Compendium
of Prospective Emerging Technologies for Mass Housing

Ministry of Housing & Urban Poverty Alleviation
Government of India

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सत्यमेव जयते

M. VENKAIAH NAIDU
Minister of Housing and Urban Poverty Alleviation,
Urban Development and Parliamentary Affairs
Government of India

Message

Housing for All by 2022 - is our goal. Considering the present housing shortage in urban areas, more than 20 million' houses with necessary infrastructure are required to be constructed in the period of next seven years. To achieve this, appropriate actions are required at all fronts. This necessarily includes, among other measures, identification and selection of appropriate building materials and technologies to bring not only economy but also quality, durability, speed with due care for safety and environment concern of the country.

Building Materials & Technology Promotion Council (BMTPC), under the aegis of the Ministry of Housing & Urban Poverty Alleviation, GoI, after detailed study and evaluation of various alternate emerging technologies, has identified and recommended, at present eight such technologies, which could be utilized in different parts of the country for mass scale housing projects. BMTPC is also working on identifying and evaluating more sound technologies.

I appreciate the efforts of BMTPC under the guidance of Mission Directorate at Ministry towards evaluating & recommending emerging alternate housing technologies from across the world so on to suit diverse Indian geo-climatic & hazardous conditions.

This booklet, which provides technical profiles of such technologies, will be helpful to housing agencies of the country in obtaining first hand information about the prospective technologies for their use in mass housing projects. The usage of such technologies could help in expediting the delivery of housing stock and in meeting the goal of "Housing for All".

(M. Venkaiah Naidu)

सत्यमेव जयते

BABUL SUPRIYO
Minister of State for Housing & Urban Poverty Alleviation and Urban Development
Government of India

Message

To provide shelter – one of the basic needs of mankind and a dream of our Hon'ble Prime Minister Shri Narendra Modi and Housing for All by 2022 is a Mission that is envisaged to achieve this noble goal and is high up in the Government's Agenda.

With the estimated shortage of 18.78 million houses in 2012, the Mission has a big challenge to face. The requirement is to construct dwelling units with quality, durability and speed, meeting the structural & functional need of different geoclimatic & hazardous conditions of the country.

Conventional building material of burnt clay bricks, reinforced concrete due to environmental constraints and non availability of basic ingredients in different parts of the country, are no longer sufficient to serve the purpose. It is, therefore, required to look for viable alternatives which would not only meet the structural and functional requirements of a dwelling units in a particular region, but also not be solely dependent on depleting natural resources. Many such technologies are used in other countries with success. It is the need of the hour that we identify and use such technologies which meet our requirements.

I congratulate the Building Materials & Technology Promotion Council for their initiative in identifying and evaluating these technologies according to their suitability in Indian condition.

It is interesting to note that BMTPC has prepared the compendium of eight different technologies which have been evaluated technically and recommended for mass scale housing. I hope state governments and their housing agencies will find the document a useful resource and a reference document for selection of appropriate technology for their projects.

(Babul Supriyo)

सत्यमेव जयते

DR. NANDITA CHATTERJEE
Secretary
Ministry of Housing & Urban Poverty Alleviation
Government of India

Message

The Government of India has a vision to provide inclusive, sustainable and affordable urban facilities and particularly to provide "Housing for All by 2022". To achieve the same, it is essential to achieve an integrated approach to deal, inter-alia, with land, finance, regulatory mechanism and use of appropriate construction materials & technologies.

The conventional building materials & construction practices are not only energy intensive but are also dependent on ever depleting natural resources; such practices also result in time and cost overruns. An enormous number of houses, to the tune of about 20 million, will be required to be constructed in the target period and hence will need to be addressed by an innovative approach by using appropriate fast track construction technologies. This will require judicial selection and evaluation of globally acceptable contemporary technology to suit Indian geo-climatic specifications. It is equally important to utilize the local resources available in the country.

It is a matter of satisfaction that Building Materials & Technology Promotion Council (BMTPC) has taken an initiative to identify and evaluate such a innovative emerging housing technology from across the world for possible application for the large scale housing scheme in India.

This booklet, containing technology profiles of eight such evaluated technologies, is expected to be a useful resource for state governments and related housing agencies. This should also facilitate selection of appropriate technology for housing projects in future.

(Dr. N. Chatterjee)

Dated : 10th February, 2015
Place: New Delhi

सत्यमेव जयते

SANJEEV KUMAR
Joint Secretary & Mission Director (Housing for All)
Ministry of Housing & Urban Poverty Alleviation
Government of India

Foreword

Under the mission of Housing for All by 2022, we need to construct almost three million houses a year in urban area for urban poor to construct 20 million houses by 2022. It is a very ambitious goal and difficult to achieve using only conventional practices of construction and energy intensive building materials based on natural resources. It is imperative to adopt and practice construction systems and technologies which help in building quicker but at the same time provide safe, durable and quality house, leading towards sustainable development.

Ministry of Housing & Urban Poverty Alleviation through its autonomous organization, Building Materials & Technology promotion Council, has been studying and evaluating construction systems not only from India, but also from abroad which may help in providing quick and durable solutions for Mass Housing projects. Mission Directorate is happy to share the compendium on eight such technologies which have been duly evaluated and certified by BMTPC and a few of them are already being used by various agencies for mass housing projects in India. The compendium contains the technical details about the technologies and gives the bird's eye-view regarding them, so that the user may get the first hand information. The identified technologies have potential to be used in mass housing projects and are structurally and functionally suitable for Indian conditions. We will continue to enlarge the list to offer wider choices. States and their agencies must also be having their own experiences of using such technologies which we would like to share with other states.

I sincerely hope that State Agencies including other Public & Private organizations involved in housing construction will find this compendium useful and explore the technologies for further usage. I would like to appreciate the efforts being made by BMTPC in studying and documenting these technologies.

(Sanjeev Kumar)
Joint Secretary & Mission Director (Housing for All)
Ministry of Housing & Urban Poverty Alleviation

Contents

Background

"Housing for All" by the 75th Years of Independence i.e. 2022 calls for construction of about 20 million (2 crore) houses in the period. This is a huge task and would require an integrated multi pronged approach. The construction of dwelling units and infrastructure in different parts of the country with diverse geo-climatic and hazard conditions with due care for quality, durability, environmental concerns and speed require fresh approach in using building materials & construction technologies in vogue. Dependence on the conventional practices, which are not only energy intensive, but consume ever depleting natural resources and also slow in speed; is not sufficient. The clarion call is to look for viable innovative construction practices. Any new innovative construction practice, however, should be sustainable and should be structurally and functionally suitable in Indian conditions.

For use of alternate materials and construction practices, National Building Code 2005 Part 2: Administration, Bureau of Indian Standards, Clause 5 ALTERNATIVE MATERIALS, METHODS OF DESIGN AND CONSTRUCTION, AND TESTS, has following provisions:

5.1 The provisions of the Code are not intended to prevent the use of any material or method of design or construction not specifically prescribed by the Code, provided any such alternative has been approved.

5.2 The Authority may approve any such alternative provided it is found that the proposed alternative is satisfactory and conforms to the provisions of relevant parts regarding material, design and construction and that material, method or work offered, is for the purpose intended, at least equivalent to that prescribed in the code in quality, strength, compatibility, effectiveness, fire and water resistance, durability and safety.

5.3 Whenever there is insufficient evidence of compliance with the provisions of the Code or evidence that any material or method of design or construction does not conform to the requirements of the code or in order to substantiate claims for alternative materials, design or methods of construction not specifically prescribed in the Code, the authority may require tests sufficiently in advance as proof of compliance. These tests shall be made by an approved agency at the expense of the owner.

The Building Materials & Technology Promotion Council (BMTPC), Ministry of Housing & Urban Poverty Alleviation, Govt. of India is studying & evaluating prospective innovative Construction system, developed within the country and from aboard and based on their technical suitability, recommended following technologies at present. A few others are under evaluation.

