/s**:

Solid fired clay bricks (solid red bricks)

➢**Green Benefits* over counterpart:**

- 50-55% reduction in embodied energy
- CO_2 emissions in production of Fal G bricks is 0.085T/m^3 and 0.219T/m^3 for Red bricks.
- Mined raw materials content in Fal G bricks is around 1/4th of its counterpart.

** Source : Greentech Knowledge Solutions Pvt. Ltd (GKSPL)*

➢**Future assessment/ Potential**

- With applicability across almost all climates, the acceptance and use is expected to see growth in new constructions across the country. For this to happen, issues related with supply of flyash and sand to manufacturers as well as quality of flyash bricks needs to be addressed.
- Government guidelines of making use of fly-ash mandatory in construction and efforts towards streamlining/regulating the fly- ash product industry will pave way for increased innovative use of Fly ash as a material

1:Techno Economic feasibility report on Flyash Bricks by BMPTC, 2:The FaL-G Concrete for Housing and Infrastructure, Second International Symposium on Concrete Technology for Sustainable Development (27 Feb-3 Mar, 2005; Hyderabad) , http://www.taramachines.com , http://www.ecobrick.in/waste_Utilization_in_Brick_Making.aspx, http://www.fal-g.com/,

➢**Manufacturing:** http://www.bmtpc.org/datafiles/cms/file/01_flyash_brick1.pdf

➢**Specifications (BIS):** https://law.resource.org/pub/in/bis/S03/is.12894.2002.pdf

➢**Other Fly ash products:** http://www.slideshare.net/varunkv222/high-volume-fly-ash-concrete,

➢**Limitations, challenges and advantages** : ***flyash****2014.missionenergy.org/files/ZEB_%20Shri%20S%20Goyalji.pdf*

7.1.1.3 Cellular Lightweight Concrete (CLC) Blocks

General Information

➢**Brief Description:** It is a version of lightweight concrete that is produced by making a slurry of Cement, Fly Ash and water, which is further mixed with stable foam in an concrete mixer under ambient conditions.

➢**Features**:

- Has homogeneous void or cell structure, attained with gas-forming chemicals of foaming agents which provides the light weight attributes.
- Lighter than traditional bricks, reduces overall dead load of a building. Lighter and larger blocks make construction easier and faster.
- The blocks are relatively large which ensures rapid construction so that more wall is laid per man-hour than in other types of wall constructions.
- Low cost machinery and production setup.
- Lower water absorption as compared to AAC Blocks

➢**Cost:** 3500 – 4000 Rs/m^3 of wall *

* Rates as surveyed in January 2016, varies with states acc. to applicable taxes

Fig. CLC Blocks used in wall construction

➢**Availability**

Manufactured & used in large scale high rise and individual housing projects in major cities.

➢**Applicability**

•**Use** : Low density blocks for non-load bearing walls and medium-high density blocks for partitions and load bearing walls.

•**Climatic Zone** : wide spread applicability across climatic zones

➢**Availability**

- Availability and manufacturing of CLC blocks is pan India.
- Manufacturing is mostly on construction sites

7.1.1.3 Cellular Lightweight Concrete (CLC) Blocks

Technical Information

➢**Raw Material*** : Flyash (50-60%), Cement (20-30%) remaining water and foam

➢**Manufacturing Scale**** : 50m^3/day

➢**Manufacturing** : On site/ Factory

➢**Applicable Standards/codes:**

IS 2185-4 (2008): Concrete masonry units, Part 4: Preformed foam cellular concrete blocks

** Greentech Knowledge Solutions Pvt. Ltd (GKSPL) data*
*** http://www.aac-india.com/comparison-between-aac-blocks-and-clc-blocks/*

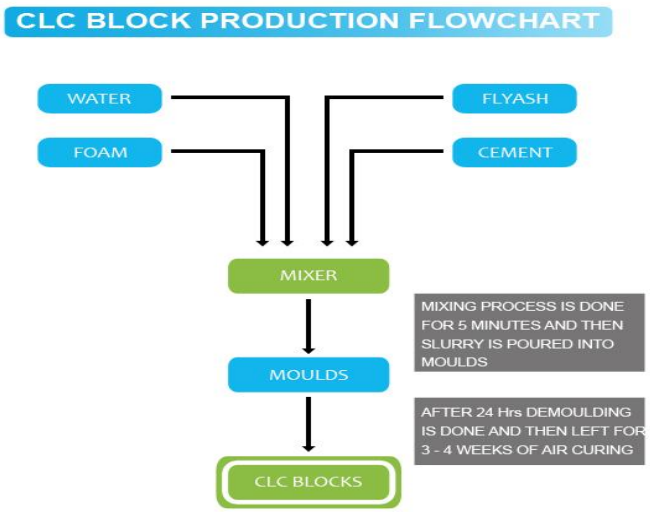


Image Source: http://www.iyantra.com/

➢**Production and scaling challenges and opportunities**

- CLC blocks production units at site offer an advantage where AAC blocks are not available. AAC blocks have been gaining ground because of their industrial production assuring quality of product and timely supply.
- On-site CLC block production methods need to develop methods of curing which occupy less land and increase the rate of supply.
- **Limitations :** The CLC equipment has lower production capacity and the finished goods require more space for curing. These blocks cannot be properly stacked on each other; therefore the present methods of curing require a lot of ground area.
- On site quality control can be difficult to achieve desired strength and consistency of shape and size.

➢**Projects where used:**

Aranya, Unnati Builders, Noida .

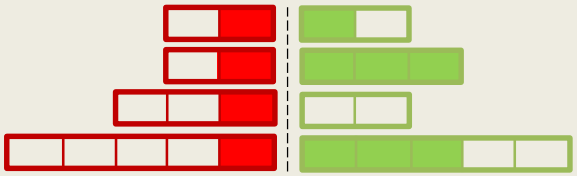
** 24 hours of work shift at manufacturing plant.

7.1.1.3 Cellular Lightweight Concrete (CLC) Blocks

Green Information

Environmental Impact

Disposability
Resource Availability
Impact on Natural Systems
Energy



Net Green Score

➢**Embodied Energy***:1000-1100 MJ/m^3

➢**Green Features**:

- Low energy consumption and CO_2 emission in production
- Productive use of industrial waste (fly ash 50-60 %)
- Has insulating properties and lowers operational energy for cooling.

** Greentech Knowledge Solutions Pvt. Ltd analysis*
**IS 2185-4 (2008): Concrete masonry units, Part 4: Preformed foam cellular concrete blocks
Appendix C: Default Values for Typical Construction - ECBC,2007

➢ **Conventional Counter part/s**:
Solid fired clay bricks (solid red bricks)

➢**Green Benefits* over counterpart:**

- 50-60% reduction in embodied energy
- K value 0.32 to 0.54** W/m-K as compared to 0.52 to 0.85# W/m-K of conventional burnt clay bricks.
- Mined raw material content in CLC is around 1/5th of its counterpart because of its low density and use of industrial waste material.

➢**Future assessment/ Potential**

- CLC blocks being less moisture absorbent than AAC blocks may be preferred in rain exposed construction.
- On site production of CLC blocks will provide for light weight walling requirement in locations where AAC blocks are not supplied.

➢ **General info** : http://brickwell.in/
➢ **Manufacturing:** http://theconstructor.org/concrete/cellular-lightweight-concretefly-ash-based/6050/
▪http://www.engineeringcivil.com/foamed-cellular-light-weight-concrete.html, http://www.celcreteindia.com/company-profile.html http://www.blite.in/
➢**Specifications (BIS):** https://law.resource.org/pub/in/bis/S03/is.2185.4.2008.pdf

7.1.1.4 Compressed Stabilized Earth Blocks

General Information

Brief Description: It is a dense solid block produced by compacting a mixture of soil, sand, stabilizer (cement/lime) and water using press machine.

Fig. CSE Blocks (left) and specialized perforated CSE Blocks for reinforcement placement in wall construction

➢Features:

- CSEB production is done on the site through soil excavated from the project sites or from nearby location. Sintering is not required for its production. This saves the transportation and fuel costs.
- Equipment for making CSEB is available in manual or mechanized models ranging from village to semi-industrial scale.
- Block sizes can be custom designed. For convenience they are of same size as the clay bricks.

➢Cost: 3067 Rs/m^3 of CSEB brick wall (24cm thick) *

* Rates as per Auroville, Oct 2010

➢Applicability

•**Use** : In load bearing construction, up to 2 floors. In non-load bearing construction, as infill.

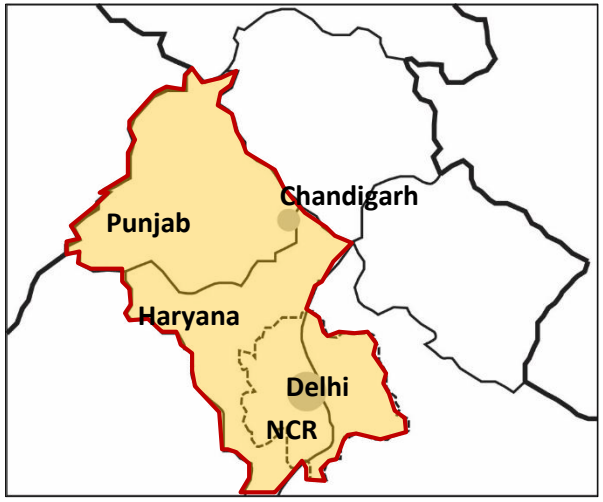
•**Climatic Zone** : CSE Blocks are climatically appropriate for all regions

➢Availability

▪Soil in this region is suitable for CSEB production but at present there is a very limited production.

▪Manufacturing equipment is portable or mobile and can be installed at/near the construction sites.

➢Availability



Limited usage in the region

7.1.1.4 Compressed Stabilized Earth Blocks

Technical Information

➢**Raw Material* :** Soil (92-94%), Cement (6-8%) and water. Optimum soil composition for the manufacture of soil cement blocks is approximately 75% sand and 25% of silt and clay. Sandy soils require 5 - 9% ; silty soils need 8 to 12%; and clayey soils require 12 to 15% cement by volume as stabilizer.

➢**Manufacturing Scale** : 4 – 5 m^3/day for one shift of 8 hrs. (100-125 blocks per hour of size 290 x 190 x 90mm)

➢**Manufacturing :** On site

➢**Applicable Standards/codes:**

·IS- 1725 (1982), CSEB's shall have a minimum average compressive strength of not less than 20 kgf/cm^2 for Class 20 and 30 kgf/cm^2 for Class 30.

* http://www.dcmsme.gov.in/reports/glass/soilcementblocks.pdf

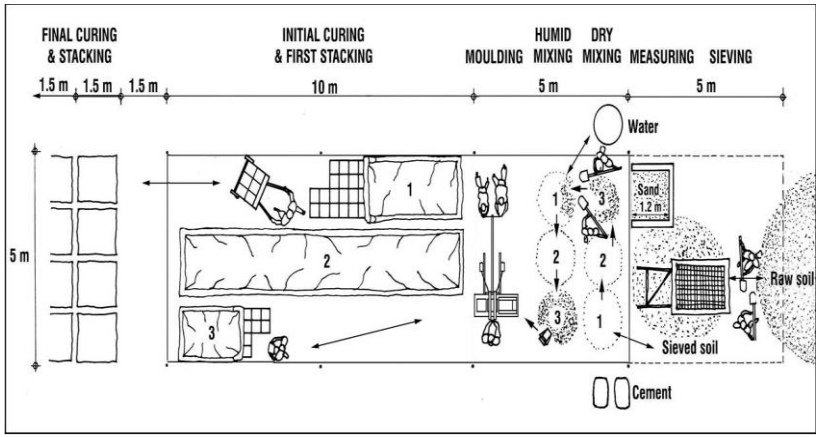


Image Source: http://www.earth-auroville.com/compressed_stabilised_earth_block_en.php

➢**Production and scaling challenges and opportunities**

- Negligible market share at present and manufactured on site.
- With increase in awareness and technical know-how of soil characteristics, CSEB can be an alternative to burnt brick or concrete block, especially in infill construction.

➢**Limitations :** The production of blocks requires technical expertise to assess soil characteristics and the appropriate mix of cement. This has been a barrier for its adoption. The popular perception is that this is a weak and less durable material than burnt brick continues to be a challenge in its adoption.

➢**Projects where used:** Only in individual houses in this region. (House in Karnal)

7.1.1.4 Compressed Stabilized Earth Blocks

Green Information

Environmental Impact

Disposability
Resource Availability
Impact on Natural Systems
Energy

Net Green Score

➢**Embodied Energy***:~550 MJ/m^3

➢**Green Features**:

- Environmentally friendly as no firing is required.
- Low energy consumption and CO_2 emissions in production.
- Soil for CSEB when excavated from foundation/basements etc. at the site of construction conserves agricultural top soil which is currently excavated for conventional clay bricks.

➢ **Conventional Counter part/s**:
Solid fired clay bricks (solid red bricks)

➢**Green Benefits over counterpart:**

- 40-50% reduction in embodied energy
- CO_2 emissions for CSEB production* is 0.057 T CO_2/m^3 against 0.219** T CO_2/m^3 of conventional red bricks.

* http://www.earth-auroville.com/compressed_stabilised_earth_block_en.php
** Appendix C: Default Values for Typical Construction - ECBC,2007

➢**Future assessment/ Potential**

- Can be adopted for formal medium to large scale housing projects where the soil excavation can be an integrated with project design. (like construction of deep foundation, water holding ponds, deep sewage treatment plants etc.)
- Also technical control of production quality can be assured .

➢ http://www.devalt.org/Home.aspx, http://www.dcmsme.gov.in/reports/glass/soilcementblocks.pdf
➢ http://www.earth-auroville.com/raw_material_introduction_en.php
➢ https://law.resource.org/pub/in/bis/S03/is.1725.1982.pdf
➢ http://municipalika.com/wp-content/uploads/2014/Presentations/TS04-Satprem-Mainin-Presentation.pdf

7.1.1.5 Hollow Clay Blocks

General Information

➢**Brief Description:** Made from clay obtained from mining, desilting of tanks/rivers, etc.
Volume of perforations may range from 25 to 70% of the gross block volume. The perforations are laid in the horizontal direction.

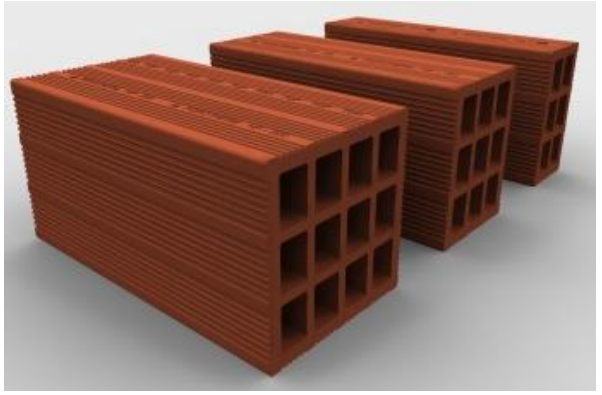


Fig. Hollow Blocks

➢**Features**:
•Light weight , compressive strength > 3.5 N/mm^2, water absorption < 20%
•Low thermal conductivity* (K value = 0.17- 0.2 W/mK) makes it a good thermal insulator.
• Wastes like coal ash, rice husk and granite slurry can be added to the clay-mix.
•Commonly available in 150mm and 200 mm widths.
•Very precise in size and surface, therefore plastering can be avoided.
•Use of Hollow clay blocks results in reduction of deadweight. The reduced deadweight reduces the use of cement and steel in structure.
•Good sound attenuation properties.

➢**Cost:** 2800-3700 Rs/m^3 (Rs. 50 for 400x200x150 mm block; Rs 60 for 400 x200x200 mm block) **

** http://www.wienerberger.in/porotherm-clay-bricks-60-light-weight-than-solid-concrete-blocks/product-catalogue*
***Rates as surveyed in January 2016, varies with states acc. to applicable taxes*

➢**Applicability**
•**Use** : For walls and masonry of all non-load bearing construction.
•**Climatic Zone** : Suitable for all climatic zones

➢**Availability**
▪ Very limited production with only a few manufacturer in the region having the capacity to produce. Presently being manufactured largely in South India
▪Can be ordered and supplied to this region.

➢**Availability**

Limited availability in this region but can be ordered from other states.

7.1.1.5 Hollow Clay Blocks

Technical Information

➢**Raw Material :** Clay

➢**Manufacturing Scale** : 50,000 – 3,00,000 blocks per day*

➢**Manufacturing :** Manufactured in factory setups which mainly includes extruders for brick moulding, artificial dryers, and tunnel kiln for firing of bricks.