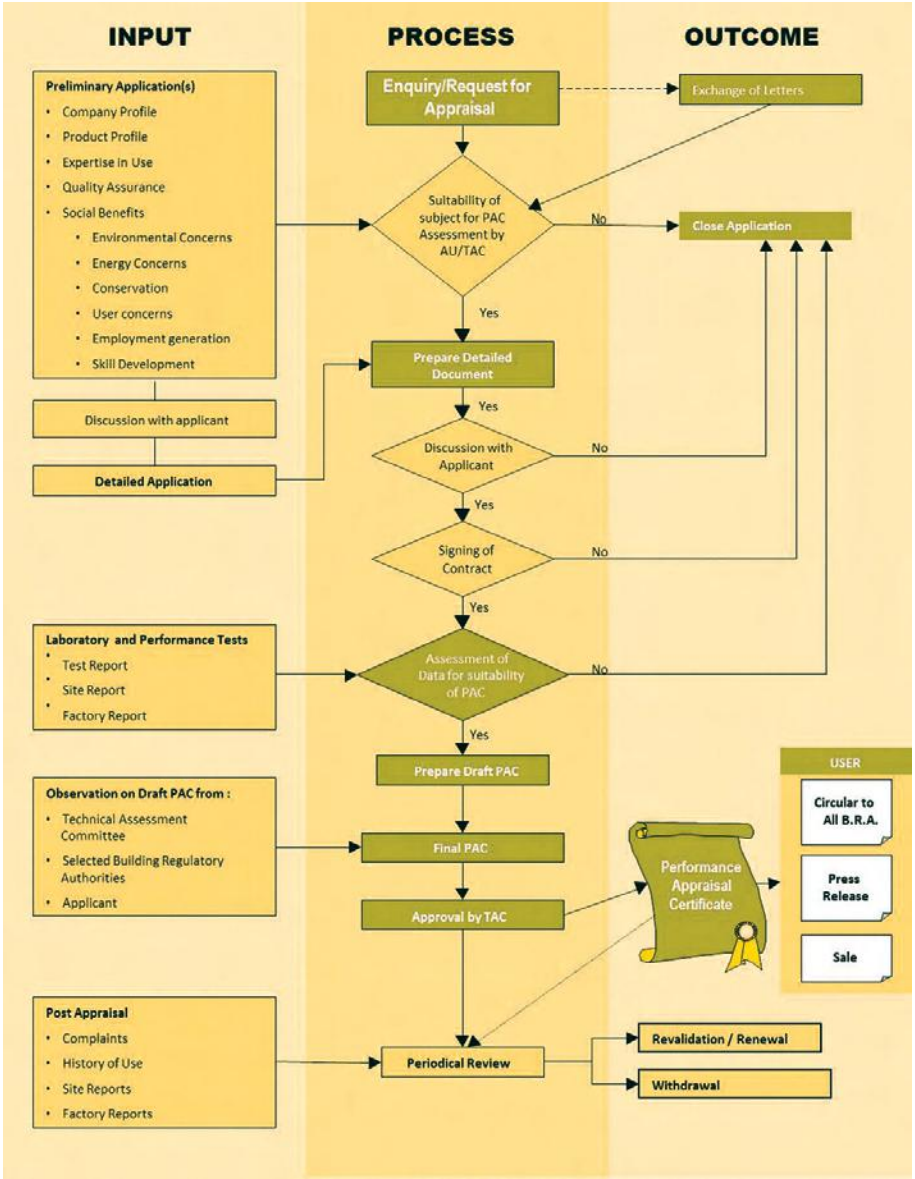
- Monolithic Concrete Construction System using Plastic - Aluminium Formwork
- Monolithic Concrete Construction System using Aluminium Formwork
- Expanded Polystyrene Core Panel System
- Industrialized 3-S System using Precast RCC Columns, Beams & Cellular Light Weight Concrete Precast RCC Slabs
- Speed Floor System
- Glass Fibre Reinforced Gypsum (GFRG) Panel Building System
- Factory Made Fast Track Modular Building System
- Light Gauge Steel Framed Structures (LGSF)

The evaluation has been done through Technology Advisory Committee and under Performance Appraisal Certification Scheme (PACS) being operated by BMTPC.

The PACS is a third party assurance system based on laboratory and field tests of the required performance criteria of the any system / building materials on which there is no Indian Standard. The broad parameters, based on which the evaluation is done inter-alia include:

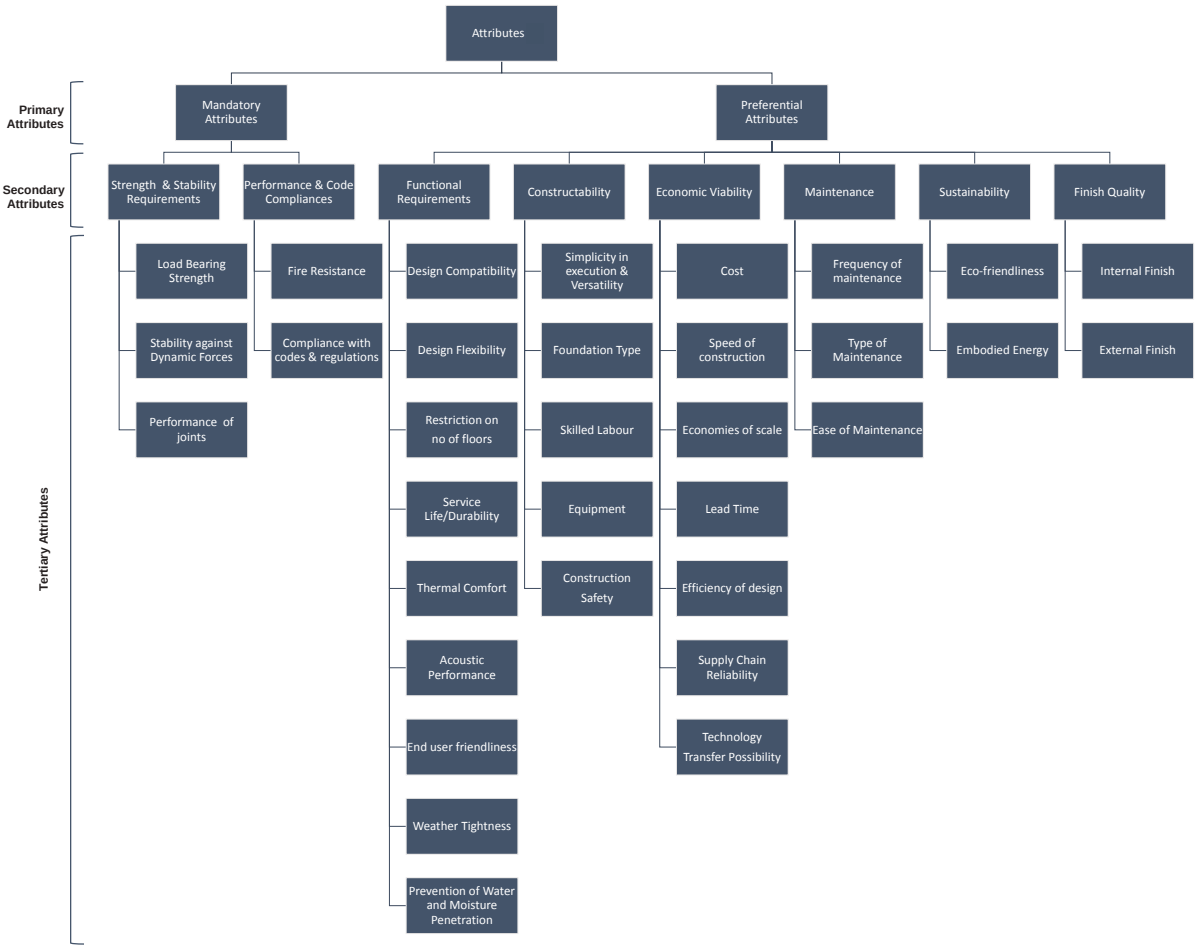
- Structural performance against vertical & lateral loads
- Fire resistance
- Protection against rain & moisture.
- Thermal behaviour
- Acoustic
- Ease of fixing services
- Quality assurance
- Durability

The process flow chart for PACS is given below:



Performance Appraisal Certification System

Whereas PACS takes care of verifying technical suitability of the system; other parameters are required to be addressed for proper selection of technology for particular place. A multi attribute evaluation system evolved by BMTPC to provide a technical framework for selection of any new technologies is given below. It may be used by agencies for selection of any technology/construction system.