➢**Applicable Standards/codes:**

•IS 3952 – (1988)

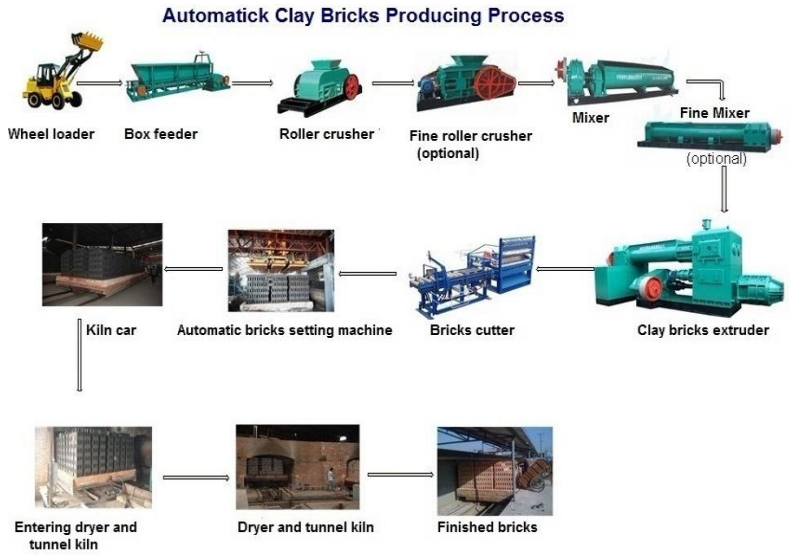
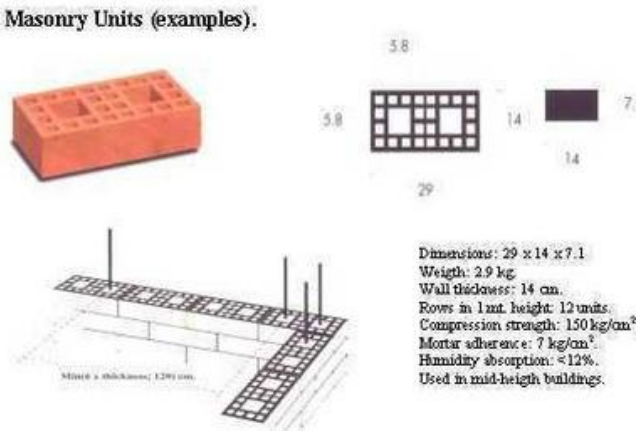


Image Source: http://www.cbecl.com/p/auto-bricks-manufacturing-plant.html

➢**Production and scaling challenges and opportunities**

•For this region, this is an appropriate clay product that can replace solid clay bricks in non-load bearing construction. It utilizes clay efficiently and also needs much less fuel/energy for production as compared to solid clay bricks.
•The scaling potential is high but high initial investment in the manufacturing and access to technology is a challenge.

➢**Limitations** Suitable for construction of non-load bearing walls only (though there are other variant of this product which can also be used for load bearing walls as claimed by the product manufacturer)



➢**Projects where used:**

Karnal Medical Centre, in Karnal, Haryana

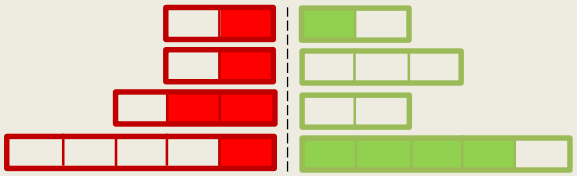
** 24 hours of work shift at manufacturing plant.

7.1.1.5 Hollow Clay Blocks

Green Information

Environmental Impact

Disposability
Resource Availability
Impact on Natural Systems
Energy



Net Green Score

➢**Embodied Energy***: 1200-1300 MJ/m^3

➢**Green Features**:

- Low energy consumption and CO_2 emissions in production
- Low raw material (clay) consumption
- Good insulation (lower K value) and hence lower operational energy
- Light weight building material

➢ **Conventional Counter part/s**:

Solid fired clay bricks (solid red bricks)

➢**Green Benefits* over counterpart:**

- ~ 50% reduction in embodied energy
- ~50% reduction in clay (raw material) consumption
- K value is 0.17 – 0.2** W/m-K as compared to K value of 0.52 to 0.85# W/m-K for conventional solid clay bricks.

**Greentech Knowledge Solutions Pvt. Ltd (GKSPL) analysis*
*** http://www.wienerberger.in/porotherm-clay-bricks-60-light-weight-than- solid-concrete-blocks/product-catalogue*

 # Appendix C: Default Values for Typical Construction - ECBC,2007

➢**Future assessment/ Potential**

- With the increase in high rise residential construction, this can be a competitor to AAC Blocks. But for that to happen, manufacturing capacity in the region as well as awareness about the product needs to be increased.
- Increase in supply has the potential to bring down the cost thereby making it affordable

1:http://www.wienerberger.in/porotherm-clay-bricks-60-light-weight-than-solid-concrete-blocks/product-catalogue,
2:Appendix C: Default Values for Typical Construction - ECBC,2007

➢**General info** : http://www.jindalbricks.in/123.pdf, https://media.licdn.com/mpr/mpr/p/7/005/084/3d5/1cd96e1.jpg, http://www.nexus.globalquakemodel.org/gem-building-taxonomy/overview/glossary/fired-clay-hollow-blocks-or-tiles--clblh

➢**Manufacturing:** http://www.cbecl.info/2012/12/auto-brick-making-process-and-equipment.html

➢**Specifications (BIS):** https://law.resource.org/pub/in/bis/S03/is.3952.1988.pdf

7.1.1.6 Hollow Concrete Blocks

General Information

➢**Brief Description:** The blocks are made by controlled mechanical compaction of a mixture of cement, sand(fine aggregates) and stone chips(coarse aggregates) in a mould. Strength, configuration and size of blocks can be designed as per requirements.

➢**Features**:

- Production process does not involve sintering and thus completely eliminates the burning of fossil fuels.
- It does not require steaming or autoclaving as the bricks are cured by water only.
- Low cost machinery and production setup.
- Lighter weight and better insulation than conventional solid concrete block masonry.
- Can be used for partially steel reinforced masonry (for up to 6 stories high construction)
- Mortar consumption can be reduced and plastering of surfaces can be reduced.

➢**Cost:** ~3000 Rs/m^3*

* Rates as surveyed in January 2016, varies with states acc. to applicable taxes

Fig. Hollow concrete Blocks used in wall construction

➢**Availability**

➢**Applicability**

•**Use** : Load bearing / reinforced/ non-load bearing infill masonry

•**Climatic Zone** : wide spread applicability across climatic zones.

➢**Availability**

▪ Is available across the region in limited quantities. The usage is limited to few applications such as boundary walls, small commercial complexes etc.

7.1.1.6 Hollow Concrete Blocks

Technical Information

➢**Raw Material :** Cement (10%), fine aggregates (30%) & coarse aggregates (60%)

➢**Manufacturing Scale** : 100-700 blocks/hour(block size 400x200x200 mm)

➢**Manufacturing :** Usually small scale manufacturing units using Concrete mixer, Hydraulic / Vibro Press and a few large scale manufacturing units having automatic plants.

➢**Applicable Standards/codes:**

- IS 2185-1 (2005): Concrete masonry units, Part 1: Hollow & solid concrete blocks
- Grade A (load bearing):Minimum block density of 1500 kg/m^3; Compressive Strength 3.5 – 15 N/mm^2
- Grade B — Block density between 1100 kg/m3 and 1500 kg/m^3; Compressive Strength 3.5 & 5 N/mm^2

http://www.engineeringcivil.com/testing-of-concrete-blocks.html

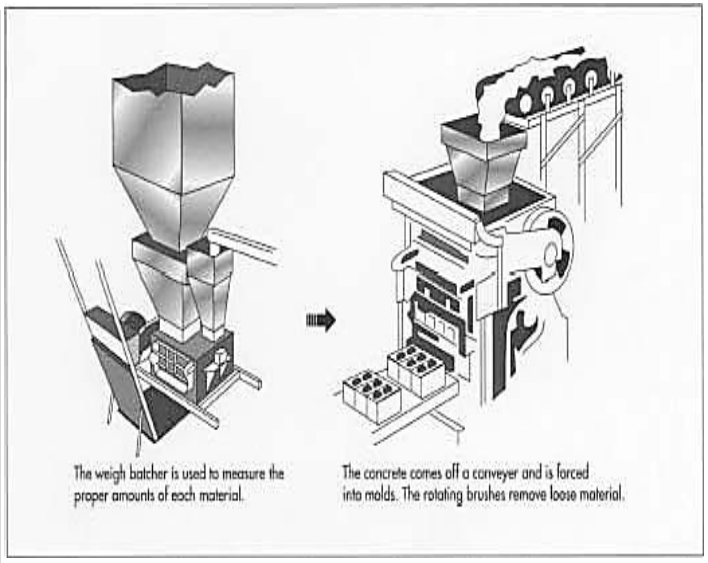


Image source: www.madehow.com

➢**Production and scaling challenges and opportunities**

Moving to complete automated production setups can reduce the quality variations. The low rise construction market can be penetrated through light weight hollow concrete blocks through consumer awareness about the product.

➢**Limitations :**

- Hollow concrete blocks are relatively heavier than its upcoming counterparts, which restricts it growth in high rise residential buildings where the demand is for lighter construction.
- For high quality blocks, coarse aggregates may not be available at all locations.

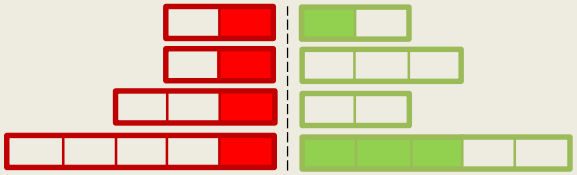
➢ **Projects where used:** High rise Housing projects across Punjab and Chandigarh

7.1.1.6 Hollow Concrete Blocks

Green Information

Environmental Impact

Disposability
Resource Availability
Impact on Natural Systems
Energy



Net Green Score

➢**Embodied Energy***: 800-900 MJ/m^3

➢**Green Features**:

▪Low energy consumption and CO_2 emission in production

➢ **Conventional Counter part/s**:

Solid fired clay bricks (solid red bricks)

➢**Green Benefits over counterpart:**

▪60-70% energy savings in production
▪CO2 emissions* in production of hollow concrete blocks is 0.144 t CO_2 / m^3 as compared to 0.219 t CO_2/m^3 for conventional red bricks.
▪K value ~0.5 ** W/mK which is comparable to 0.52 to 0.85# W/mK for conventional red bricks

**Greentech Knowledge Solutions Pvt.Ltd (GKSPL) analysis*
***http://www.movidaproject.eu/files/17_thermal_resistences%20D27.pdf*
 # Appendix C: Default Values for Typical Construction - ECBC,2007

➢**Future assessment/ Potential**

▪Reinforced hollow block masonry systems are very suitable and economical for low and mid rise buildings especially in earthquake prone areas. Increased use of waste materials (e.g. flyash) in its production can reduce its cost.

➢**General info** - http://www.engineeringcivil.com/m-15-mix-designs-as-per-is-10262-2009.html
➢**Manufacturing:** http://www.bmtpc.org/DataFiles/CMS/file/02_Concrete%20Hollow%20&%20Solid%20Block1.pdf
▪http://www.dcmsme.gov.in/reports/glass/hollowconcreteblocks.pdf, http://jkedi.org/EResources%5Chollowblock.pdf
▪http://www.eng-ent.com/hydraulic.html
➢**Specifications (BIS):** https://law.resource.org/pub/in/bis/S03/is.2185.1.2005.pdf

7.1.1.7 Thermo Insulated Concrete Blocks

General Information

➢**Brief Description:** Expanded Polystyrene (EPS) is sandwiched between two concrete layers to form an integral insulating masonry block.

➢**Features**:

- Saves operational energy for heating / cooling due to high insulating value and high thermal mass.
- Production process does not involve sintering and thus completely eliminates the burning of fossil fuels.
- Size : 400 X 200 X 200 mm.
- Offers sound attenuation of about 52 dB*, blocking out all major sounds and disturbances.
- Density : 1100-1200** kg/m3
- Precise surface reduces finishing plaster thickness.

➢**Cost:** Rs 145 per piece. (Rates as surveyed in 2015)

** http://www.ecologicbuild.com/insulated_block.html*

*** http://kjsconcrete.com/kjsconcrete/product_thermoInsulatedBlock.html*

Fig. Thermo Insulated Concrete Blocks

➢**Availability**

Currently being used in independent houses only. The application is scattered and limited in the region because of awareness of the product

➢**Applicability**

•**Use** : Outer walls of the buildings which provides insulation. Usable for non-load bearing masonry.

•**Climatic Zone** : Specially suitable for composite, hot and dry, and cold climate regions.

➢**Availability**

- It is a new building product with availability currently limited to few major cities across the region.
- Manufacturing is currently centered around NCR with distribution network having smaller reach.

7.1.1.7 Thermo Insulated Concrete Blocks

Technical Information

➢**Raw Material :** EPS- Polystyrene, Cement (10%), fine aggregates (30%) coarse aggregates (60%) for the concrete block*

➢**Manufacturing Scale:** N. A.

➢**Manufacturing :** In mechanized industries.

➢**Applicable Standards/codes:** EN 13163: 2012- Thermal Insulation products of buildings. Factory made expanded polystyrene (EPS) products. For hollow and solid concrete blocks IS 2185-1 (2005): Concrete masonry units

* Source : Ecologic

Machinery consisting of Concrete mixer, Hydraulic/Vibro Press, moulds

➢**Production and scaling challenges and opportunities**

The product has ideal thermal properties. Currently, there is low awareness about the product, as well as the cost is on higher side. Increased awareness and demonstration has the potential to increase the demand ; larger production volumes can also lead to reduction in cost.

Limitations :

Disposal of EPS is an environmental concern. With increase in high rise building construction, light weight building materials like AAC are preferred for their lighter weight in multi storey construction even though thermo insulated block give better thermal performance.

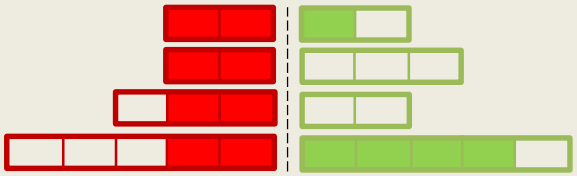
➢**Projects where used:** Independent houses, small scale residential, institutional construction in Delhi, NCR, Himachal Pradesh.

7.1.1.7 Thermo Insulated Concrete Blocks

Green Information

Environmental Impact

Disposability
Resource Availability
Impact on Natural Systems
Energy



Net Green Score

➢ **Embodied Energy**: 1400-1500* MJ/m^3 (embodied energy of EPS – 104** MJ/Kg)

➢ **Green features:**

- EPS is a by-product of petroleum industry which gets utilized in packaging and building industry (in form of insulation). Thermo insulated blocks utilizes EPS thus reducing waste.
- Good thermal insulation properties.

* Greentech Knowledge Solutions Pvt Ltd analysis
** http://eplusinternational.com/en/news/49-vaplatenata-energiya-na-toploizolatzionnite-materiali
# http://www.ecologicbuild.com/insulated_block.html

➢ **Conventional Counter part/s:**

Fired clay bricks

➢ **Green Benefits over counterpart:**

- U value of 0.44# W/m^2K as compared to 1.6 W/m^2k of conventional red bricks.
- 35-40% reduction in energy savings in production.

➢ **Future assessment/ Potential**

- The chief advantage of thermo insulated blocks is that it is a quick and effective way of building insulated non load bearing (generally external) walls. This is likely to be an ideal solution for single homes and mid rise buildings. Their relatively heavy weight limits its use in taller buildings where light weight building materials are preferred. These blocks are expensive which may limit their application to certain type of construction.
- There is a potential to utilize construction and demolition waste in the production of these blocks (in lieu of the fresh concrete cover over EPS).

➢ http://www.ecologicbuild.com/insulated_block.html
➢ **Manufacturing Process :** *https://www.youtube.com/watch?v=xgQyp-kfJSg*
➢ *Machinery :* **EG - Prometal** Europe, **Yinan Huarun Tianyuan Machinery Co. Ltd China**
➢ **Specifications** *: http://www.ecologicbuild.com/insulated_block.html*

7.1.1.8 Insulated Concrete Formwork

General Information

Brief Description: Hollow moulded forms are made from a high density, self extinguishing grade EPS (expanded polystyrene). These are used as a permanent shuttering system, where blocks are positioned like masonry and then concrete is poured in the cavity.

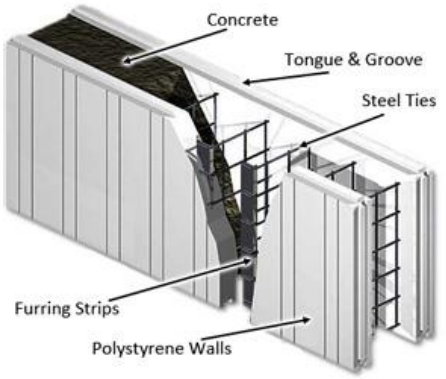


Fig. EPS Panel with core as concrete

➢Features:

- This is a load bearing wall construction system in which insulation is integral to the construction method.
- Modular in nature and pre-engineered for precision. Can be configured and designed for any type of plan.
- EPS being on the outer face of the wall, it needs a projective layer of waterproof plaster by specialized applicators.
- Energy savings due to low thermal conductivity.

➢**Cost:** Rs 10,000 per m^3 (construction cost with the technology)

* Rates as surveyed in January 2016.

➢Applicability

•**Use** : Inner concrete core can be designed for multistory load bearing construction.

•**Climatic Zone** : As the system uses substantial thickness of EPS, and provides high insulation it is suitable for predominantly cold climates or where air conditioning is a must.

➢Availability

- Availability is currently limited to few major cities.
- Manufacturing is currently centered around NCR with distribution network having wider reach.

➢Availability

Currently being used in independent houses. The application is scattered in the region depending on the awareness of product

7.1.1.8 Insulated Concrete Formwork

Technical Information

➢**Raw Material :** EPS- Polystyrene, water (for steam). Binding: high strength galvanized wire of 2.5to 3 mm dia. 3 -4 mm dia galvanized steel truss wire, plastic web, steel reinforcement *

➢**Manufacturing Scale:** N.A.

➢**Manufacturing :** In factory **

** 8 hours of work shift at manufacturing plant.

➢ **Applicable Standards/codes:**

- EN 13163: 2012- Thermal Insulation products of buildings
- CED 46 (8029) BIS Draft paper for pre fabricated building systems. http://www.bis.org.in/sf/ced/CED46(8029)_07092015.pdf

* (Source : Reliable insupack Industries)

➢**Production and scaling challenges and opportunities**

The ICF technique with EPS as the core and shotcrete as the external membranes could be suitable for applications of non load bearing walls where high level of insulation is desirable. The system cost being considerably higher than the conventional building techniques, the potential of growth will be limited to projects in cold climates or where the air conditioning is the norm.

➢ **Limitations :**

Disposal of EPS has become an acute environmental concern. Not convenient where walls may be chased and equipment / storage units be hung from walls.

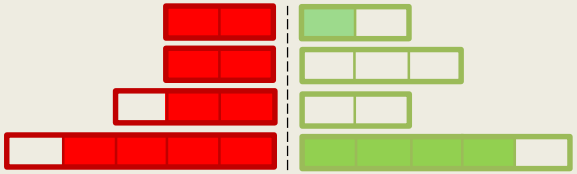
➢**Projects where used:** Some industrial and commercial construction in Delhi and NCR.

7.1.1.8 Insulated Concrete Formwork

Green Information

Environmental Impact

Disposability
Resource Availability
Impact on Natural Systems
Energy



Net Green Score

➢ **Embodied Energy:** N.A.

➢ **Green features:**

▪Highly insulative system of wall construction.

➢ **Conventional Counter part/s:**

Fired clay bricks or any other block work materials for wall.

➢ **Green Benefits over counterpart:**

▪Reduction in energy consumed to cool or heat buildings due to thermal resistance (50 mm in thickness) is 0.825 m^2.k/w.

➢ **Future assessment/ Potential**

- Not suitable for housing projects in this region. Potential is limited.
- May be suitable for very cold climate and regions with limited accessibility.

▪ http://epsa.org.au/about-eps/what-is-eps/properties-of-eps/, *www.**epa**ck.in/**eps-panels**/*

➢ **Manufacturing Process :** *http://eps-block-machine.com/EPS-Production-Line/what-is-eps.html*

➢ **Specifications** *: http://www.prefabricated-houses.com/eps-panels.html*

http://www.thermalinstallations.com.au/insulated-panel-products/thermlock-eps-panel/technical-specifications, *www.bmtpc.org/.../Annex-03_TECHNOLOGY%20PROFILE_**EPS**.pdf*, *http://www.greenspec.co.uk/building-design/insulation-oil-derived/*

7.1.1.9 Construction & Demolition Waste Blocks

General Information

➢**Brief Description:** It is a dense solid block produced by compacting a mixture of cement (20-25%), crushed demolition waste (65-70%), admixture (5-15%) and water. Its usage has been initiated under a pilot project of National Buildings Construction Corporation and New Delhi Municipal Corporation.

Fig. C&DW Blocks used in wall construction

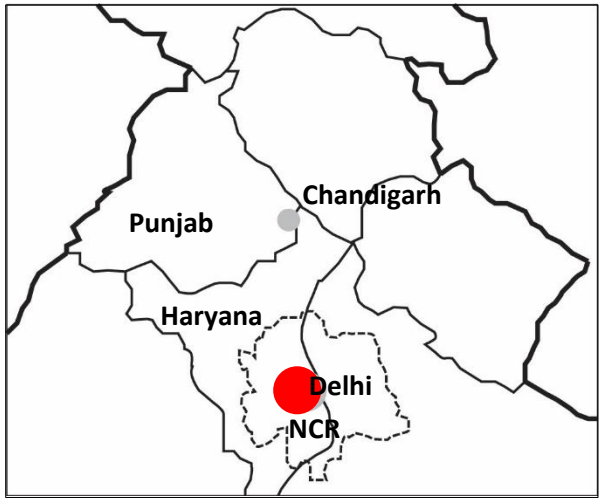
➢**Features**:

- Makes productive use of construction & demolition waste.
- Heavier than traditional bricks, increases overall dead load of a building, therefore currently being used in lower floor constructions (of multi-storey buildings) only. Density range: 1600 - 1850 kg/m^3 , Compressive strength: 6.75 N/mm^2
- Due to addition of admixtures, need of curing the blocks is only once in first 24 hours.
- Low cost machinery and production set up.
- It is produced in modular (230X110X65mm) and other customized sizes

➢**Cost:** 5500 – 6300 Rs/m^3 of material

* Rates as surveyed in February 2016, varies with states acc. to applicable taxes

➢**Availability**



Manufactured & used in pilot project by NBCC and NMC in Delhi.

➢**Applicability**

- **Use** : Suitable for load bearing construction.
- **Climatic Zone** : Suitable for hot dry and composite climates.

➢**Availability**

- Availability depends upon construction waste collection in urban areas where demolition waste is available due to a process of urban regeneration.

7.1.1.9 Construction & Demolition Waste Blocks

Technical Information

➢**Raw Material :** Construction & demolition waste (65-70%) break up – {soil, sand & gravel -36%, bricks & masonry - 31%, concrete -23%, metals – 5%, Bitumen – 2%, timber residue -2%, others -1%} Cement (20-25 %), Admixture (5-15 %) and water.*

➢**Manufacturing Scale :** ~ 50,000 units/day **

➢**Manufacturing :** In factory / In situ

➢**Applicable Standards/codes:**

- N.A.

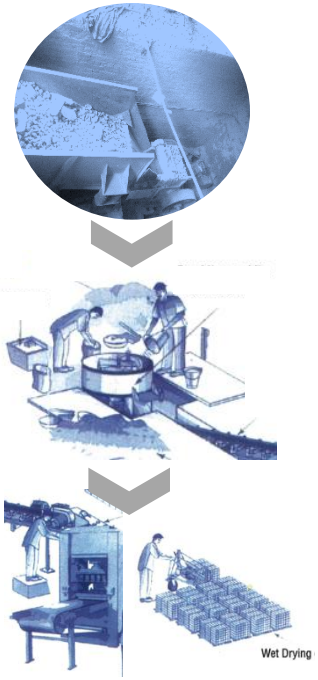
Process of Manufacturing

Collection + segregation of demolition waste

70 mm sieving & crushing | 50 mm sieving & crushing | 20 mm sieving & crushing

Cement, admixture and water addition

Moulding, Drying & Curing



➢**Production and scaling challenges and opportunities**

C&D waste bricks are still in a very nascent phase of product development. The challenge lies in optimizing the compressive strength vis-à-vis density to achieve cost efficiency. It can further be developed in load and non load bearing variants for various other walling needs. Technical know-how of the admixtures being used is proprietary.

➢**Limitations :** It is not suitable for light weight construction. At the present, its being used as an (over designed) infill walling material.

➢**Projects where used:**

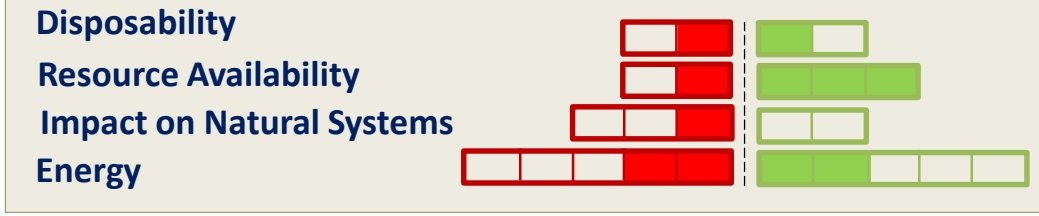
Redevelopment of Kidwai Nagar, Delhi (lower floors only).

* http://dpcc.delhigovt.nic.in/pdf/construction-demolition.pdf
** 10 hours of work shift at manufacturing plant.

7.1.1.9 Construction & Demolition Waste Blocks

Green Information

Environmental Impact



Net Green Score

➢**Embodied Energy**: 1350-1450 MJ/m^3
excluding the embodied energy of admixtures

➢**Green Features**:

- Makes productive use of construction & demolition waste.
- High density of block provides for good acoustic insulation.

➢ **Conventional Counter part/s**:
Solid fired clay bricks (solid red bricks)

➢**Green Benefits over counterpart:**

- 35-40% reduction in embodied energy as compared to conventional bricks.
- 60-70 % composition is construction and demolition waste.

➢**Future assessment/ Potential**

- With applicability across many climates, the acceptance and use is expected to see growth in new constructions across the big cities.
- The increase in R&D has potential to bring down the cost and make it usable in affordable segment.
- This technology can be developed for non-structural precast products like walls, jalis & grills panels.
- Scope of flyash addition in C&D waste blocks is yet to be tested.

➢**Pilot Initiative :** http://www.cdeglobal.com/news/516/cd-waste-processing-in-india-delhi-shows-the-way
➢**Machinery Set up :** Vibrating Screen, Hammer Crusher, Sieve, Sand mill, Belt Conveyor, Pan mixer, Hydraulic Press.
➢**Manufacturing Process :** Experience of the first commercial scale pilot project for C &D Waste Management in India – IL&FS , Environmental Infrastructure & Services Ltd
➢ **Scientific Journal :** Dakwale VA & Ralengaonkar RV, IJEMS 21(4) 451-457

7.1.1.10 Cement Fibre Board – Wall Panels

General Information

Brief Description: These are light weight cement fiber boards which can be used in dry wall construction. These are manufactured from a homogenous mixture of Portland cement, treated cellulose fibers, finely ground silica quartz and other mineral fillers. Cement acts as binder, and cellulose fibers interlock with cement and quartz matrices to add strength to the boards. These are cured by autoclaving processes.

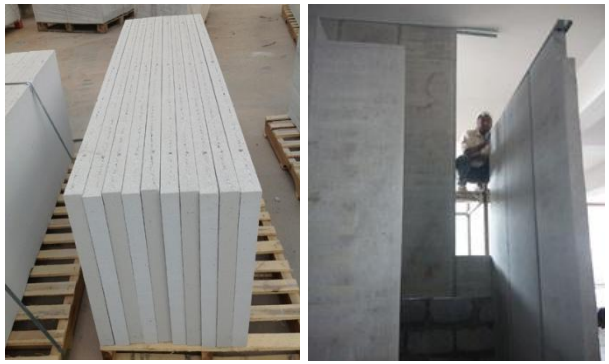


Fig. cement fiber board ; Interior dry wall construction

➢**Features**:

- Non combustible material and fire rated for 2 hours.*
- Good thermal insulation with moisture resistance.*
- Light weight (density 750-850kg/m^3) easy to handle.*
- Low insulation upto 40dB for 75mm*
- High workability, can be dismantled and relocated but needs to be handled with care. Takes ¼th of time to erect a wall as compared to conventional masonry wall.
- Available in sizes 3000x600, 2700x600, 2400x 600 mm in 50 and 75mm thickness.

➢**Cost:** 1800 - 2200 Rs/m^2 of walling area (for 50mm thickness) **

*http://www.everestind.com/products/wall-solutions

**Rates as surveyed in January 2016, varies with states acc. to applicable taxes

➢**Availability**

Manufactured & supplied across the regions with concentration around NCR and major cities.

➢**Applicability**

•**Use** : Internal and external dry walls

•**Climatic Zone** : applicability independent of climatic zones for internal use

➢**Availability**

▪ There are limited number of suppliers for cement fiber board-wall panels with concentration around Delhi and NCR.

7.1.1.10 Cement Fibre Board – Wall Panels

Technical Information

➢**Raw Material :** Cement (20-30%), Silica (58.5-68.5%), Pulp (5.5-10.5%) and Additives (2-5%)*

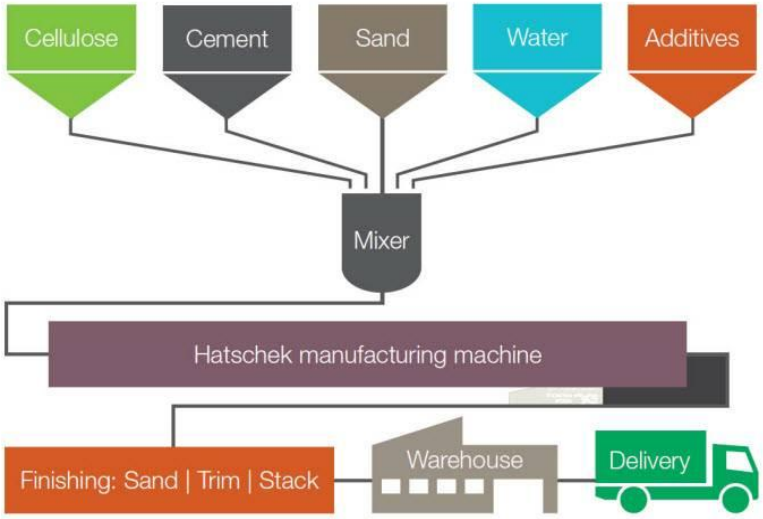
➢**Manufacturing Scale** : 2-20MT/hr (approx. 2.5-25 m^3/hr)**

➢**Manufacturing :** In factory

➢**Applicable Standards/codes:**

• CED 4(7782) : Draft under process : Dry wall and partitioning using cement/gypsum based boards

*http://www.google.com/patents/WO2004087412A1?cl=en
**http://www.wehrhahn.de/en/fibre/plants/index.php



➢**Production and scaling challenges and opportunities**

- With rising demand for pre fabricated systems to engender speedy construction, cement fiber board wall panels have a good potential to become a preferred material for dry wall construction.
- With pan-India availability of raw materials, new manufacturing units of cement fiber board wall panels can be set up in this region.

➢ **Limitations :** Low consumer awareness with lesser presence of manufacturers in this region limits the demand and use of cement fiber board panel system in dry wall construction.

➢**Projects where used:**

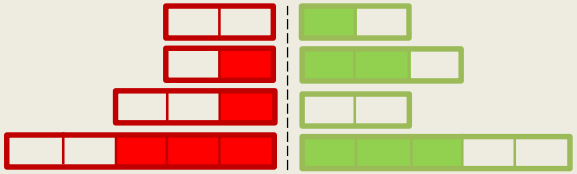
Industrial and institutional projects in the region

7.1.1.10 Cement Fibre Board – Wall Panels

Green Information

Environmental Impact

Disposability
Resource Availability
Impact on Natural Systems
Energy



Net Green Score

➢**Embodied Energy**: 1000-1100* MJ/m^3
Excluding the embodied energy of pulp and additives

➢**Green Features**:

- Low thermal conductivity.
- Low energy consumption and CO_2 emissions in production.