Multi-Attribute Evaluation System for New Technologies

The details of the technologies evaluated and recommended, as contained in this booklet, will help user agencies in getting informed choice of different innovative construction practices, which could be utilized for mass housing scheme. For any further details regarding technologies, the following may be approached:

1. The Joint Secretary (RAY),
   Ministry of Housing & Urban Poverty Alleviation, Government of India,
   Room No.116, G-Wing, Nirman Bhawan, Neew Delhi, Tel: 011-23061419;
   Fax: 011-23061420, E-mail: sanjeev.kumar70@nic.in

2. The Executive Director,
   Building Materials & Technology Promotion Council, Core-5A, 1st Floor,
   India Habitat Centre, Lodhi Road, New Delhi, Tel: 011-24636705;
   Fax: 011-24642849, E-mail: bmtpc@del2.vsnl.net.in or ska@bmtpc.org.

Monolithic Concrete Construction System using Plastic - Aluminium Formwork

(Suitable for Low Rise to High Rise Structures)

ABOUT THE TECHNOLOGY

In this system, in place of traditional RCC framed construction of columns and beams; all walls, floors, slabs, columns, beams, stairs, together with door and window openings are cast-in-place monolithically using appropriate grade of concrete in one operation. The specially custom designed modular formwork made up of Aluminium/ Plastic/Aluminium-Plastic Composite is easy to handle with minimum labour & without use of any equipment. Being modular formwork system, it facilitates in rapid construction of multiple/mass unit scale.

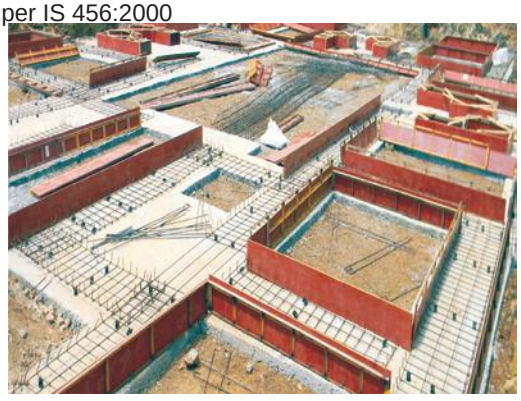
BASIC MATERIAL REQUIREMENTS

Formwork system

Formwork system is propriety system and designed as per loading requirements of the structure. It has adequate stiffness to weight ratio, yielding minimum deflection under concrete loading. The panel should fix precisely, securely and require no bracing. Being recent advancement in technology, IS 14687 : 1999 Guidelines for falsework for concrete does not cover requirements of special type of formwork system.

Concrete

Shall be of appropriate grade based on environment condition as per IS 456:2000



Reinforcement

Shall conform to IS 1786:2008

DETAILS OF FORMWORK

The formwork made of Aluminium Extruded Section conforming to IS 733:1983 and PVC of Grade PVC 67G ER01 in in accordance with IS 10151:1982. It consists of different sections including starter of MS Angle, top frame of aluminium channels, wall panels, slab panels & truss.

The formwork is designed based on the structural requirements of building units. A quality control scheme is required to be followed in manufacturing of formwork components.

Under Performance Appraisal Certification Scheme, the present formwork system manufactured by M/s Sintex Industries, Ahmedabad, has been evaluated and certified by BMTPC (PAC No. 1006-A/2011).

STRUCTURAL REQUIREMENTS OF THE CONSTRUCTION

The Monolithic RCC construction is considered as shear wall system. The maximum spacing between cross wall shall be limited to 1.5 times the floor height if supported on two edges and 2.0 times the floor height, when supported on all four edges.

The walls are designed primarily for loading and also for in-plane lateral load (shear) and out of plane (bending) due to wind load and earthquake forces as per relevant Indian Standard Code IS 875(Pt.3):1987 and IS1893(Pt.1):2002 respectively. For out of plane loading, the plate can be assumed to be supported by floor slabs / diaphragm and cross walls and continuity can be assumed, wherever applicable.

The structural design of plain & RCC shall be as per IS 456:2000 while IS 13920:1993 is referred for ductile detailing of reinforced concrete structure. Thickness of wall below plinth level should be minimum 200 mm with double layers reinforcement.

Guidelines on Monolithic Concrete Construction prepared by BMTPC may be referred for material requirements & design aspects of this system.

DURABILITY

Since concrete is main constituent material in this system, durability of the structure can be achieved by using proper ingredient, Grade of concrete as per IS 456:2000 and mix design in accordance with IS 10262:2009.

Thickness of the wall is generally 100 mm with the centrally placed reinforcement. Therefore, adequate cover is likely to be maintained, as a result high durability is achieved.

THERMAL BEHAVIOUR OF STRUCTURE

100 mm thick RCC walls and slab has thermal transmittance (*U*) value as 3.59 W/m^{2}K) (as per IS 3792:1978). As, it is more than the normal plastered brick masonry walls (thermal transmittance (*U*) 2.13 W/m^{2}K), it is advised that implementing agency shall ensure proper planning for heat insulation and air ventilation in the housing units through proper orientation, shedding etc. (*see* IS 3792:1978 for guidance).

ACOUSTIC

Average sound reduction for 100 mm concrete is ≥ 45db (IS 1950:1962), which refers reasonable acoustic insulation.

EASE OF FIXING SERVICES

All electric and plumbing fixtures, lines have to be pre-planned and placed appropriately before pouring concrete in RC walls & slabs. Post construction alternation is not desirable.

ECONOMY OF SCALE

Economy of scale depends upon the volume of work and number of repetition of the formwork. To achieve economy, minimum 100 repetitions are desirable.

For very small project of less than 500 units, this system may not prove to be economical.

OTHER FEATURES

1) Pre designed formwork acts as assembly line production and enables rapid construction of multiple/mass scale units of repetitive type.
2) Varying work cycle is possible, however, for speed and economy 3-4 days cycle are desirable.
3) It is flexible in design and can form any architectural or structural configuration, such as stairs, windows, etc.

LIMITATION

1) A lead time of about 3 months is required for initiation of work, as the formwork are custom designed, manufactured and prototype approved before manufacturing required number of sets of formwork.
2) Capital cost to initiate construction is high and may require regular flow of funds.
3) Post construction alterations are difficult.
4) All the service lines are to be pre-planned in advance.
4) Not much saving in construction in one storey structure.

MAJOR COMPLETED PROJECT

1) 5008 houses at Kanjhawala Narela, Delhi for DSIIDC.
2) 512 houses in Bawana, Delhi for DSIIDC.
3) 3000 houses in Ahmedabad for Ahmedabad Municipal Corporation.
4) 3000 houses in Lucknow for Lucknow Development Authority & other projects in major Indian Cities among many others....