* Greentech Knowledge Solutions Pvt Ltd Analysis
**http://www.wehrhahn.de/en/fibre/plants/index.php
Appendix C: Default Values for Typical Construction - ECBC,2007

➢ **Conventional Counter part/s**:
Timber paneling / bricks

➢**Green Benefits over counterpart:**

- 40-50% reduction in embodied energy
- Mined Raw Materials content in Cement fiber boards 800-900* kg/m^3 as compared to 1600-1900 kg/m^3 in red bricks.
- K value of 0.16** – 0.21 W/m-K as compared to 0.52# to 0.85 W/m-K

➢**Future assessment/ Potential**

- With rise in demand for light weight and fast paced construction system, cement fiber board wall panel as a dry walling material is expected to gain ground because of its high workability paired with desirable thermal behavior.

➢ **Manufacturers:** http://www.everestind.com/products/wall-boards, http://www.everestind.com/products/wall-boards
➢ **Manufacturing Set up:** http://www.wehrhahn.de/en/fibre/plants/index.php, http://www.intraautomation.com/index.html
➢ **Manufacturing Process:** http://www.yunionboard.com/2015/02/fiber-cement-board-manufactured/
➢ **Specifications (BIS):** https://law.resource.org/pub/in/bis/S03/is.14862.2000.pdf

7.1.2 Fact sheets on Building Components

7.1.2.1 Ferrocement

General Information

➢**Brief Description:** It is a form of fine and dense reinforced concrete using closely spaced multiple layers of galvanized mesh/small diameter rods completely infiltrated with, or encapsulated in mortar of cement and fine aggregate. Ferrocement can be shaped to make for roofing elements, doors and windows, tanks and wall panels. It is an alternative to conventional RCC for roofs and floors.

➢**Features**:

- It is highly versatile material which can be used to create various building components, varying the content of steel/wire mesh reinforcement.
- It's thickness rarely exceeds 25mm, while counterpart RCC components are seldom less than 75mm (Compressive strength range: 4-7.5 KN/mm^2) *
- It avoids shrinkage cracks. It is waterproof and long lasting.
- It has high tensile strength-to-weight ratio as compared to RCC.

* http://www.gnshousing.org/index.php/search-results/item/242-ferrocement-embodied-energy-in-different-walling-systems

➢**Cost:** varies, but it has been seen 15-20% cheaper than conventional counterpart **

** Rates as surveyed in January 2016, varies with states acc. to applicable taxes

➢**Applicability**

Use : structural shell roofing, door & window frames shutter, kitchen & miscellaneous counter slabs, partition wall panels, lintels & sun shades, water tanks etc.

Climatic Zone : N.A.

➢**Availability**

- Construction is on site or prefabricated.
- Projects like Bhawana Industrial Housing, Delhi exhibits very extensive and efficient use of pre fabricated elements like Ferrocement lintels , kitchen slabs, staircases etc.

Fig. Cross section of Ferrocement

➢**Availability**

Used across the region for sub components and roof/ floor construction.

7.1.2.1 Ferrocement

Technical Information

➢**Raw Material :** Fly ash (55-60%), Gypsum (2-3%), Cement (10-12%), Lime (12-14%) and Aluminum Powder (0.03%) #

Source : Development Alternative

➢**Manufacturing Scale** : varies, small to medium scale industrial set up

➢**Manufacturing :** In factory / in situ

➢**Applicable Standards/codes:**

- IS: 1489-1991 , IS: 2502:1963
- IS: 13356:1992 for Ferrocement water tanks
- CED 2 (7922) (BIS document on cement concrete and Ferrocement)

➢**Production and scaling challenges and opportunities**

Requires good artisanal skills and careful preparation of raw materials. As an economical solution to many building components , Ferrocement has a great potential for scaling. The reliable quality production requires technical control and good artisanal skills.

➢**Limitations :** Being a slender relatively light weight material, it is not very conducive to attain thermal comfort. Therefore, when used at structural slab, it should be insulated enough (U value range: 0.2W/m^2K for 200 mm thk) .





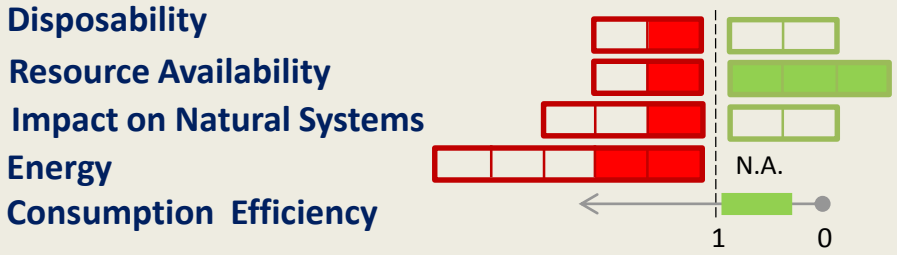


➢ **Forms of Use :** (From left top most, in a clockwise direction) Door shutters, window frame, internal wall partition, shell roof, prefabricated vaulted roof, staircase.

7.1.2.1 Ferrocement

Green Information

Environmental Impact



Net Green Score

➢**Embodied Energy**: 500- 700 MJ/m^2 approx. *
*http://www.agpworkshops.com/atach_ments/EGM/SESSION_03_AUROVILLE.pdf

➢**Green Features**:

- Efficient use of materials.
- High longevity with relatively no maintenance $

$ http://www.devalt.org/newsletter/jun96/of_5.htm

➢ **Conventional Counter part/s**:
RCC, timber, PVC

➢**Green Benefits over counterpart:**

- Despite using materials with high embodied energy, it utilizes little material to satisfy the functional requirements of building components.

➢**Future assessment/ Potential**

- With precast technology, it is high recommendable for creating mass components for housing projects like railings, wall panels, chaukath, chajjas, shading devices, door shutters etc.

- http://www.ferrocementindia.com/
- http://www.devalt.org/newsletter/jun96/of_5.htm
- http://www.csir.res.in/external/heads/achievements/Rural/tech/detail.asp?g=2&s=9&t=3

➢**Manufacturing Process** http://www.cipremier.com/e107_files/downloads/Papers/100/26/100026040.pdf
➢http://www.bmtpc.org/topics.aspx?mid=90&Mid1=233

7.1.2.2 Bamboo composite door shutters

General Information

➢**Brief Description:** Bamboo composite door shutters are primarily made up of bamboo mat, hybridized with other reinforcement materials saturated with polymeric resin and then processed under high temperature and pressure by compression moulding technique. They give comparable performance to plastics and plywood doors in terms of strength, durability and resistance to termite.

➢**Features**:

• Heat (thermal conductivity value range: 0.17 – 0.23 W/mK) [$] & sound insulative.

($ Source: http://www.jmaterenvironsci.com/Document/vol3/vol3_N6/112-JMES-322-2011-Mounika.pdf)

• Negligible environmental impact.

• Light weight, high strength & good stiffness (density: 500 kg/m3) & water resistant.

• Maintenance free & available in various colors.

• Available in standard thickness of 35, 40 & 65 mm. (^Source : RV TIFAC composite design centre)

Other variants (natural fibers + synthetic resins) available in composite board form to create door/window shutters are – coir composite board, bagasse composite shutter & jute composite shutter

➢**Cost:** Rs 1250-1750/m^2 of shutter area *

* Rates as surveyed in January 2016, varies with states acc. to applicable taxes

➢**Applicability**

•**Use** : Appropriate for dry areas and wet areas door shutter.

•**Climatic Zone** : Applicable across all climatic zones.

➢**Availability**

▪ Product is made in eastern and southern parts of country and sold locally. As a green substitute it could be imported in the region.

Fig. Bamboo composite door shutters

➢**Availability**

Not produced in this region. Suppliers are in NCR only.

7.1.2.2 Bamboo composite door shutters

Technical Information

➢**Raw Material :** (Natural Fibres) Bamboo/ Bagasse/coir (83%) and Synthetic resin (17%) ^

➢**Manufacturing Scale** : ~ 200 shutters/day ^ **

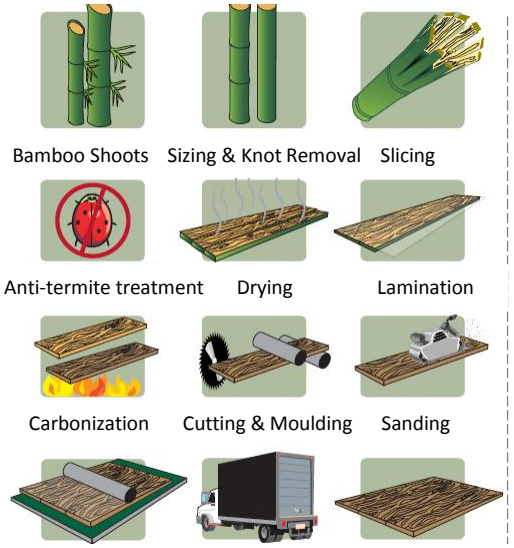
(^Source : RV TIFAC composite design centre)
** 8 hours of work shift at manufacturing plant with 8 people man power.

➢**Manufacturing :** In factory

➢**Applicable Standards/codes:**

- BIS Technical Document (Draft in circulation): CED 11 (7700) Phenol Bonded Bamboo – Jute Composite Hollow Door Shutter, CED 11 (7701) Phenol Bonded Bamboo – Jute Composite Solid Panel Door Shutter

Processing



Manufacturing set up

➢**Production and scaling challenges and opportunities**

Setting up of organic fiber composite building industry (particularly bagasse)which is abundantly available locally and involves a small scale infrastructure can be encouraged in this region.

Coir composite boards have been pilot tested in Karnataka Housing Board projects. Bagasse and Jute composite door shutters are under R&D and not commercially available as yet

➢**Limitations :**

Where high acoustic barrier performance is expected of a door shutter, only high density bamboo composite (beyond 650kg/m^3) is suitable. #

(source : TV TIFAC composite design centre)

➢**Projects where used:** (generally pilot initiatives)

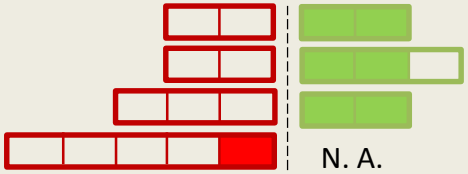
Karnataka State housing pilot project in Kengeri, Bangalore;
Prefab house door shutter, IPRTI, Gujarat

7.1.2.2 Bamboo composite door shutters

Green Information

Environmental Impact

Disposability
Resource Availability
Impact on Natural Systems
Energy



Net Green Score

➢**Embodied Energy**: 1.8 – 2.0 MJ/kg

(source : http://www.saitm.edu.lk/fac_of_eng/RSEA/SAITM_RSEA_2013/imagenesweb/40.pdf)

➢**Green Features**:

- Bamboo as a material has lower embodied energy than timber.
- Bamboo composite shutters are (80%) biodegradable.
- It performs at par with wood / wood composite as an acoustic barrier.

➢ **Conventional Counter part/s**:

Timber, Steel & U-PVC shutters

➢**Green Benefits over counterpart:**

- Biodegradable & recyclable as a material
- Involves less embodied energy than conventional counterparts
- Raw material has shorter harvesting cycle than timber.

➢**Future assessment/ Potential**

- Challenge lies in developing the composite in a manner which is easily biodegradable and gets back to the environment with least negative impact.
- In this region there is a good potential for bagasse based products since it is a by-product of the large and existing sugar industry.

- https://www.researchgate.net/publication/274610006_A_review_on_Biodegradability_of_Hybrid_BambooGlass_fiber_polymer_composites
- **Machinery Set up:** http://ipirti.gov.in/facilities.html
- **Manufacturing Process:** http://tifac.org.in/index.php?option=com_content&view=article&id=474&Itemid=190
- **Specifications:** http://www.bamboocomposites.com/bamboomatmouldedskinboard.html
- http://www.bmtpc.org/admin/PublisherAttachement/Bamboo%20A%20Material%20for%20Cost%20Effective%20and%20Disaster%20Resistant%20HousingAtt.pdf

7.1.2.3 Micro Concrete Roofing Tile

General Information

Brief Description: MCR are light weight interlocking roofing tiles for sloping roofs. The commonly used size is 450mm X 300mm. They are made from cement mortar, which is vibrated on a table at a controlled frequency, set on a mould to shape and further cured for strength. The mortar mix is vibrated for about 45 seconds and then transferred on to a High Impact Polyethylene to give the tile profile. After initial setting for 24 hours, they are water cured for 7 days.

Fig. MCR Tiles used in roofing construction

➢Features:

- Lighter than other traditional roofing tile elements. (Density range: 225 kg/m^3)
[source: Development Alternative]
- Non-combustible and fire resistant.
- Can resist hailstones.
- Can be pigmented in different colors.

➢Cost: Rs 90 – 110/m^2 of roofing *

* Rates as surveyed in January 2016, varies with states acc. to applicable taxes

➢Applicability

•**Use** : Pitched roofing

•**Climatic Zone** : Light weight roofing material suitable for open spaces requiring shade and protection against rain.

➢Availability

- Can be produced at any location.
- Manufacturing is possible in remote locations with a small capital investment.

➢Availability

With decentralized local manufacturing, it has been used in small scaled projects across the region.

7.1.2.3 Micro Concrete Roofing Tile

Technical Information

➢**Raw Material :** Cement (20%), Fibres (5%), Graded sand (50%), Stone grid (25%)

➢**Manufacturing Scale** : ~ 200 tiles/day ** (Source: Development Alternatives)

** 8 hours of work shift at workshop, with 1 skilled and 2 non skilled manpower.

➢**Manufacturing :** In workshop

➢**Applicable Standards/codes:**

- IS code : NA
- BMTPC http://www.bmtpc.org/topics.aspx?mid=90&Mid1=240

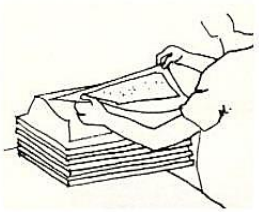
1.

Placing polythene interface sheet

2.

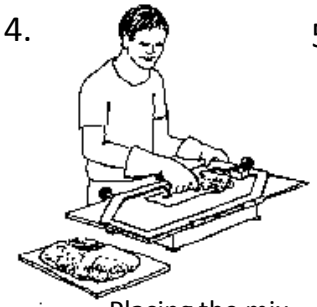
Fixing frame holding catch

3.



Compacted mix on mould

4.

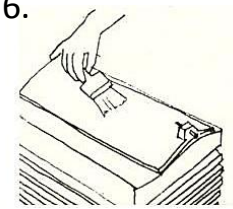


Placing the mix under vibration

5.

Smoothing under vibration

6.



Closing cracks with brush and cement mixture

➢**Production and scaling challenges and opportunities**

Growth has picked up in the low rise building construction market because of easy installation and lower cost of construction. Even in affordable housing (mid rise) construction, it can be used for *chajjas* and other like shed like elements.

➢**Limitations :**

- It is only meant for sloping roofs.
- Poor thermal barrier (U value range: 1-2W/m^{2}K) [source: Development Alternative]
- MCR tiles have shown the instances of cracking due to high diurnal temperature variations. Addition of linear fibers in the mortar mix can resist cracking.

➢**Projects where used:**

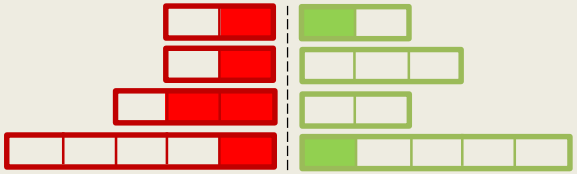
Model eco village Housing, Punjab

7.1.2.3 Micro Concrete Roofing Tile

Green Information

Environmental Impact

Disposability
Resource Availability
Impact on Natural Systems
Energy



Net Green Score

➢**Embodied Energy**: 900-1100 MJ/m^3
(source: Development Alternative and Ashok B Lall Architects)

➢**Green Features**:

- It produces waterproof, long lasting roofing with minimum consumption of raw material. (compressive strength range: 80 kg / tile)

(Source: Ashok B. Lall architects)

➢ **Conventional Counter part/s**:
Mangalore / Burnt brick tiles

➢**Green Benefits over counterpart:**

- Weighs almost 25% of Mangalore tiles.
- Low embodied energy as compared to conventional counterpart as no heat, burning and fusing is involved in manufacturing process.

(Source: Development Alternatives)

➢**Future assessment/ Potential**

- A scalable building component for all low rise affordable housing roofing, chajjas and shed covering material.