STANDARDS/GUIDELINES REFERRED

IS 456:2000	Code of Practice for plain and reinforced concrete (fourth revision)
IS 733 : 1983	Wrought Aluminium and Aluminium Alloy Bars, Rods and Sections (for General Engineering Purposes)
IS 875 (Pt.3):1987	Code of Practice for Design Loads (Other than Earthquake) for Buildings and Structures - Part 3 : Wind Loads
IS 1786:2008	High strength deformed steel bars and wires for concrete reinforcement-
IS 1893 (Pt.1):2002)	Criteria for Earthquake Resistant Design of Structures - Part 1 : General Provisions and Buildings
IS 1950: 1962	Code of practice for sound insulation of non-industrial buildings
IS 3792: 1978	Guide for heat insulation of non-industrial buildings
IS 10151:1982	Polyvinyl Chloride (PVC) and its Copolymers for its Safe Use in Contact with Foodstuffs, Pharmaceuticals and Drinking Water
IS 10262:2009	Concrete Mix Proportioning - Guidelines
IS 13920 : 1993	Ductile detailing of reinforced concrete structures subjected to seismic forces - Code of practice
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Concrete

Shall be of appropriate grade based on environment condition as per IS 456:2000

Reinforcement

Shall conform to IS 1786:2008

DETAILS OF FORMWORK

The formwork systems used are made of light weight Aluminium. The recommended concrete forms generally use robotics welding system for manufacturing. A soft alloy weld wire is utilized in the concrete form weld process. Fixing of the formwork is done using tie, pin & wedges system. Does not require very skilled labour to do the job.

The formwork can be designed based on requirements of dwelling unit and the project. A repetition of about 1000 cycle is claimed (This, however, needs, verification).

STRUCTURAL REQUIREMENTS OF THE CONSTRUCTION

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system. The maximum spacing between cross wall shall be limited to 1.5 times the floor height if supported on two edges and 2.0 times the floor height, when supported on all four edges.

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4) All the service lines are to be pre-planned in advance.
4) Not much saving in construction in one storey structure.

MAJOR COMPLETED PROJECT

1) Houses in Bangalore for Karnataka Slum Development Board.
2) Houses in Mysore for Karnataka Slum Development Board.
3) Houses in Bangalore for Bangalore Development Authority & several other projects in major cities of India, among many others...

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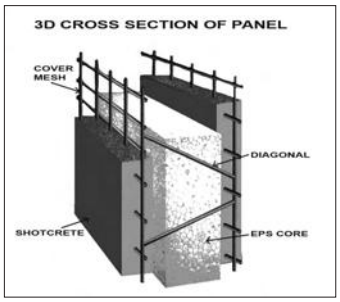
Expanded Polystyrene Core Panel System

(Suitable for Low Rise to Medium Rise Structures)

ABOUT THE TECHNOLOGY



Expanded Polystyrene (EPS) Core Panel System is based on factory made panels, consisting of self extinguishing expanded polystyrene sheet (generally corrugated) with minimum density of 15Kg/m^3, thickness not less than 60 mm, sandwitched between two engineered sheet of welded wire fabric mesh, made of high strength galvanized wire of 2.5 mm to 3 mm dia. A 3 mm to 4 mm dia galvanized steel truss wire is pierced completely through the polystyrene core at the offset angle for superior strength and welded to each of the outer layer sheet of steel welded wire fabric mesh. The panels are finished at the site using minimum 30 mm thick shotcrete of cement & coarse sand in the ratio of 1:4 applied under pressure. *(Refer sectional details as shown)*. The shotcrete coat encases the EPS Core with centrally placed streel welded wire fabric mesh.

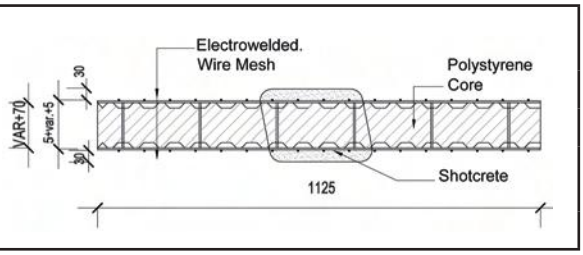
The technology (developed about 30 years back) is in use successfully in many countries like Morocco, Algeria, South Africa, Kenya, Austria, Malasiya, Ireland, Romania & Australia with involvement of different agencies and brand names.

PANEL TYPES

The Panels being manufactured are of different types depending upon the application. The details of different types of typical panels are given below:

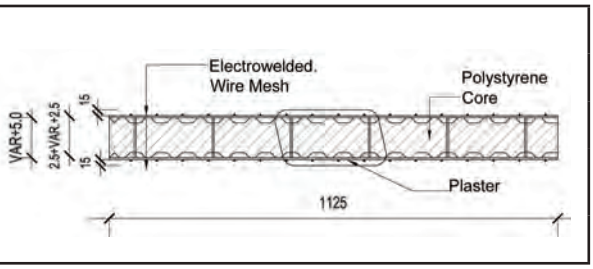
Single Panel for structural uses

Longitudinal wire	2.5 mm / 3.5 mm ø spaced @ 65 mm
Transverse Wire	2.5 mm ø spaced @ 65 mm
Cross Steel Wire	3.0 mm ø approx 68 nos. / m^2
Polystyrene Core	Density >15 Kg/m^3, Thickness not less than 60 mm
Finished Masonry	Not less than 130 mm thick



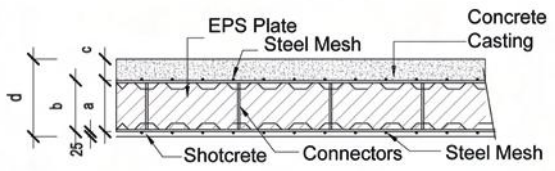
Single Panel for Internal partition, external walls and insulation

Longitudinal wire	2.5 mm ø spaced @ 70 mm
Transverse Wire	2.5 mm ø spaced @ 70 mm
Cross Steel Wire	3.0 mm ø approx 68 nos. / m^2
Polystyrene Core	Density > 15 Kg/m^3, Thickness 40 mm to 320 mm
Finished Masonry	90 mm to 370 mm thick



Single Panel for horizontal structure for floor/ roof

Longitudinal wire	3.5 mm / 4.5 mm spaced @ 65 mm
Transverse Wire	2.5 mm ø spaced @ 65 mm
Cross Steel Wire	3.0 mm ø approx 68 nos. / m^2
Polystyrene Core	Density 15 - 25 Kg/m^3 Thickness 80 mm to 160 mm
Finished Masonry	155 mm to 235 mm thick

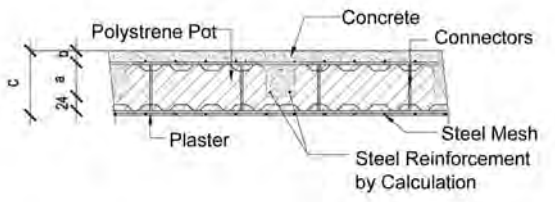


a = EPS Nominal Thickness (variable between 80 mm to 160 mm); b = Distance between thickness steel meshes (a + 10 mm); c = Shotcrete thickness (average ≥ 25 mm); d = Total thickness (2xc+a)

Generally used for buildings of not more than 4 storeys for floor and covering slabs with maximum span of 4 m.

Floor Panel with reinforcement at joist

Longitudinal wire	2.5 mm ø spaced @ 70 mm
Transverse Wire	2.5 mm spaced @ 70 mm
Cross Steel Wire	3.0 mm ø approx. 68nos. /m^2
Polystyrene Core	Density > 15 kg/m^3



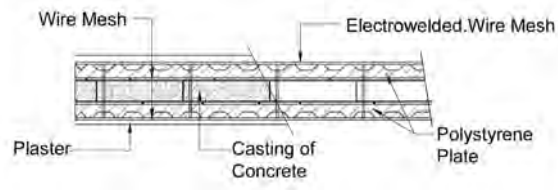
a = thickness of core; b = thickness of concrete; c = overall thickness

Panels are used for the floor and the roof system and reinforced in the joists with concrete casting on the site. The reinforcement of the panel is integrated during the panel assembly by additional reinforcing bars inside the joists as per the design.
Suitable upto 8m span with the live load of up to 4 kN/m^2.

Double Panel

External mesh

Longitudinal wire	2.5 mm ø spaced @ 65 m
Transverse Wire	2.5 m ø spaced @ 65 mm
Cross Steel Wire	3.0 mm ø approx 68nos. /m^2
Polystyrene Core	Density 25 Kg/m^3 thickness 50 mm to 80 mm
Finished Masonry	Finished inter-plate thickness 120 mm to 200 mm



Internal mesh

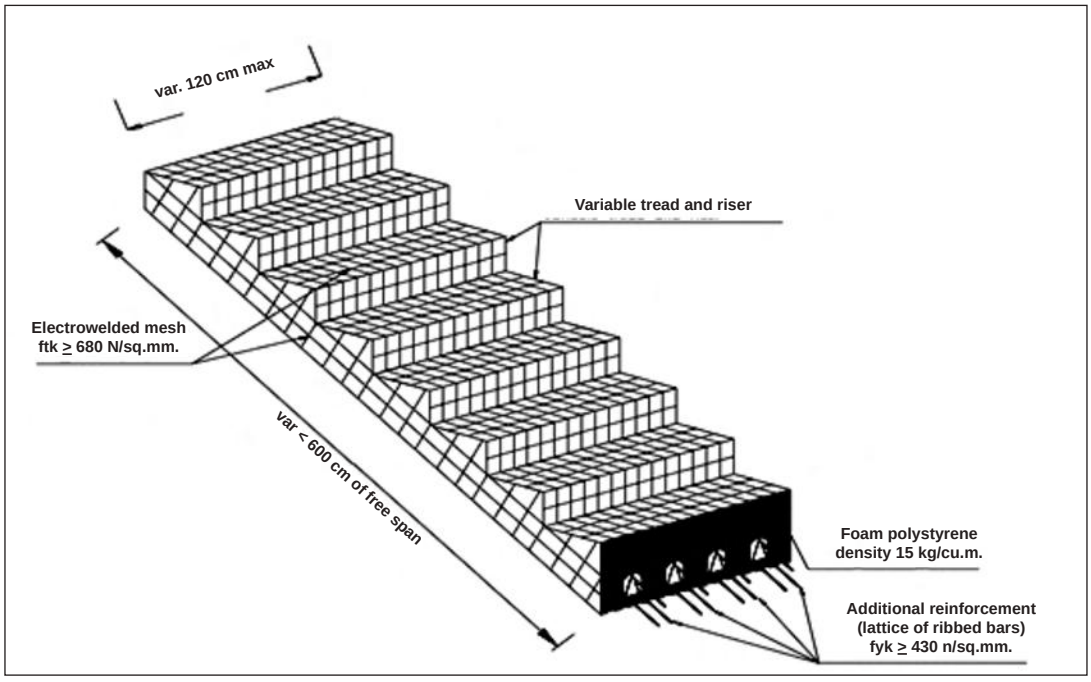
Longitudinal wire	5 mm ø spaced @ 100 mm
Transverse Wire	5 mm ø spaced @ 260 mm
Polystyrene Core	Density 25kg/m^3 thickness 50 mm to 80 mm

Externally the panels are sprayed with traditional pre-mixed cement based plaster. The space between the panels are filled with concrete. It functions as insulating elements as well as formwork.

Connections

Connecting the wall panel to the concrete substrata	By dowels embedded in concrete with adequate anchorage length.
Coplanar panels	By overlapping one row of electro welded mesh and tying using 16 gauge wire.
Walls panels and ceiling panels of intermediate floors	By protruding the inner vertical dowels that connect the upper and lower wall panels through. Then putting corner mesh, tied with 16 gauge wire to the mesh of the lower wall panels as well as to the base mesh of the ceiling panel. Openings for doors & windows etc. are braced using flat mesh at 45^{o} above and below corners of the opening.
Consecutive Floors	Using the same dowels utilized to connect the walls of the first floor to the foundation. Additional reinforcement of electro–welded mesh is provided on edges and diagonal fringe by tying on the inner and outer face of the panels by suitable wire.

Staircase Panel



Galvanized steel wire mesh:

Longitudinal wires:	2.5 mm dia
Transversal wires:	2.5 mm dia
Cross steel wire:	3.0 mm dia
Polystyrene slab density:	> 15 kg/m^3

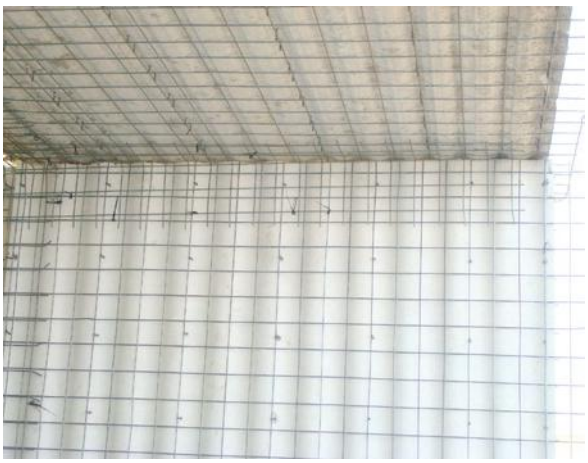
FEATURES OF PANEL SYSTEM

Load carrying capacity

Numerous lab tests, performed in different parts of the world, have highlighted the high load resistance of the panels which after compression testing with centred load performed on a single finished panel, 2700mm high, have shown that they withstand a maximum load of up to 1530 kN/m ≈ 153 ton/m. The Monolithic joints of the building system provide a high level of structural strength to buildings.

Seismic Performance

The prototype houses tested using both artificial and natural accelerograms with peak values over 1.0g, came through unscathed. Buildings made using panels are particularly lightweight, so have a low seismic mass, but are at the same time rigid due to two sheets of reinforced plaster that interact to create an enveloping ‘shell’ of the whole structure.



Thermal Behaviour

The thickness and density of the panel can be customised to deliver specific thermal insulation requirements. Furthermore, the EPS core extends throughout the surface which makes up the building envelope eliminating thermal bridging.

For example, a wall with a 80 mm core and finished thickness of about 150mm provides the same thermal insulation as an insulated solid masonry wall of about 400mm, with obvious advantages in terms of additional space.

Acoustic Behaviour

The panel has good acoustic behaviour, coupling with sound-absorbing materials (such as plasterboard, cork, coconut fibre, rock wool, etc.), further optimizes the acoustic insulation of walls.

Sustainability and Energy Efficiency

The insulating envelope provided by polystyrene core eliminates thermal bridges and ducts within the panel. This brings high level of energy efficiency. The system provides significant improvements in indoor thermal comfort by greatly reducing energy consumption and promoting strategies aimed at sustainable development.

Fire Resistivity

The expanded foam polystyrene used for panels is self-extinguishing and is perfectly encased by layers of reinforced concrete as external coat to sides of the panel and inhibit combustion. Fire resistance has also been verified in tests performed in various laboratories. For instance, a wall erected using a 80 mm core single panel

with 150 mm thickness provides REI* 150 fire resistance, which means that for 150 minutes, the panel can resist fire for 150 minutes with respect to load bearing capacity, integrity and insulation.

** R=Load bearing capacity; E=Integrity; I=Insulation*

Cost Effectiveness

Compared to traditional products, panels achieve far better results, at considerably reduced cost. The speedy construction represent additional savings.

Rapid Installation

The system has been used in many countries worldwide. The construction experiences using the system show a marked reduction in construction time compared to traditional building methods. Panels are industrialized, and for this reason, assembly processes are optimised, labour is significantly reduced, and construction time decreased by roughly 40%.

Lightness, Ease of Transport and Handling

Being light weight and rigid, panels are both easy to handle and transport even in the most adverse conditions. Prior to an application of shortcrete, a panel weighs between 3.5kg/m^2 to 5 kg/m^2 which means that a single worker can easily handle a 3 m^2 wall, that is, a panel as high as the storey height.