- http://www.sankalpacmfs.org/arts/04sshe/mcrt.html
➢**Machinery Set up** http://www.taramachines.com/TARA-Micron.aspx
➢**Manufacturing Process:** http://www.naturalbuildingblog.com/low-cost-roof-tile-manufacture-mcr/
➢http://www.dongyuegroup.com/product/index.asp
➢**Status:** http://www.devalt.org/newsletter/mar92/of_1.htm

7.1.2.4 Parquet Flooring

General Information

➢**Brief Description:** It is a flooring method consisting of geometric mosaic of (fresh / recycled) timber. It uses recycled/waste timber from other such sources, cut into small pieces (200 - 300 mm long 100 - 150mm wide and 15 – 25 mm thick), installed using adhesives on a structural sub-floor. This cuts down on raw material cost and gives an flooring using recycled natural material.

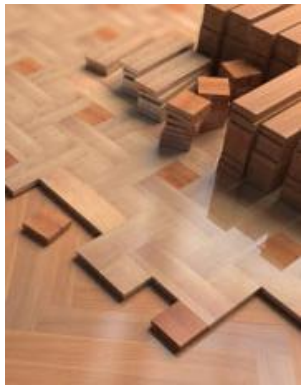


Fig. Parquet flooring

➢**Features**:

- Has heat insulating properties (Thermal conductivity value range: 0.14 – 0.17W/m^{2}K)

[source : http://www.new-learn.info/packages/clear/thermal/buildings/building_fabric/properties/conductivity.html]

- Least negative impact on environment.
- Light weight flooring finish.
- Can be produced from a variety of timbers.

➢**Cost:** Rs 450-700/m^2 of floor area *

➢* Rates as surveyed in January 2016, varies with states acc. to applicable taxes

➢**Availability**

Available across the main cities of the region.

➢**Applicability**

•**Use** : Appropriate for floors with low to moderate usage.

•**Climatic Zone** : Applicable across all climatic zones.

➢**Availability**

- Largely available with retail agents and suppliers in all major cities of the region. These suppliers have specialized applicators.

7.1.2.4 Parquet Flooring

Technical Information

➢**Raw Material :** recycled timber

➢**Manufacturing Scale** : details not available, small scale industrial set up

➢**Manufacturing :** In factory

➢**Applicable Standards/codes:**

- IS:5389-1969
- IS:9472-1980

➢**Production and scaling challenges and opportunities**

Since it uses waste timber, its scaling production is allied to other production of timber products and thus it can't be produced in large volumes. It needs small plant installed near timber waste production.

➢**Limitations :**

- Parquet flooring has been prone to moisture penetration and termite infestation.
- Timber needs maintenance by oiling / polishing.
- Needs a firm, moisture proof sub-floor.
- Not suitable for high traffic areas.

Fig. Cycle of wood

Fig. Parquet flooring Installation (from recycled wood)

➢**Projects where used:**

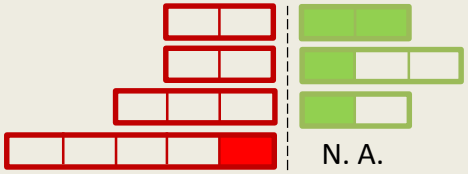
Individual houses in the region

7.1.2.4 Parquet Flooring

Green Information

Environmental Impact

Disposability
Resource Availability
Impact on Natural Systems
Energy



Net Green Score

➢**Embodied Energy:** 2MJ/kg
(source: http://ohp.parks.ca.gov/pages/1054/files/embodied%20energy.pdf)

➢**Green Features:**

- Uses recycled wood as raw material.
- Carbon absorbing and biodegradable.
- Can be attained sourced locally, involving minimum transportation.

➢ **Conventional Counter part/s:**
Stone / ceramics flooring

➢**Green Benefits over counterpart:**

- Biodegradable & recyclable flooring material
- Uses waste timber as raw material
- Low embodied energy
- Light weight flooring material (density 450-700 kg/m^3) as compared to conventional stone/ ceramics (2000 kg/m^3).

➢**Future assessment/ Potential**

- Can be an economical green alternative to ceramic floor tiling where timber pieces are a by-product of timber based manufacture.
- Possibility is to replicate same system in engineered bamboo board with appropriate edge / sealing detail, for mass housing projects.

- http://www.designlife-cycle.com/hardwood-flooring/

➢**Specifications:** https://law.resource.org/pub/in/bis/S03/is.5389.1969.pdf
➢ https://law.resource.org/pub/in/bis/S03/is.3670.1989.pdf

7.1.2.5 Expanded Polystyrene (EPS) & Extruded Polystyrene (XPS)

General Information

➢**Brief Description:** These are polystyrene based thermal insulation materials, available in form of rigid boards. EPS is made out of expansion process of polystyrene into a mole whereas XPS is made out of an extrusion process. XPS performs better than EPS because its homogenous closed cell structure does not allow water to get absorbed.

➢**Features**:

- Since EPS & XPS fall under same manufacturing standards, EPS is white (colour coded) and XPS is available in blue, pink and yellow etc. colours.
- The boards are available with interlocking profiles. This avoids any gaps in the insulating layer.

Advantages	Disadvantages
• Recyclable, high longevity	• Direct exposure to sun deteriorates its properties
• High R-value, negligible thermal transmittance	• Some solvents can cause an irreversible damage to physical composition of polystyrene.
• Doesn't support growth of mold	• Melts beyond 240 deg Celsius, is flammable.

(Source: Owen Corning, XPS and EPS comparison)

➢**Cost:** Rs. 350-550/m^3 *

* Rates as surveyed in January 2016, varies with states acc. to applicable taxes

➢**Applicability**

•**Use** : For insulation of roofs and walls

•**Climatic Zone** : Traditional construction in this region utilizes capacitive thermal resistance rather than insulative resistance. However with walls and roofs becoming thinner, use of insulating layer over external roof/wall surfaces improves their thermal performance.

➢**Availability**

- Available across major cities in the region, with concentration around Delhi, NCR & Chandigarh

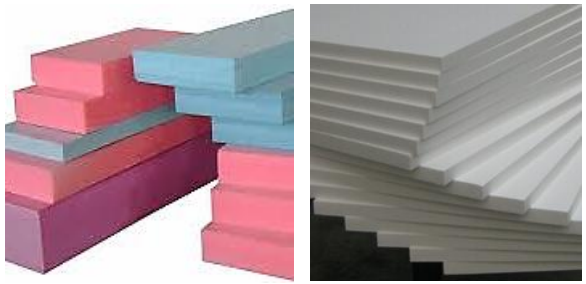


Fig. XPS & EPS insulation boards

➢**Availability**

Manufacturers spread across major cities in the region, with concentration around Delhi, NCR & Chandigarh.

7.1.2.5 Expanded Polystyrene (EPS) & Extruded Polystyrene (XPS)

Technical Information

➢**Raw Material :** Polystyrene

➢**Manufacturing Scale** : ~ 900 Sq.m/day

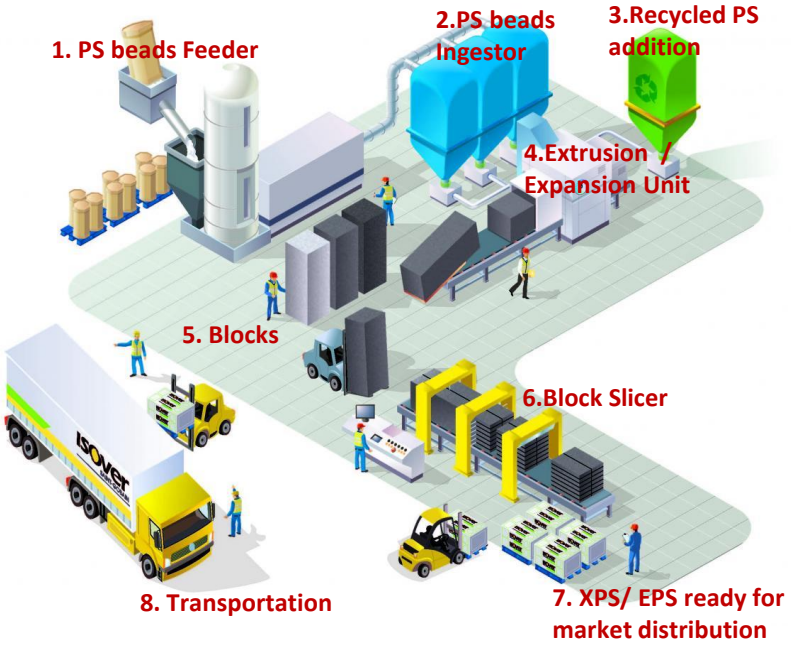
(source: Reliable insupack manufacturing data

** 8 hours of work shift at manufacturing plant.

➢**Manufacturing :** In factory

➢**Applicable Standards/codes:**

- IS 4761-1984 (Rev 2004) expanded polystyrene for thermal insulation in buildings.



➢**Production and scaling challenges and opportunities :**

- The demand for XPS / EPS insulation boards is growing steadily as the thermal resistance in roofs and east/ west facing walls is felt to be necessary in order to achieve indoor thermal comfort. Most EPS manufacturing units produce EPS for disposable packaging. These can be easily adapted for manufacturing insulation boards for buildings.
- The XPS production system is only for manufacturing extrusions. Investments in XPS production units require substantial demand in extruded products. Such demand is likely to grow with expectation of better thermal comfort and air-conditioning.

➢ **Limitations :**

- The raw material is a by-product of the petroleum industry.
- The insulation boards need to be protected from mechanical damage and water egress.

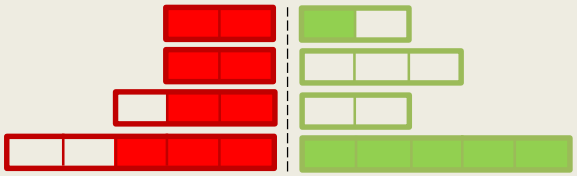
➢**Projects where used: N. A**

7.1.2.5 Expanded Polystyrene (EPS) & Extruded Polystyrene (XPS)

Green Information

Environmental Impact

Disposability
Resource Availability
Impact on Natural Systems
Energy



Net Green Score

➢**Embodied Energy:** Expanded polystyrene: 2080-3780 MJ/m3
Extruded polystyrene: 2200-2850 MJ/m3

(source : Wikipedia, embodied energy of building insulation materials)

➢**Green features:**

- High operational cost savings.
- Recyclable many times, if dismantled carefully.
- High product longevity
- High R- value
- XPS is water-resistant

➢ **Conventional Counter part/s:**

Mud Phaska, Brick bat Koba

➢**Green Benefits over counterpart:**

- Since EPS/XPS is a very efficient insulating material with high R-value, the volume of material required to attain thermal comfort is substantially low. It is a light weight material. Therefore, also reducing the deadweight substantially.
- It is easier to work (comes in boards) with as compared to its traditional counterparts, i.e. *mud phaska, brick bat koba* etc.

➢**Future assessment/ Potential**

- While using for wall or roof insulation in residential buildings, it needs to be used paired with wall and roof construction of reasonable thermal mass. Insulation will reduce operational energy for cooling/heating of indoor spaces. Its demand will grow with the expectation of better comfort in homes.
- As it is a non biodegradable product, its use may require guarantees for safe recovery and recycling.

- https://igbc.in/igbc/html_pdfs/technical/Building%20Insulation.pdf
- http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.639.9633&rep=rep1&type=pdf
- http://www.owenscorningindia.com/ocindia/Building_Material/Foamular%5Cfoamular.asp, http://ww3.owenscorning.com/sciencedoesntlie/
- **Manufacturing Process:** https: //www.youtube.com/watch?v=DUQyEuH4PIo
- http://beepindia.org/sites/default/files/IIF%20-%20Case%20Studies.pdf

7.1.3 Fact sheets on Integrated Structural Systems

7.1.3.1 Pre cast concrete construction systems

General Information

➢**Brief Description:** Precast concrete elements are produced by casting concrete in a reusable moulds for building components like walls, columns, beams, staircase and floor slabs etc. It is then cured in a controlled environment, transported to the construction site and lifted into place.

➢**Features**:

- Mass production of building components, increases speed and reduces time for on-site construction.
- Uniform quality and size for similar panels.
- Highly mechanized system, reduces labor component and external / internal plastering can be avoided
- Saves on water for on-site casting curing.
- Precast concrete is designed to withstand the most common corrosive agents.

➢**Cost:** 8000-9000 Rs/Sqm

* Rates as surveyed in November 2015, varies with states acc. to applicable taxes

➢**Applicability**

•**Use** : All stories of load/non-load bearing construction. High rise mass housing projects.

•**Climatic Zone** : Concrete surfaces need insulation in this climatic regions.

➢**Availability**

- Large real estate developers have set up their own in-house production capacities.
- Specialized companies offering precast concrete system for the general market are not yet established.

Fig. Precast concrete wall

Fig. Precast hollow core slab

➢**Availability**

Specialized companies offering precast concrete system for the general market are not yet established.

7.1.3.1 Pre cast concrete construction systems

Technical Information

➢**Raw Material :** Ready Mix Concrete, water

➢**Manufacturing Scale:** Hollow core slab 725 Sqm per day on 8 beds (1.2*114m) of size 130 Sqm.

** 8 hours of work shift at manufacturing plant. (Source: Supertech Noida Factory visit)

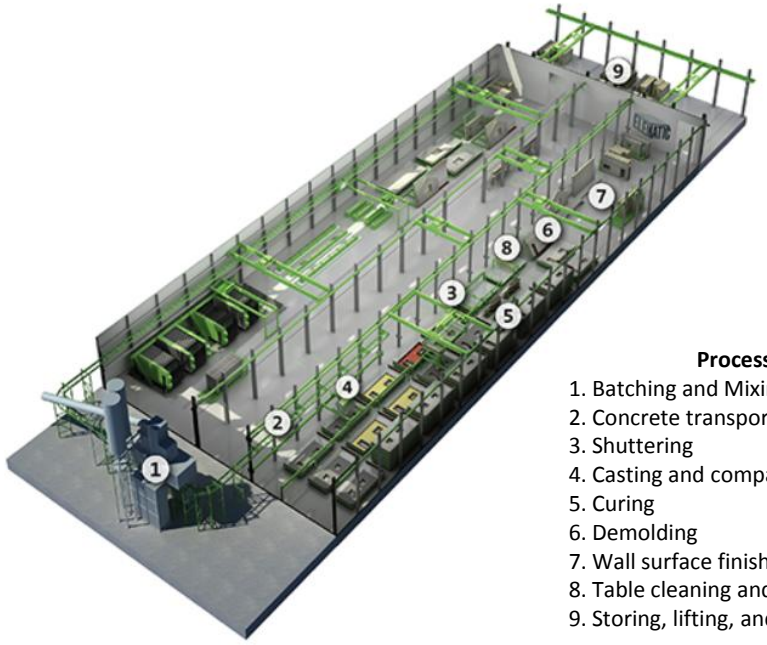
➢**Manufacturing :** In factory

➢**Machinery** : Imported

Applicable Standards/codes:

IS 11447 -1985 Code for Construction with Large Panel Prefabricates, IS 15916:2010, Building Design and Erection using Prefabricated Concrete-Code of Practice

➢**Size** : Width of panel is restricted to 1-2 m max



Process

1. Batching and Mixing
2. Concrete transportation
3. Shuttering
4. Casting and compaction
5. Curing
6. Demolding
7. Wall surface finishing
8. Table cleaning and oiling
9. Storing, lifting, and transferring

➢**Production and scaling challenges and opportunities**

Alternatives with insulation sandwiches for walling may be necessary to overcome the high thermal conductivity of dense concrete walls.

The technology has opportunities in large mass housing projects where speed is priority. The low requirement of skilled labor for production is countered by requirement of skilled personnel for pre-production and assembly supervision. The challenge for production is to achieve a balance between investment in land and machinery with demand (full utilization of production capacities), for financial viability.

➢ **Limitations :**

- Precision in joining components on site, proper sealing of junction is essential to ensure good quality end product.
- Large space requirements for plant operation, storage and utilities/infrastructure.
- Heavy machinery required for lifting and transportation, impacts cost.

➢**Projects where used:**

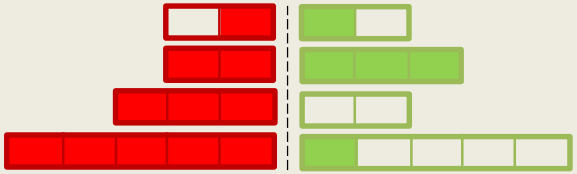
Multi story high rise housing projects in NCR, Amarpali group, Supertech, Noida and Jindal city Sonipat

7.1.3.1 Pre cast concrete construction systems

Green Information

Environmental Impact

Disposability
Resource Availability
Impact on Natural Systems
Energy



Net Green Score

➢**Embodied Energy**: Pre cast concrete has 2.0MJ/kg * as compared to 1.9MJ/kg of in-situ concrete.
(*www.yourhome.gov.au/materials/**embodied-energy***) *Data for Australian context, Indian counterpart not available yet.

➢ **Green Features**:

- The material is recyclable. The concrete can be removed from reinforcement during demolition, and both materials can be reused.

➢ **Conventional Counter part/s**:

Cast in-situ concrete structure.

➢**Green Benefits over counterpart:**

- Several common industrial by-products like Fly ash, slag, and silica fume, can be incorporated into concrete as a replacement of Portland cement.
- Reinforcement can be made from recycled steel.

➢**Future assessment/ Potential**

- There are innovation potentials in the technology of pre-cast concrete in terms of reducing its environmental impact. Cement can be reduced by introducing recycled fly ash and GGBS. The panel systems may be designed in a manner to reduce the consumption of steel.
- Such systems will become advantageous where speed with large volume of construction are the main determinants. They may become necessary when labour cost is high and labour is short in supply.

- ***precast**.org/, www.**pre-cast**.org/docs/Sustainability_and_**Precast**_**Concrete**.pdf, http://supercast.in/*
- **Manufacturing Process :** http://www.elematic.com/en/precast-academy/, http://supercast.in/gallery5.html
- ➢ Refer BMTPC's Compendium on Emerging technologies

7.1.3.2 Light Gauge Steel Construction System

General Information

Brief Description: This rapid construction system has been developed as a non combustible steel equivalent of wood frame construction. It uses cold formed C and S sections to create closely spaced system of studs, joists, and rafter. The light gauge steel frame of the building is sheathed, cladded and insulated to attain desirable internal comfort.

Fig. Light Gauge Steel Construction

➢Features:

- It is light and speedy form of construction.
- System can be engineered for different types of requirement and earthquake zones.

➢Cost:

Not available

* Rates as surveyed in January 2016, varies with states acc. to applicable taxes

➢Applicability

•**Use** : For low to mid rise applications, structural system (roofs, floors & walls) can be framed with light-gauge steel members.

•**Climatic Zone** : Low mass of the system makes it unsuitable for hot dry and composite climates.

➢Availability

▪ These are proprietary systems being marketed by large companies, located in region.

▪ Design and build services can be provided on demand.

➢Availability

Specialized manufacturer concentrated in and around NCR.

7.1.3.2 Light Gauge Steel Construction System

Technical Information

➢ **Raw Material :** Cold formed galvanized steel sections form the primary material, infill and cladding is variable

➢ **Manufacturing Scale :** Details not available. Medium to large scale Industrial set up

➢ **Manufacturing :** In factory

➢ **Applicable Standards/codes:**

- IS 800.2007

Fig. Light Gauge Steel Construction.

➢ **Production and scaling challenges and opportunities:**

Steel framed construction is still in very nascent stage of development, majorly due to its high cost. This system of construction may be economical in large scale projects, where speed of construction is important. In affordable housing segment, there is no precedence of its use.

➢ **Limitations:**

These structures allow passage of sound more readily than solid masonry construction. They also have low thermal mass and therefore are not appropriate for composite climates. They would rely on high insulation and air conditioning for indoor thermal comfort. These structures lose their strength on the advent of fire. Adequate fire protection must be used.

➢ **Projects where used:**

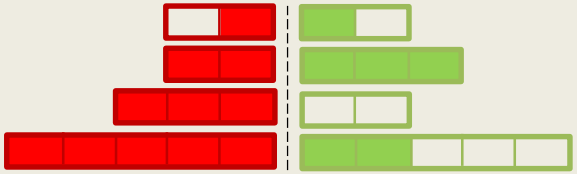
Villa in Mohali by MGL Infra Pvt. Ltd.

7.1.3.2 Light Gauge Steel Structural System

Green Information

Environmental Impact

Disposability
Resource Availability
Impact on Natural Systems
Energy



Net Green Score

➢**Embodied Energy**: 1.2 to 1.4 GJ/m2 of construction**
***Modern Construction handbook by Andrew watts*

➢**Green Features**:

- Steel products used in construction are recyclable.

➢ **Conventional Counter part/s:**

Timber Frame Structures and conventional masonry / RCC frame construction

➢**Green Benefits over counterpart:**

- 100% recyclable; speedy construction.
- Almost zero waste at construction site.

➢**Future assessment/ Potential**

- N.A.

- http://www.understandconstruction.com/light-gauge-steel-construction.html, http://www.pessi.in/pdf/JSPLConstructionMaterials.pdf
- Challenges:http://www.constructionweekonline.in/the-power-of-steel/
- Embodied energy and green features: http://repository.up.ac.za/bitstream/handle/2263/14400/Lyons_Comparative(2009).pdf?sequence=1
- http://www.tribuneindia.com/news/real-estate/spaces/matching-stability-and-style/157744.html
- http://www.mgiinfra.com/lgsf.html

7.1.3.3 Monolithic Concrete Construction System using Plastic/Aluminium Formwork

General Information

➢**Brief Description:** In this system building components are cast-in-place monolithically using appropriate grade of concrete in one operation with use of precision-engineered modular formwork made up of Aluminium/Plastic/Aluminium-Plastic Composite. Being a modular formwork system, it facilitates in rapid construction of repetitive units.

➢**Features**:

- Thickness of the wall is generally 100 mm with the centrally placed reinforcement
- It is flexible in design and can form any architectural or structural configuration, such as stairs, bay windows, curved features, etc.
- The formwork panels being light weight are manually handled. It saves on heavy equipment and carriage. Monolithic casting of building components saves time compared to block masonry.
- The aluminium formwork reveals a good quality fair face onto which a 4–5mm skim coat can be applied for a perfect finish. Saves time and money for plastering.

➢**Cost:** 8000-10,000Rs/m^3 of * (To achieve economy, minimum 100 repetitions are desirable.) * Rates as surveyed in January 2016, varies with states acc. to applicable taxes

➢**Applicability**

•**Use** : It is found to be economical only where large number of repetitions are possible.

•**Climatic Zone** : Formwork is not dependent on climatic conditions. Monolithic RCC for external walls is unsuitable for this climatic region.

➢**Availability**

▪ The formwork material is at present being supplied and manufactured in this region. It is in use of multi-storey construction in this region.

Fig. Aluminum Formwork used in wall construction

➢**Availability**

Manufactured in and around the region.
Suppliers concentrated in and around NCR.

7.1.3.3 Monolithic Concrete Construction System using Plastic/Aluminium Formwork

Technical Information

➢**Raw Material :** Aluminum and its alloy or PVC for formwork *

➢**Manufacturing Scale** : ~ 35000 sq. m in 6 acre by 500 persons ** (source : Maxformwork, Unimax International)

➢**Manufacturing :** Formwork manufactured in factory

➢**Applicable Standards/codes:**

- Concrete-Shall be of appropriate grade based on environment condition as per IS 456:2000
- Reinforcement- IS 1786:2008
- Formwork of Aluminium Extruded Section conforming to IS 733:1983
- http://www.bis.org.in/sf/ced/CED46(8029)_07092015.pdf

Profile banking

Punching & welding

Semi finished product

Q C Inspection

Cleaning

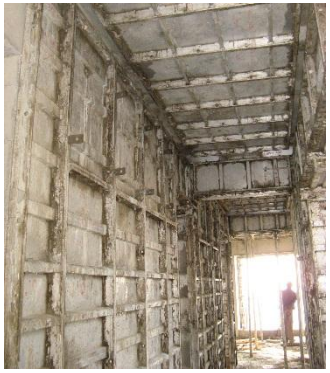
Aluminium moulds

Source: http://constructionduniya.blogspot.in/

➢**Production and scaling challenges and opportunities**

In past few years, manufacturing plants have been set up in this region. With the growing need for large scale housing projects with repetitive unit type, this system of construction can be effective in speedy construction.

➢**Limitations :** The system requires high initial capital investment and would be economically feasible only if number of reuses are maximized. The thickness of the RCC walls pose challenges for concealed electrical and plumbing services. Changes in design are not possible as formworks are customized.



➢**Projects where used:**

Multi story high rise housing projects in NCR, Housing at Kanjhawala Narela, Delhi for DSIIDC., 512 houses in Bawana housing project, Delhi for DSIIDC

* maxformwork, Unimax International

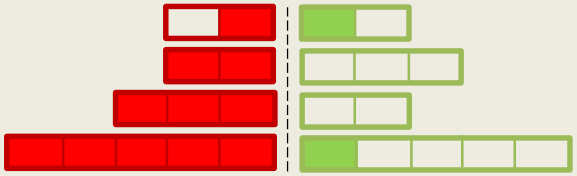
** 8 hours of work shift at manufacturing plant.

7.1.3.3 Monolithic Concrete Construction System using Plastic/Aluminium Formwork

Green Information

Environmental Impact

Disposability
Resource Availability
Impact on Natural Systems
Energy



Net Green Score

➢**Embodied Energy**: Details not available, Highly energy intensive
(Embodied energy of Aluminium: 170MJ/kg* As the material is light weight and recyclable, energy savings can be made over the lifetime of the metal's use.)
**Source: Lawson building materials, energy and environment (1996)*

➢ **Conventional Counterpart/s:**
RCC Column Beam structure with masonry walls.

➢**Future assessment/ Potential**

- The property of high reusability (100 or more times) of the formwork provides opportunities of usage in the mass scale housing projects.
- The economic viability can be achieved by adopting repetitive type designs.
- The potential is further enhanced as little skilled labor is required.
- The system of construction may become a more economical alternative as skilled labor becomes more expensive.
- A hybrid construction system using RCC shear walls partially and flat slabs for floor/roofs, with light weight masonry for walls may prove to be the most economical construction system as well as being more suitable climatically.

➢**Green Benefits over counterpart: N.A.**

- This system does not offer any green benefits over its counterpart.

- http://constructionduniya.blogspot.in/2012/02/mivan-aluminium-formwork.html
- http://bauxite.world-aluminium.org/refining/energy-efficiency.html
- http://theconversation.com/the-trouble-with-aluminium-7245

➢**Manufacturing Process :** https://www.youtube.com/watch?v=eM096O0pCNs, *https://www.youtube.com/watch?v=RGAP_Zvo9ZY*
➢**Specifications (BIS):** *http://www.bis.org.in/sf/ced/CED46(8029)_07092015.pdf*
➢ Refer BMTPC's Performance assessment certificate and other publications for monolithic construction technology.

7.2.1 Fact sheets on integrated structural systems not available in the region but appropriate for the region

7.2.1.1 Glass Fibre Reinforced Gypsum

General Information

➢**Brief Description:** It is a lightweight hollow panel building material that can provide for load bearing, partition walls and structural floor slabs. It is made up of calcinated gypsum plaster and reinforced with glass fibers. These panels have cavities that may be left hollow, partially or fully filled with concrete (or reinforced concrete) depending on structural requirement of its use.

➢**Features**:

- Uses phosphogypsum in manufacturing, an industrial waste of phosphoric acid based fertilizer industry.
- GRFG panels are manufactured in thickness of 125 mm (with cavity, refer Fig on right) under carefully controlled conditions in panel dimension of 12m X 3m.
- No water curing requirement.
- Density range - 1000-1200 kg/m^3 *
- Compressive strength > 0.73kg/mm^2 *
- High heat transmittance (U value: 2.85 W/m^2K)*

➢**Cost:** varies as per component usage

* Source : BMTPC Compendium of Prospective emerging technologies for mass Housing

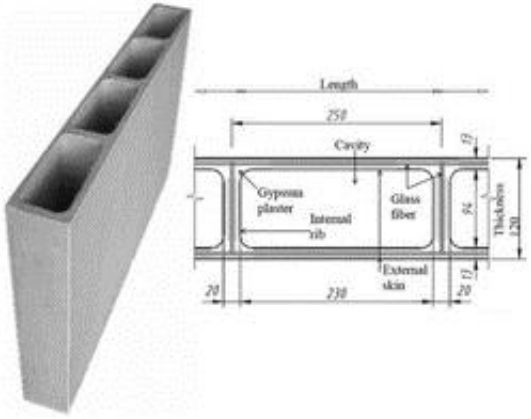


Fig. GFRG panels used in wall construction.

➢**Availability: N.A.**

Not available in the region.

➢**Applicability**

•**Use** : Load bearing and non load bearing walls, floor slabs

•**Climatic Zone** : Suitability similar to conventional burnt clay bricks.

➢**Availability**

▪ GFRG manufacturing units are currently based only in Cochin. And can be supplied pan-India.

7.2.1.1 Glass Fibre Reinforced Gypsum

Technical Information

➢**Raw Material :** Phosphogypsum (96.5%), water, chemicals and fiberglass strand reinforcement

➢**Manufacturing Scale** : N.A.

➢**Manufacturing :** In factory

➢**Applicable Standards/codes:**

GFRG / Rapidwall Building Structural Design Manual, prepared by IIT Madras, published by BMTPC, New Delhi
http://www.bmtpc.org/DataFiles/CMS/file/PDF_Files/TP_06_GFRG_small.pdf

Manufacturing at Factory

Transportation and installation at site

➢**Production and scaling challenges and opportunities**

- At present FRBL is the only company manufacturing the GFRG load bearing panels.
- These panels are very new to the market and lack awareness amongst consumers.

➢**Limitations : N.A.**

➢**Projects where used:**

Pilot initiative by IIT Madras, Chennai

7.2.1.1 Glass Fibre Reinforced Gypsum

Green Information

Environmental Impact

Disposability
Resource Availability
Impact on Natural Systems
Energy

N.A. * (only used in pilot initiative)

Net Green Score

➢**Embodied Energy**:800-900** MJ/m^3 of panel without any concrete fillings in the cavity.

➢**Green Features**:

- Makes productive use of recycled industrial waste (phosphogypsum)
- Does not need any plastering
- Lower embodied energy as compared to fired clay bricks

➢ **Conventional Counter part/s**:

Solid fired clay bricks and RCC framed structure

➢**Green Benefits over counterpart:**

- 90 % of its material composition is industrial waste (phosphogypsum)
- 0.0926** t CO_2/m^3 as compared to 0.219* t CO_2/m^3 of conventional brunt clay bricks

***GKSPL analysis*
** CLEAN DEVELOPMENT MECHANISM PROJECT DESIGN DOCUMENT, Manufacturing of Rapidwall at FRBL, India*

➢**Future assessment/ Potential**

- This technology is highly appropriate for repetitive mass housing projects which need to be built in short span of time.

- http://www.frbl.co.in/index.html
- http://www.biltechindia.com/

➢ **Machinery Set up** http://www.rapidwall.com.au/
➢ **Manufacturing Process:** Clean development mechanism project design document, Manufacturing of Rapidwall at FRBL, India
➢ **Specifications:** https://law.resource.org/pub/in/bis/S03/is.2095.3.1996.pdf

8 Conclusions and recommendations

8.1 Context

This survey and compendium has been prepared in support of the task of providing housing for urban citizens at the required scale and speed, through means that are both environmentally sustainable and affordable for the majority of urban citizens for whom there is a growing shortfall of satisfactory` housing. The Survey has been conducted for the region comprising Haryana, Punjab, the National Capital Region (NCR) and Union territory of Chandigarh.

8.2 Scope of the Survey

The scope of the survey has been to a)identify the current construction practices in the housing sector as exemplified by construction activity in the urban agglomeration of the NCR, Chandigarh, Ludhiana and Panipat, b) Catalogue the construction materials, products and construction technologies that are being produced or marketed in the region giving technical information regarding them, c) List manufacturers and suppliers of building materials and products in the region, d) Identify and present built housing projects of note as exemplary case-studies and e) List design practitioners in the region who specialize in s environmentally sustainable construction or “green” design for housing. In the technical information of the catalogued construction material products and construction technologies a simple analytical assessment of their environmental performance or “greenness” is also provided.

8.3 Informal and formal modes of Housing provision

It is expected that at least 50% of homes and extensions or improvements to existing homes are likely to be self-built by individual households, small cooperative groups and small builders. The remaining half may be provided by the real estate market and state sponsored housing programs. Each of these two modes for housing provision offer different opportunities for adoption of appropriate building materials and construction technologies to enable rapid and sustainable construction.