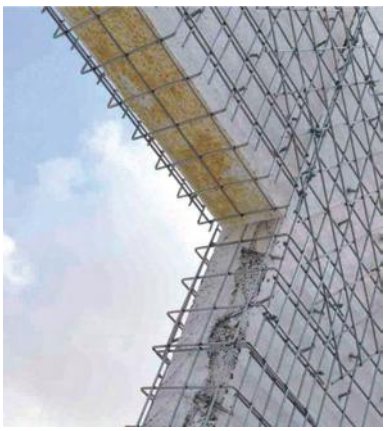
Versatility

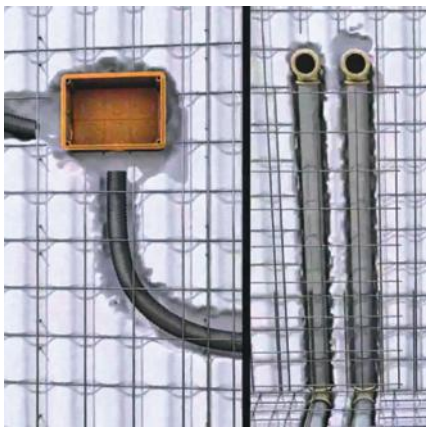
The building system gives full design flexibility as it offers a complete range of building elements such as load-bearing walls, curtain walls, floors and stairs.

The panels are easy to use in the construction of any type of structure, and can be shaped to any geometric requirement i.e. flat or curved by simple cutting the panels at site.

Compatibility with Other Existing System

It is an extremely versatile building system which is completely compatible with all other existing construction systems; in fact, panels are even suitable for completing reinforced concrete or steel structures. In addition, panels can be easily anchored to other construction elements, such as steel, wood, and pre-stressed concrete.





Blast Resistance

A series of tests has been carried out on a variety of panels finished with different types of high strength concrete. These tests were conducted using a powerful explosive, in a test chamber optimized to produce a uniform shock waves on the face of the panels.

The panels performed excellently withstanding explosions of 29.5 tons/m^2.

Wide Choice of Finishes

Buildings constructed using panels can be completed in a variety of finishes, or can be painted traditionally on smoothed plaster.

The surface of the walls has the appearance of a thin sheet of reinforced plaster that can easily accommodate all types of wall coverings including stone tiles and rain screen cladding.

Cyclone Resistant

Laboratory tests conducted on buildings, to determine the resistance of cyclone impact and damage caused by wind-borne debris confirm the strength of the building system against such loads.

Building constructed in cyclone prone area have shown very high resistance to cyclonic wind.

REQUIREMENTS FOR SETTING UP OF PLANTS

The viability depends upon the quantum of work. Generally requirements of 1.5 lakh sqm of panel per year for minimum period of three years makes the plant viable.

CERTIFICATION

BMTPC under Performance Appraisal Certification Scheme has evaluated the System by EMMEDUE SPA, Italy and issued Performance Appraisal Certificate No 1010-S/2014 (may be downloaded from website www.bmtpc.org). The systems by any other agency may required to be verified, appropriately.

REFERENCES

- PAC No. 1010-S/2014 : Performance Appraisal Certificate issued by BMTPC, New Delhi, India.
- Manual on M2 System by EMMEDUE, S.P.A. Italy.
- Manual on Schnell Home, Schnell Wire, Italy.
- Certificate No. 06/0241, Irish Agreement Board, Ireland.
- Technical Report on Experimental Evaluation of Building System M2 by Structure Lab. Department of Engineering, Ponitificia Universidad Catolica Del, Peru.
- Review of EVG-3D Technology for residential buildings in India, IIT Mumbai, India.
- Report on Performance Tests conducted on EMMEDUE Panel System at Hesarghalta, Bangalore Civil Aid Techno Clinic Pvt. Ltd., Bangalore.

Industrialized 3-S System using Precast RCC Columns, Beams & Cellular Light Weight Concrete Precast RCC Slabs

(Suitable for Low Rise to High Rise Structures)

ABOUT THE TECHNOLOGY

The industrialized total prefab construction technology, being used since 1972, is based on factory mass manufactured structural prefab components conforming to provisions of relevant Indian Standards. The major precast elements are:

- RCC hollow columns with notches
- RCC solid beams (T/L/Square Shape)
- Staircase
- RCC precast slab
- AAC precast slab
- AAC precast block

In the system, precast dense concrete hollow column shell of appropriate sizes are used in combination with precast dense concrete rectangular / 'T' shape / 'L' Shape beams with light weight reinforced autoclaved cellular concrete/Precast RCC slabs for floors and roofs. The hollow columns are grouted with appropriate grade of in situ concrete. All the components and jointing of various structures are accomplished through on-site concerting along with secured embedded reinforcement of appropriate size, length and configuration to ensure monolithic continuous resilient, ductile and durable behaviour. Autoclaved Aerated Concrete (AAC) slabs can be used as floor / roof slabs. Joints are filled with reinforced screed concrete (minimum 40 mm thick) of M20 grade minimum. RCC screed is laid over entire area of slab before flooring / water proofing.

BASIC MATERIAL REQUIREMENTS

RCC hollow columns & Beam

Concrete

Shall conform to appropriate grade based on environmental and structural requirements condition as per IS 456 : 2000

Reinforcement

Shall be of Fe 415 Grade or Fe 500 Grade as per IS 1786:2008

AAC Precast Slab

Grade 1 of Density 551 – 650 Kg/m^3 of IS 6073:2006

AAC Precast Block

Density 451-550 Kg/m^3 for internal wall, 551-650 Kg/m^3 for external wall as per IS 2185 (Pt. 3) :1984

OTHER REQUIREMENTS:
EVALUATION OF STRUCTURAL REQUIREMENT OF JOINTS

Against vertical load

- Full Scale load test on assembly of precast elements by Tor Steel Research Foundation in India, Bangalore

found it safe.

- Structural Design evaluation for HIG – II Buildings at Powai by Shri H.P. Shah; Stanford University found that based on the design concept, design calculation and detailing; the structure is safe against vertical loads, seismic loads and the wind loads.
- Scrutiny of design for S+24 type buildings by IIT Mumbai found it safe.
- Scrutiny of design details for Delhi project by IIT Roorkee found jointing & connections ensuring monolithic, durable & ductile behaviour.

Against seismic and wind load

A Test was performed by CBRI on full-scale building to establish behaviour of various joints under all design loads including seismic Zone IV. The experimental results on Full Scale Building Structure demonstrated the desired performance and behaviour of the 3S system under all loading condition as envisaged.

When designed for use in Zone V, independent verification may be needed.

DURABILITY

- Anti corrosive treatment given to reinforcement used in AAC slab panels for durability, was evaluated by CBRI, Roorkee with satisfactory results.
- Concrete and cover requirement are as per durability clause of IS 456 : 2000, to ensure adequate durability.

FIRE RESISTANCE PROPERTY OF BLOCK / SLAB AS DWELLING UNIT

AAC blocks / Slabs used will have fire rating as per the NBC norms for dwelling units.

THERMAL BEHAVIOUR

Kvalue – 0.122 k cal/h/m^{o}c of AAC blocks*.

ACOUSTIC COMFORT TEST

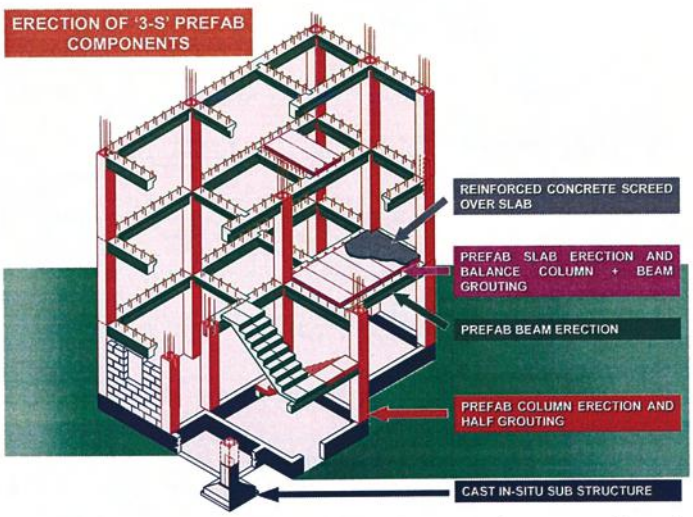
For 100 mm ACC Wall, Sound absorption is 38 – 40 db*

IMPACT RESISTANCE

Not tested*

EASE OF FIXING SERVICES (ELECTRICITY & PLUMBING)

With pre-planning, electricity & plumbing services can easily be placed.