8.4 Alternative new technologies

Our survey of existing practices and available alternatives in the Punjab, Haryana, NCR and Chandigarh regions indicates that alternative new technologies for mass rapid construction are in a nascent stage. They fall into two broad categories: RCC-based and steel frame-based. At present these are more expensive than conventional methods.

The RCC pre-fab systems offer the advantage of speed and precision of finish if executed well. The advantage is significant for high-rise construction. The same advantage for high rise construction is enjoyed by systems of cast-in-situ RCC using Aluminium formwork in which most walls are cast in RCC. In the case of RCC prefab the environmental impact of the method of construction is similar to that of conventional construction. In the case of cast-in-situ RCC using aluminium formwork, however, the environmental impact is greater than conventional construction. This is on account of the increased consumption of steel which has very high embodied energy. And also, on account of the thermal characteristics of mass concrete, this type of construction will result in increased energy requirement to achieve thermal comfort indoors.

Proprietary systems of construction that are on offer, based on steel frame and lightweight infill and cladding, are also more expensive than conventional construction. Their carbon foot print on account of the consumption

of steel is considerably higher. Their very light mass for external walls is not suitable for residential buildings in this climatic zone. Their chief advantage would be the speed of construction.

8.5 High-rise and low-rise residential buildings

Here, it is to be noted that tall buildings above 15 meters high are inherently more expensive to build than buildings that are below this height. This is on account of the greater consumption of steel and cement in the building structure which needs to resist greater gravitational loads, wind loads and, most significantly, earthquake forces as the buildings become taller. Additionally, in tall buildings the services infrastructure for lifts, pumps, fire safety and back up generation of electricity, increase capital costs further and also increase building maintenance and operation costs. The overall construction and running costs of an eight storey high building would be 10 to 15 per cent higher than a four storey high building.

The sustainable and affordable strategy for mass housing would need to focus on high density utilization of land with buildings up to 15mters in height. Therefore, the recommendations below focus on materials and technologies that offer economy, speed and lower environmental impact for construction up to five storey in height.

8.5.1 Current scenario and trends

In the region of Haryana and Punjab the predominant mode of construction continues to use burnt brick for walls and RCC for floors. This shifts to RCC frame with brick infill when the buildings are taller than three stories. It is only for multistory/ high rise construction in the NCR and around Chandigarh that lightweight aerated autoclaved concrete (AAC) block work is replacing burnt brick. This makes multi-storey/high rise buildings environmentally more sustainable on two counts : a)the lighter weight of the AAC block work compared with brickwork reduces structural loads and saves on reinforcing steel and b) AAC block work reduces the cooling requirements because of better thermal insulating properties compared to brick work, thereby saving on operational energy for cooling indoor spaces. This is a positive trend that needs to be further encouraged in the region.

8.5.2 The potential of improved burnt clay products

It is seen that burnt clay brick continues to be good quality, plentiful and affordable building material. Burnt clay fired brick has a long history in the region and a high acceptance in the market. Its primary raw material - alluvial soil – is plentiful throughout the region, which means decentralized production near to the point of consumption is possible However, the current manufacturing practices for burnt bricks have two big negative environment impacts – a) utilization of agricultural top soil for brick making, b) use of inefficient brick kiln technology for firing, which results in wastage of fuel, air pollution and CO_2 emissions. It is possible to minimize these negative environmental impacts significantly. Currently, almost all burnt clay bricks that are manufactured are solid; shifting a part of the production to perforated and hollow burnt clay bricks/ blocks can result in up to 50% savings in soil, significant reduction in fuel consumption and associated air pollution, benefits in the form of lighter weight and faster construction. Utilization of clay obtained from dredging of dams, rivers, canals, drains, deep mining of clay, and mixing various kinds of industrial and agricultural wastes to soil, can significantly reduce the dependence on agricultural top soil for brick making. There is a strong case for supporting a programme for the manufacturing of resource efficient burnt clay bricks/ blocks in the region.

8.6 Recommendation for self-build, small scale construction, informal sectors

In this sector production will be undertaken by small contractors and builders and the scale of each project will be limited mostly to single buildings. To catalyze and enable affordable and environmentally sustainable construction, a strong program for promotion of alternative materials of construction, and economical and part pre-fabricated walling and floor/ roof construction systems, as exemplified by the case study of the Bhawana housing project, is needed. To scale up such production capacity needs to be supported by microfinance.

The most effective means of disseminating such materials and techniques of construction is by building small demonstration projects in each city. These projects would probably have to be taken up by local or state authorities and professionally supported by practitioners who specialize in cost – effective sustainable construction.

In addition to the burnt clay products mentioned above the following materials and construction techniques are recommended for promotion and dissemination:

These materials and techniques achieve, with small investments in production equipment, a significant improvement in productivity. They also ensure greater reliability and consistency of product quality while reducing the consumption of raw materials and minimizing wastage.

8.6.1 Construction systems:

Reinforced hollow block masonry

Pre-cast floor panels

Precast T beam with hollow clay / concrete block filler

Pre-cast T beam with pre-cast arched panels

8.6.2 Materials and components:

High strength hollow concrete blocks

Hollow burnt clay blocks

Prefab ferrocement door and window frames

Doors and windows using secondary timbers

Composite board panels of agricultural wastes and bamboo for partitioning and door panels

Fire resistive expanded or extruded polystyrene for roof insulation

8.7 Recommendation for large group housing projects

8.7.1 Low rise high density

It is seen that construction costs of residential buildings are optimum at three or four storeys height (low rise). The construction cost of an eight storey building, irrespective of the mode of construction, would be approximately 15% higher than that of a four storey building. This is on account of the increase in the use of steel and concrete required in the structural system - especially to resist earthquake forces, and due to the

additional needs of fire escapes, fire protection equipment, lifts and pumps. Equally, the operation and maintenance costs as well as the consumption of electricity rises by at least 15% in multistory buildings compared with low-rise buildings. From an environmental sustainability point of view a low-rise (up to 15 meter high) high-density pattern of housing offers the optimal economy with environmental sustainability for affordable housing.

8.7.2 Rapid Construction and pre-fabrication technologies

Two kinds of construction systems are on offer in this region a) Lightweight steel structures with infill and cladding b) Large structural element pre-cast RCC structures. The chief benefit of these systems is speed of construction. However, they are a considerably more expensive option for low rise construction compared with conventional and rationalized construction systems discussed above. Their potential for economy is perhaps better exploited in taller buildings. The lightweight steel structures have high embodied energy because of the extensive use of steel. Their low thermal mass is not suitable for achieving thermal comfort by passive means in the composite climate of this region. They would be suitable where artificial cooling is relied upon for thermal comfort.

On the other hand RCC based structural systems would be more appropriate climatically, provided that external walls are not solid concrete. External solid concrete walls are more conductive than other walling materials and would also absorb more heat during the daytime and cause discomfort during evenings and night. This would incur an increase in cooling loads and greater reliance on electro- mechanical devices for thermal comfort. With the use of high volume Fly ash GGBS and recycled reinforcement steel RCC based systems would be more environmentally sustainable compared to structural steel based systems.

8.8 Conclusion

The current trends of construction for housing in the Haryana, Punjab, UT Chandigarh and NCR regions show a little response to the need for economical and green rapid construction systems. The proprietary rapid construction systems that have recently come on the market have high environmental impact, are expensive and not climatically suitable for residential buildings. The potential for intermediate technologies of reinforced hollow concrete block and hollow burnt clay block and pre-cast floor panels to build four to five storey housing offers a promising direction. These would provide an optimal solution for quick and economical construction with low environmental impact. Promotion of these materials and building systems will require incentivized finance and demonstration housing projects at key locations in the region to catalyze investment in and adoption of such technologies.

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Savneet Kaur, Imarat Architects. 2015. "Abodes in Adobe." 30th INTERNATIONAL PLEA CONFERENCE.

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n.d. *www.coomonfloor.com.* Accessed December 21, 2015. https://www.commonfloor.com/project-search?search_intent=sale&search_entity=project&rent_min_inr=-&rent_max_inr=-&page=1&city=Greater%20Noida&use_pp=0&set_pp=0&show_ungrouped_results=0&physically_verified=0&bath_rooms=0&fetch_max=1&number_of_children=2&ma.

n.d. *www.indiatoday.in.* Accessed December 21, 2015. http://indiatoday.intoday.in/story/noida-greater-noida-property-affordable-property-price/1/418746.html.

10 Annexure

10.1 List of manufacturers of green building products

Compendium of Green Technologies for Composite Climatic zone of India						
List of Manufacturers						
Sl. No		**Manufacturers/ Brand Name**	**Contact Info**	**Manu-facturing Location**	**Distributio**	**Remarks / Miscellaneous Information**
Materials						
1	**AAC blocks**					
1.1		RS Green Infra India Pvt. Ltd.	Mr.Amit– 9569971687, Vill Beer Plasi, Teh. Nalagarh Distt Solan(H.P) – 174101	Solan, Himacha Pradesh	Punjab, Himachal Pradesh	
1.2		Shiv Enterprises	Contact Person: Mr. Shiv Charan Contact Number: +91-9810359940 Email ID : shiventerprises92@gmail.com Address : Plot No. K 546, Near Gas Pump, Vasant Kunj Road, Mahipalpur Extn., New Delhi - 110037	New Delhi	States of North India	
1.3		Superlite, Kannav AAC	http://www.kannavaac.com/ 0120 - 429 7440	Greater Noida	NCR	
1.4		Biltech Buidling Elements Ltd	http://www.biltechindia.com/index.asp +91-11-49696600	Palwal	NCR	
1.5		JK Smartbox (JK Laxm	91-9711459974/011-30179846, +91-98683 30179882, http://www.jklakshmi.com/proc jk-smartblox/ +91-9873466744	Jhajjhar	NCR	
2	**Flyash Blocks**					
2.1		Hind Infradevelopers	Hind Infradevelopers India Pvt. Ltd. Govind Singh Chauhan (Director) 59/10, 2nd Floor, Kalkaji Delhi- 110019, India	Delhi	Delhi NCR	
2.2		SS Fly Ash Bricks	Dhoom Kheda, Uttar Pradesh 203207	Ghazia-bad	Delhi NCR	
2.3		Puzzolana Green Bricks	D-1/11, Janakpuri, New Delhi, Delhi 110058	Delhi	Delhi NCR	

2.4		KJS Concrete	Mr. Vineed Raj Pillai (Vice President) Ph: +91-8860077003 Mr. Ritesh Nayak (Manager - Business Development) Ph: +91-7838265577 http://kjsconcrete.com/kjsconcrete/	Ghazia-bad	North India	
2.5		Flyash bricks Gurgaon	Street Number 13, Block R, Mahipalpur Villa 084474 08486	Gurga-on	Delhi NCR	
3	**Cellular Light weight Concrete block (Machinery)**					
3.1		Manju Concrete Fabri Developers Pvt. Ltd.	Manju concrete fabricator and developer pvt ltd. Garish Aggarwala Village Bhagwanpura, Derabassi- Barwala Road, Derabassi, Mohali - 140507 , Punjab	Mohali	Punjab, Harya NCR	
3.2		Novamac	Novamac No.1910, Street No.4, Maharaj Nagar, Ludhiana - 141001 , Punjab	Ludhia-na	Punjab Haryana	
3.3		RTK Engineering Co	Rtk Engineering Co. Raddakisan Kenddre (Proprietor) Gat No. 365, Bhandgaon, Near Western Hatcheries Society, Khor Road, Taluka Daund, District Pune Pune - 412214, Maharashtra	Pune Maha-rastra	Pan India	
3.4		Readymix constructio pvt. Ltd.	Readymix construction machinery pvt. Ltd. Plot No. 209, SR No. 96/2B, 4th Floor, Near Joshi Park, Right Bhusari Colony, Paud Road, Kothrud, Pune - 411038 , Maharashtra	Pune Maha-rastra	Pan India	
3.5		Hardic Engineering	Hardic Engineering Hardic N. Panchal (Business Director) C-1/77/1, Kaka Estate, Ambica Nagar Road, National Plastic, Odhav Ahmedabad - 382415, Gujarat	Ahme-Dabad Gujar-at	Pan India	
4	**Compresses earth stabilized block (Machinery)**					
4.1		Auroville Earth Institu (Machinery)	Aspiration, Auroville 605 101, Tamil Nadu Phone: +91 (0)413-262 2278 / 262 2134 / 262 2651 – Fax: +91 (0) 413 - 262 2274 Email: aureka@auroville.org.in - Web: www.aureka.com	Chen-nai	Pan India	http://www.earth-auroville.com/compressed_st rth_block_en.php
5	**Hollow Clay blocks**					

5.1		Stellent Infratech Priv	Rajesh Singla (Director) 282-A 2nd Floor, Shiva Ji Market, Pitampura New Delhi - 110034, Delhi	Harya-na Delhi	Delhi- NCR, Haryana, UP Punjab	
5.2		Dadoo Brick Kilns Priv	Kartikey Dadoo (08046077232) 502, Building Laxmidee, Laxmi Nagar Delhi - 110092	Harya-Na Delhi	Delhi- NCR, Haryana, UP Punjab	
5.3		Wienerberger India Pr Limited	88/4, Richmond Road,Bangalore 560 025 Karnataka,India T : 91 80 41491 682 - 7, F : 91 80 40918 441 E-Mail: marketing@wienerberger.in	Kunigal	South India	
5.4		Ganesh bricks Patel (proprietor)	13-14, Dharmjivan Building, Near Dabholi Char Rasta, Opposite Matrubhumi School Dabholi Surat - 395004 , Gujarat Mob : +91-9904467716, +91-9904064566	Surat	Gujarat Maharastra	
6	**Hollow Concrete Blocks**					
6.1		Ecologic	www.ecologicbuild.com	Punjab	North India	
6.2		Dynamic Building Concepts Pvt. Ltd.	www.dynamicbuilding.in			
6.3		Jindal Mechno Bricks I	507, Aggarwal Millennium Tower Netaji Subhash Place, Pitampura Delhi - 110034 Ph: 011 65380552, Fax : + 911147050595 http://www.jindalbricks.in/	Village Badli , District Jhajjar Harya-na	Delhi-NCR, Punjab, Haryana, Rajasthan	
6.4		Ramjee Concretes Pvt. Ltd. Ramdeep Kaur (Director)	Village-Jhanjheri, Landran-Chunni Road, Tehsil Kharar, Mohali - 140062 Punjab	Mohali	Delhi-NC Punjab Haryana Rajasthan	
6.5		KJS Concrete	Mr. Vineed Raj Pillai (Vice President) Ph: +91-8860077003 Mr. Ritesh Nayak (Manager - Business Development) Ph: +91-7838265577 http://kjsconcrete.com/kjsconcrete/	Ghazia-bad	North India	
6.6		Oriental Ceramics & R Private Limited	Varun Arora (Director) Village Daun, District Mohali Mohali - 140 301, Punjab, India	Mohali	Delhi-NCR Punjab, Haryana Rajasthan	
6.7		Modern Tiles & Concr	Rajeev Gupta (Managing Director) Ramgarh Road, Near Balaji Petrol Pump, Mubarikpur, Mohali Dera bassi - 140201, Punjab, India	Mohali	Delhi-NCR, Punjab, Haryana, Rajasthan	
7	**Thermo Insulated blocks**					

7.1		KJS Concrete	Mr. Vineed Raj Pillai (Vice President) Ph: +91-8860077003 Mr. Ritesh Nayak (Manager – Business Development) Ph: +91-7838265577 http://kjsconcrete.com/kjsconcrete/	Ghazia-bad	Delhi-NCR Punjab Haryana Rajasthan	
7.2		Ecologic	143, Udyog Vihar, Phase-I, Gurgaon Haryana - 122015	V.P.O Bathu Tehsil-Haroli, Dist Una, Hima-chal Prade-sh	North India	
8	**Insulated Concrete Formwork blocks**					
8.1		Reliable Insupacks Pri Limited	Mr. Ranjit Prasad (Marketing) Mobile : +(91) 9910990138, +(91) 9818058 Email : admin@reliableinsupacks.com kooltile@reliableinsupacks.com	Greater Uttar Prade-sh	Himachal Pradesh, Delh	
8.2		Jayshree Machines &	Tel.: +91-22-6702-2620 Fax : +91-22-6702-2621 Mob. : +91-98671-80179 email : info@jmt.in url : www.jmt.in	Mum-bai	India and abroad	
8.3		Coffor Construction Technology Pvt. Ltd. India	Chandan Metal Compound, Opp. State Bank of India, Gorwa Road, Baroda	Surat Gujar-at	India and abroad	
9	**Construction & Demolition waste blocks**					
9.1		Enzyme Infra	Plot No D-61, Okhla Industrial Area phase I New Delhi - 110020, Delhi , India Contact Person : Mr. Miki Kedam (Director) Phone : 91-11-26811299 Mobile : +919711532777	On site Kidwai Nagar Delhi		pilot initiative
10	**Cement fibre board wall panel**					