Pictorial view showing various elements / stages of work

AVAILABILITY OF PLANTS & MACHINERY

Plants & Machineries for production of Components available in Pune, Mumbai, Bangalore and Delhi

ECONOMY OF SCALE

- For a new plant to be setup, a minimum project of 5000 dwelling units may be needed.
- In places, where plant is already set up, smaller project may also be viable.

ESSENTIAL REQUIREMENTS

- Precasting yard / factory set up is required with facilities such as Casting Yard, Computerised batching plant, Moulds, Transportation facility, Stacking yard for materials & components, Lifting and loading facility, Laboratory to test raw material & finished products, Water tank of enough holding capacity as required for 2 – 3 days, Service road, etc.
- Utmost attention is required for process engineering before taking up any field work. Close co-ordination between design crew, field staff and quality crew is essential.

LIMITATION

The project is taken as turnkey project by the agency M/s B.G.Shike & Co., Pune. No other agency is involved in this propriety system.

MAJOR CONSTRUCTION WORK DONE

1. Multistoried prefab residential buildings comprising over 400 Lacs sft built area have been completed since 1974
2. Residential EWS, LIG, MIG and HIG housing projects at Kharghar, Navi Mumbai for CIDCO.
3. Residential mass housing project of MHADA, Powai, Mumbai.
4. S+24 Multistoried Residential Building for mill workers & transit accommodation for 1000 families at Mumbai.
5. Mass Housing Project at Delhi for DDA.
6. S+14 multi storeyed MIG & HIG type buildings at Versova, Mumbai for MAHADA.
7. Multistoried residential buildings of Transit, LIG, MIG & HIG type of 10,650 families at SION Mumbai.
8. Several projects are being taken up / completed in the state of Maharastra, Karnataka, Andhra Pradesh, Tamil Nadu & Delhi.

STANDARDS/GUIDELINES REFERRED:

IS 456:2000	-	Code of Practice for plain and reinforced concrete.
IS 875 (Pt.3):1987	-	Code of Practice for Design Loads (Other than Earthquake) for Buildings and Structures - Part 3 : Wind Loads
IS 1786:2008	-	High strength deformed steel bars and wires for concrete reinforcement-
IS 1893 (Pt.1):2002	-	Criteria for Earthquake Resistant Design of Structures - Part 1 : General Provisions and Buildings
IS 1950:1962	-	Code of practice for sound insulation of non-industrial buildings
IS 2185 (Pt.3):1984	-	Specification for Concrete Masonry Unit - Part 3: Autoclaved Cellular (Aerated) Concrete Blocks
IS 3792:1978	-	Guide for heat insulation of non-industrial buildings
IS 6073:2006	-	Autoclave Reinforced Cellular Concrete Floor and Roof Slabs - Specification
IS 13920:1993	-	Ductile detailing of reinforced concrete structures subjected to seismic forces - Code of practice
NBC 2005	-	National Building Code, 2005

Speed Floor System

(Suitable for Low Rise to High Rise Structures)

ABOUT THE TECHNOLOGY

The Speed Floor System is a suspended concrete flooring system using a roll formed steel joist as an integral part of the final concrete and steel composite floor. It is essentially a hybrid concrete/steel tee-beam in one direction and an integrated continuous one-way slab in other direction. The joists of different depths are manufactured from pre-galvanized high tensile steel in a one pass roll former, where it is roll formed, punched, pressed and slotted in a fully computerized machine. The joist depth and the concrete thickness are varied depending on the span, imposed loads and other functional considerations. The Speedfloor composite floor system is suitable for use in all types of construction. The Speedfloor joists are designed and custom manufactured to suit particular job conditions.

DESIGN

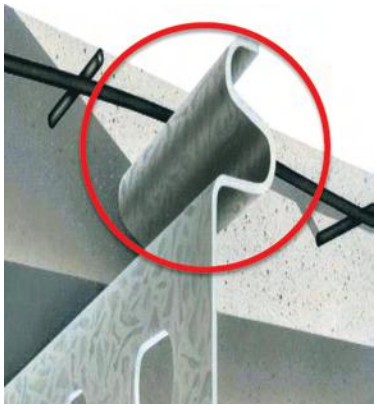
The design of the speed floor system is based on NZS 3404 (Part 1 &2) 1997, AS/NZS 4600, 1996 and the Australian Composite Standard AS 2327 (Part-I). The design load shall be taken as prevalent in IS 875 (Part 1 & 3):1987. Earthquake forces shall be taken in accordance with IS 1893 (Part-1):2002.

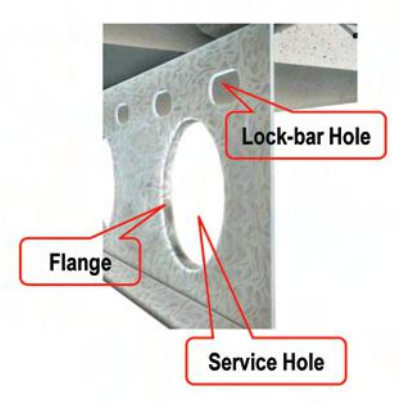
The section properties and design parameters are calculated from the section geometry, supplementary full scale tests and finite elements analysis.

THE JOIST

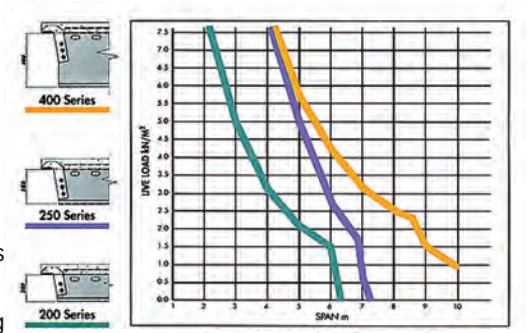
The joist is manufactured from G 350 Z 275 pre-galvanized steel conforming to AS 1397:2001. Size may be any one of the following i.e. 200mm, 250mm, 300mm, 350mm and 400mm, depending upon the design requirements. Concrete thickness may be 75mm or 90mm as required.

The joist weight vis-à-vis the depth are given below:





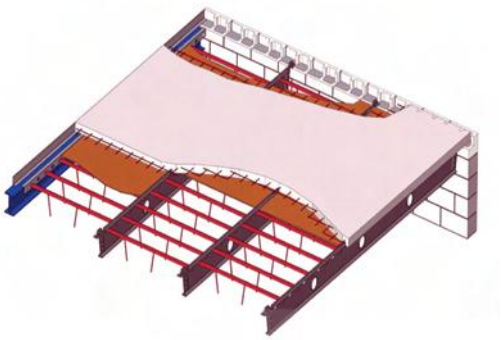
Depth (mm)	*Weight (kg/ ln m)*
200	9.41
250	10.59
300	11.76
350	12.94
400	14.12



Load span graph – 75mm topping

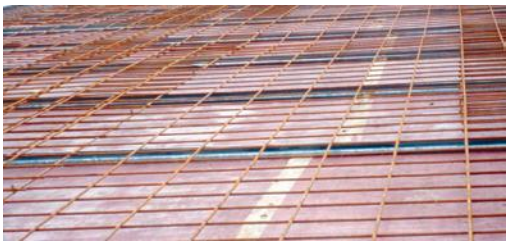
The ***top section*** of the joist is embedded in concrete and has following functions:

- It is the compression element of the non-composite joist during construction
- It is a 'chair' for the welded mesh or the reinforcement which develops negative moment capacity in the concrete slab over the joist
- It locks in and supports the slab shuttering system (lock bar and plywood forms)
- It becomes a continuous shear connector for the composite system. The bottom section of the joist acts as a tension member both during the construction phase and when the joist is acting compositely with the slab.