10.1		Everest Industries Lim	Genesis, A-32, Mohan Co-operative Industrial Estate Math New Delhi - 110 044 (INDIA) Phone +91 - 11 - 41731951 / 52 09958037777 Fax +91 - 11 - 46566370 Email: info@everestind.com	Roor-kee, Uttar-akhand	Pan India	
10.2		Gyproc India	Saint-Gobain India Ltd, 5th Level, Leela Business Park, Andheri Kurla Road, Andheri (East),Mumbai Maharashtra, India	N.A.	Pan India	

Components

1	**Ferrocement components**					
1.1		Joint Developer- Development Alternatives, New Delhi.		TARA-gram across India	Distribution Through TARA gram (local organization)	Product is being produced At several Building Centers. BMTPC is taking up with BIS to prepare the Indian Standards
1.2		Ferrocement Works	1-1/2, Safdarjung, Arjun Nagar, Arjun Nagar, New Delhi, Delhi 110029	Delhi	Delhi, Haryana, Rajasthan, Western UP	
1.3		Ferrobuild	B-156, Ground Floor, New Ashok Nagar, Ne 110096 , Delhi , India	Delhi	Delhi, Haryana, Rajasthan, Western UP	
1.4		J. A. Desai Ferrocement Pvt. Ltd.	1703, Charai, R.C. Marg, Chembur Naka, Mumbai - 400 071 , Maharashtra, India	Mumb-ai, Maha-rastra	Maharastra	
2	**Fibre resin composite**					
2.1	Corru-Gated Bam-Boo Roof-ing sheet	Magnifico Crafts Private Limited	Firingi Kali Tower, Kolkata, West Bengal	West Bengal	Pan India	
2.2	Bamb-Oo Boar-d	MMJ Exports Private Limited	Ballygunge, Kolkata, West Bengal	West Bengal	Pan India	

		Bambusahutsnhome Pvt Ltd	New Wood Craft, C/o Rup Chand Saw Mill Samta Ashram Marg, Barielly Road Haldwani - 263139 Uttarakhand, India	Haldw-ani, Uttara-khand	Uttarakhand	Roofing, walling
		Neo Products pvt ltd	Flat No.37 Dda Flats Lado Sarai Delhi - 110030	Gurga-on and delhi		Non-structural bamboo products
2.3	Bamb-oo Mat Corru-gated Roofi-ng Sh-eets	Joint Developer-Indian Plywood Industries Research & Training Institute, Bangalore	Indian Plywood Industries Research & Training Institute (Autonomous body of Ministry of Environment, Forests & Climate Change, Govt.of India) Post Bag No.2273, Tumkur Road, Yeshwanthpur PO, Bangalore - 560 022			
		Ambica Hydraulics,	No. 502, Shefali Center, Paldi Cross Road Ahmedabad - 380006 Gujarat			
2.4	Coir CSNL Insul-Ation Board	Technology Inform-ation Forecasting and Assesement Council (TIFAC) pilot project initiative	Technology Information, Forecasting and Assessment Council (TIFAC) Department of Science and Technology (DST) 'A' Wing, Vishwakarma Bhavan, Shaheed Jeet Singh Marg New Delhi 110016	Kerela and Karna-taka	Karnataka and Kerela	Coir composite can be used for false ceiling , insulation, door shutters and cladding purposes.
3	**Micro Concrete Roofing Tiles**					
3.1		Joint Developer-Development Alternatives, New Delhi.	Development Alternatives B-32, Tara Crescent, Qutab Institutional Area, New Delhi, Delhi 110016	Localis-ed prod uction throu gh Taragr am	Pan India	
4	**Parquet Flooring**					
4.1						
5	**XPS / EPS**					
5.1		Reliable Insupacks Private Limited	Mr. Ranjit Prasad (Marketing) Mobile : +(91) 9910990138, +(91) 9818058899 : admin@reliableinsupacks.com kooltile@reliableinsupacks.com	Greater Noida, Uttar Prade-sh	Himachal Pradesh, Delhi-NCR	
5.2		Lloyd Insulations (India) Ltd.	Mr. K. K. Mitra (Vice President) Punj Star Premises, Kalkaji Industries Area, New Delhi - 110019. Phone: +91-11-30882874 / 75 Fax: +91-11-44-30882894 /95 Email: kk.mitra@lloydinsulation.com	Chan-digarh, Kanpur Kota etc.	Pan India	

5.3		E-pack Polymers Pvt. Ltd.	61- B & C, Udyog Vihar, Surajpur-Kasna Road , Greater Noida, Uttar Pradesh -201306, India	Greater Noida, Uttar Prade-sh	Delhi- NCR, UP, Haryana	
5.4		Dow Building Solutions	Dow Chemical Int'l Pvt. Ltd. Ltd.Corporate Park, Unit No. 1, V. N. Purav Marg, Chembur, Mumbai-400071	Maha-rastra	Pan India	
6	**Glass Fibre Reinforced Polymer Door and Door frames**					
6.1		Joint Developer- RV TIFAC Composite Design Centre, Bangalore	Technology Information, Forecasting and Assessment Council (TIFAC) Department of Science and Technology (DST)'A' Wing, Vishwakarma Bhavan, Shaheed Jeet Singh Marg New Delhi 110016, India. Phone: +91-11-26592600, 42525600			Technology transferred to 40entrepreneurs in the Country. jointly by NSIC, RV-TIFAC and BMTPC. Raw material:Glass fibre, Phenol formaldehyde resin, secondary species of timber Tested as per IS:14856. Being used in demonstration housing under VAMBAY
6.2		Dura Plast	Plot No. 84, Sector-46, Near Kapil Vihar Faridabad - 121001, Haryana, India (91)-9350803033, +(91)-8744060394 +(91)-(129)-2438446	Farida-bad	Delhi- NCR, UP, Haryana	
6.3		Shiv Shakti Fiber Udyog	Vinay Bansal (Partner) Kila No. 71/8/1/1, Village Hasangarh, Tehsil Sampla , Rohtak - 124404, Haryana +(91)-(11)-26671057 +(91)-9810397393 +(91)-9810906109	Rohtak	Delhi- NCR, UP, Haryana Punjab, Himachal	
6.4		Poly Process Engineers (sister Concern Of Nalin Enterprises)	Sanjeev Gupta (Proprietor) 131, Industrial Area-1, Phase 1 Chandigarh- 160002 +(91)-(172)-2640446 +(91)-(172)-5075291	Chan-digarh	Delhi- NCR, UP, Haryana Punjab, Himachal	
6.5		Sagar Frp Industries	P. M. Yadav (Director) Plot No. 475/7, Kadipur Industrial Area, Kadipur , Gurgaon - 122005, Haryana +(91)-9810272042 +(91)-9312504955	Gurg-aon	Delhi- NCR, UP, Haryana	
7	**Rubber / Poplar wood flush door**					

7.1		Joint Developer-BMTPC and Jambhekar Management Consultant Pvt.Ltd., Thane	BMTPC	Thane	Western part of India	
7.2		S & Co. Wood Industries	S & Co. Wood Industries, Valapattanam, Kannur, Kerala	Kannur,	Kerela Karna-Taka Tamil Nadu	

Integrated Structural System

1	**Aluminium formwork shuttering**					
1.1		max formwork and scaffolding system	Head Office Unimax International Plot No- 312, Pkt. G-21, Sec-7, Rohini, New-Delhi-85.(India) Phone No:011-47322686 Fax No:011-43701469 Email – info@maxformwork.com,	Uttar-Khand and Harya-na	Pan India	
1.2		ajay maini group	Maini Construction Equipments Pvt Ltd Plot No -25A, Sector-5, BAWAL- (Haryana) Pin-code: 123501 Corporate office Tel. No. : 011-49686800, 011-49686868 Fax : 91.11.49686802 Email : info@mcepl.com www.mainiscaffolding.com	Hary-ana	Pan India	
1.3		Ishaan Industries	Contact Info Phone : +91-22-26861395 Mobile : +91-9769822776 / 9322509504 Email : info@ishaanindustries.co	Gore-gaon (E), Mum-bai	Pan India	
1.4		JSL Ispat (P) Ltd.	125, Prakash Industrial Estate (Opp. Aradhna Cinema) P.O. Sahibabad, Ghaziabad - 201005(U.P) Telefax: +91-120-4193838 E: info@jslscaffolding.com	NCR-Ghazi-abad	Pan India	
2	**PVC formwork**					
2.1		Nova Plas Mold Pvt. Ltd.	A-7/21-23, South Side G.T. Road, Indl. Area, Opp. Rathi Steel Udyog, Ghaziabad, U.P. Mob. : +91 - 9910 76 4416,, 8010 23 7526	Ghazi-abad, U.P.	Pan India	
2.2		Bajaj Products Contact Person: Nishant Bajaj	A - 5, D. S. I. D. C. Industrial Complex, Nangloi, Delhi - 110041 Mob:91-8376807659 www.bajajpro.com	Indust-rial comp-lex Nagloi, Delhi	Pan India	

3	**Pre cast T Beam Slab**					
3.1		Baisiwala construction	Baisiwala Constructions, 3/F, Sunder Path Noida - 201301	Noida	Delhi NCR Haryana Punjab	
3.2		MBM Precast India pvt. Ltd.	Navroz Villa,Parsi Colony, Opp. Abad Dairy, Kankaria Road, Ahmedabad	Ahme-dabad	Gujarat, Rajasthan, Haryana, Delhi NCR	
4	**Glass Fibre Reinforced Gypsum (GFRG)**					
4.1		FRBL	Fact-rcf building products ltd, Fact cochin division campus, Ambalamedu p.o, kochi, Kerala-682303 http://www.frbl.co.in/index.html	Kochi	Pilot Initiative at IIT Madras	Glass Fibre Reinforced Gypsum(GFRG)/ Rapidwall is panel product,made essentially of gypsum plaster,reinforced with glass fibres.
5	**Prefabricated dwelling structure with EPS based panels**					
5.1		Jindal Steel & Power li	Mohit Srivastava (Deputy Manager) Ist Floor, Tower B, Jindal Centre, Plot-02, Sector-32 Gurgaon	Gurg-aon	Pan India	
5.2		Anchor Container Serv	Anchor Container Services Private Limited, (DGM), Shop No. 7, Gokulpura Road, Jhotwara, Jaipur # 08048003348	Jaipur	Rajasthan Haryana	
5.3		Synergy Thrislington	B-27, Phase 3, Industrial Area Mohali, Sector 58, Sahibzada Ajit Singh Nagar, Punjab 160055	Punjab	Punjab, Chandigarh, Himachal, Haryana	
6	**Hollow Core Slab, Beams, Columns, Solid Walls, Stairs, etc.**					
6.1		MBM Precast India pvt. Ltd.	Navroz Villa,Parsi Colony, Opp. Abad Dairy, Kankaria Road, Ahmedabad	Ahme-dabad	Pan India	
7	**Reinforced Concrete and Joist slab**					
7.1		Being Developed by CBRI, Roorkee	Central Building Research Institute, Roorkee			IS 13990:1994 (SP) IS 13994:1994 Extensively used for cost-Effective housing. Machine available. Being produced by various Building Centres. http://www.basinsa.net/

						training_menual/Plank%20and%20Joist%20Roof.pdf
8	**Pre cast system - RCC precast components**					
8.1		Jindal prefab pvt. ltd	705, sector-15, part-2 gurgaon. Haryana-122001 phone no: 91-124-2271090 mobile : 8010377904 mail: marketing@jindalprefab.com	Gurga-on, Harya-na	Pan India	
8.2		Supertech India Pvt. L	Supercast, I-15, Sector 9, Gautam Budh Nagar, Noida, Uttar Pradesh 201301	Noida, Uttar Prad-esh	Pan India	
9	**Speed floor Systems**					
9.1		Jindal Speed floor Systems	705, sector-15, part-2 Gurgaon. Haryana-122001 phone no: 91-124-2271090 mobile : 8010377904 mail: marketing@jindalprefab.com	Jharkh-and, Odisha Chatti-sgarh	Pan India	
10	**Light Gauge Steel Construction**					
10.1		Jindal Light Gauge steel construction system	705, sector-15, part-2 gurgaon. Haryana-122001 phone no: 91-124-2271090 mobile : 8010377904 mail: marketing@jindalprefab.com	Jharkh-and, Odisha Chattis-garh	Pan India	

10.2 List of practitioners of green technologies

BMTPC Compendium of Green technology List of Known Relevant 'Green Technologies'			
	PRACTITIONERS		
	Name	**Contact Detail- Telephone, wesite, email etc**	**Description/Remarks**

DELHI			
1	Anangpur Building Centre Ar. Anil Laul -	Faridabad, Haryana 121003 (India) Fax: +91-129-2512364 Mobile: +91-98100-59691 anillaul@anangpur.org connect@anangpur.org	
2	Arvind Krishan	Centre for Advanced Studies in Architecture,	
3	Environment Design Solutions Tanmay Tathagat -	D- 1/25 vasant vihar new delhi - 11005 info@edsglobal.com +91 . 11 . 2614 7085 +91 . 11 . 4056 8633[fax]	
4	Kamath Design Studio	n-19, 301, green park extension, new delhi, 110016 email: studio@kamathdesign.org	
5	Development Alternatives	B-32, Tara Crescent, Qutab Institutional Area, New Delhi, Delhi 110016	
6	Vinod Gupta	Space Design Consultants G 4, Masjid Moth, GK 2 New Delhi-110048 Phone: 011-40573213 Ext. 31, 40573264 Web: http://www.space-design.com	
7	M/s.DPAP Deependra Prasad	9958355553(M) deependra@intbau.in	
8	Space Matrix Design Consultants Pvt Ltd	59 Okhla Industrial Estate Ph-III New Delhi 110 020 T +91 11473 73000 F +91 11473 73099 E: newdelhi@spacematrix.com	
	Romi Khosla Design Studio	info@rk-ds.comAddress: C-9, Maharani BaghNew Delhi – 110065Phone: + 91.11.41730173, 41730174, 26834758	

10	Adhlakha Associates PROMOD ADLAKHA Managing Director	F-70, First Floor, Bhagat Singh Market Near Gole Market, Connaught Place, New Delhi 110001 Ph: 011-23344471, 72; Mob: 09811118803 Email: adlakhaoffice@gmail.com	
11	Ashok B Lall Architects	2-B Ramkishore Road, Civil Lines, Delhi website: www.ashokblallarchitects.com	
12	Greentech Solutions	197, Indraprastha Apartment, Pocket 3, Sector 12, Dwarka, New Delhi -110078	Green building services like energy modelling, performance check etc
NCR			
1	Green Tree Building Energy (P) Ltd.	H-19, Sector 63, Noida-201301, NCR-Delhi (India) Phone: +91120-4373374 Mobile: +91-9891852358 Fax: +91120-4376978 Email: contact@greentree-india.com	Green building services like energy modelling, performance check etc.
Chandigarh & Sourrounding areas (Mohali, Panchkula, Greater Mohali)			
1	Renu Khanna and Associates	Studio: House no. 138, Sector 10, Panchkula, Haryana – 134109 Ph: +91-172-2563379	Forest Complex , Mohali
2	Surinder Bahga	Sakaar Foundation, SCO 53-55, 3rd Floor, Near GPO, Sector 17-D "Chandigarh - 160017 India Ph: + 91-172-2722466 / 2711931 , saakaarfoundation.com	
3	Sangeet Sharma & SD Sharma	SD Sharma and Associates, SCO 54/1, Swastik Vihar, Mansa Devi Complex, Panchkula (Haryana), 134109, INDIA 0172-2555538 (O)	KMG Towers , IT building, Mohali

4	Planners Group	Chandigarh , S.C.O. 3-4 (F.F.) Sector 17 E Chandigarh-160017 +91(172)2703917, 2703391 / +91(172)2713241 , www.plannersgroup.net	Maya Garden Avenue , Zirakpur
5	The elements	SCF 59 First Floor, Sector 6, Panchkula – 134109 SCF-99, Sector 6 , Panchkula www.elements.in	
HARYANA			
1	Bhavneet and Savneet- Imarat Architects-	#187, Model Town, Karnal-132001 Haryana (INDIA) +91-184-2269187, +91-184-2266740 info@imaratarchitects.com	