The ***mid section*** or web of the joists has the flanged service hole and the lock-bar hole punched into it. The flanging of the service hole provides stability to the web and services can pass through without requiring protection from the sharp edges of the punched material.

The ***bottom triangular*** section of the joist acts as a tension member both during construction phase and when the joist is acting compositely with the slab.



THE LOCKBAR

The lockbars support the temporary plywood formwork between the joists during construction. They shall be spaced approx. 300mm apart and engage in the slotted holes punched in the top section of the joist. They also maintain the exact spacing of the joists.

The standard lockbars when installed will position the joists 1230mm, 930mm or 630mm apart. There are also special adjustable lockbars that will position the joists in increments of 50mm from 330mm to 1530mm. Other type of lockbars are provided for special situations such as cantilevers or lowered soffits.

TEMPORARY PLYWOOD FORMWORK

High density paper overlaid 12mm shuttering plywood conforming to IS 4990:2011 or equivalent is used as formwork to produce a good finish to the underside of the slab. The rigid plywood sheets are used in conjunction with the lockbars and when locked in place, provide lateral stability to the entire Speedfloor system during the construction phase.

REINFORCING MESH

Welded reinforcement mesh made of 8mm dia bar (fy 415 N/m^2) placed @ 200mm c/c in both directions, is laid and tied into place. No chairs are required as it is held off the plywood forms by the top section of the joist, which becomes embedded in the concrete.

CONCRETE

i) Minimum grade of concrete shall be M25 as per IS 456:2000. It should preferably be batched at 60mm and super plasticized to 110mm slump to provide good placement and shrinkage characteristics. A curing compound should be used and an expanding agent may be introduced in consultation with the engineer to further control shrinkage during the curing period.

(ii) The concrete should initially be placed evenly and continuously over the area to be formed. Special attention should be given to ensure the concrete is screened and finished to the specified thickness so that designed deflections are achieved in the Speedfloor joists and the supporting structures.

(iii) In structures for carparking, an expanding agent is generally used to reduce the effect of shrinkage during initial cure and a curing compound is used to help control the curing process.

ACCESSORIES

Edge angles

A standard edge form is available in two heights – 75mm & 90mm.Special heights and specially shaped edge angles may be manufactured but would require longer lead times.

Jointers

Precut sections of galvanized sheet steel may be provided to overlay joints in the ply to ensure they are flush and remain well supported while the concrete is poured.

Lockbar Hanger Angles

A galvanized steel angle with pre-punched lockbar holes is used for situations where the lockbars need support on slab edges parallel to the joists.

LIMITATIONS

The system is used as framed steel structure in all types of construction for laying RCC roof.

Maximum length of joist which can be used is 10m.

DURABILITY

The technology provider shall provide necessary structural warranty ensuring durability of the system to the user, on demand.

INSTALLATION PROCESS

Installation process is as follows:

(i) Lightweight bundles of joists is lifted into position and then individual joists are placed by hand.

(ii) Speedfloor joists are generally placed at 1250 mm c/c.

(iii) Joists are held in place using the lockbars which slip into slotted holes.

(iv) The lockbars is placed at 300mm apart to support plywood formwork. The propping is not required.

(v) Full sheets of 12.5mm plywood formwork is to be laid from above creating a working platform. Cam action of lockbars secures plywood.

(vi) Mesh is placed on top section of joist thereby embedded in the concrete poured thereafter.

(vii) After three days of concreting, lockbars and plywood are removed from the underside revealing a clean surface ready for services or a fire rated suspended ceiling.

MAINTENANCE REQUIREMENTS

Speedfloor is a composite floor system using both steel and concrete. The two materials must be treated and maintained separately.

Steel : If the joists are in a clean and dry environment, they may not require any maintenance. If it is exposed to aggressive environment, they shall require maintenance to ensure that the expected performance is achieved. Guidelines given below should be followed for maintenance

a) Keep surfaces clean and free from continuous contact with moisture, dust and other debris.
b) Periodically inspect the joists for any signs of corrosion. Remove any by-products of the corrosion by mechanical means and spot prime the exposed steel substrate with an appropriate steel primer. Repaint the area using an appropriate paint.

Concrete: During the service life of the Speedfloor system, if any cracks appear in the concrete floor, they should be filled using an epoxy injection grout or equivalent, to completely close the crack and prevent moisture ingress.

For detailed Installation process, manufacturer's Installation Manual shall be referred.

APPLICATIONS

The Speed floor composite flooring system is suitable for use in all types of construction including:

- Steel frames structures
- RCC frame buildings
- Poured insitu or precast concrete frames
- Light gauge steel frames
- Conventional Structural brick wall constructions etc

The range of end uses include :

- General individual Houses
- Multi-storey residential blocks
- Single and multi-storey retail developments
- Mezzanine floors
- Car parks and storage buildings
- Multi-storey office complexes etc.

CERTIFICATION REFERENCES

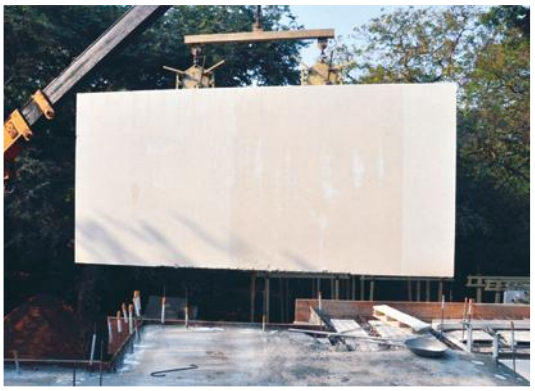
IS 277:1992	Specifications for Galvanized Steel Sheets (Plain & Corrugated)
IS 456:2000	Code of Practice for plain & reinforced Concrete (Fourth revision)
IS 875 (Parts1to3):1987	Code of Practice for Design Loads (other than earthquake) for buildings & structures
IS 1893 (Part-1):2002	Criteria for Earthquake Resistant Design of Structures - Part-1: General Provisions and Buildings
IS 2062:2011	Specifications for hot rolled medium & high tensile structural steel
IS 11384:1985	Code of Practice for Composite Construction in Steel and Concrete
AS/NZS 1170-2 (Parts 0 & 2) : 2002	Structural Design Actions—General principles and Wind actions
AS 2327(Part1):1996	Design of simply supported Composite structures
NZS 3101(Part1):2006	Design of Concrete Structures
NZS 3404 (Part1):1997	Design of Steel Structures
AS/NZS 4600:2005	Design of Cold Formed Steel Structures
AS/NZS 4671: 2001	Specifications for Steel reinforcing materials

Glass Fibre Reinforced Gypsum (GFRG) Panel Building System

(Suitable for Low Rise to High Rise Structures)

ABOUT THE TECHNOLOGY

Glass Fibre Reinforced Gypsum (GFRG) Panel also known as Rapidwall is made-up of calcined gypsum plaster, reinforced with glass fibers. The panel was originally developed by GFRG Building System Australia and used since 1990 in Australia for mass scale building construction. In recent times, these panels are being produced in India and the technology is being used in India.



The panel, manufactured to a thickness of 124mm under carefully controlled conditions to a length of 12m and height of 3m, contains cavities that may be unfilled, partially filled or fully filled with reinforced concrete as per structural requirement. Experimental studies and research in Australia, China and India have shown that GFRG panels, suitably filled with plain reinforced concrete possesses substantial strength to act not only as load bearing elements but also as shear wall, capable of resisting lateral loads due to earthquake and wind. GFRG panel can also be used advantageously as in-fills (non-load bearing) in combination with RCC framed columns and beams (conventional framed construction of multi-storey building) without any restriction on number of storeyes. Micro-beams and RCC screed (acting as T-beam) can be used as floor/ roof slab.

The GFRG Panel is manufactured in semi-automatic plant using slurry of calcined gypsum plaster mixed with certain chemicals including water repellent emulsion and glass fibre rovings, cut, spread and imbedded uniformly into the slurry with the help of screen roller. The panels are dried at a temperature of 275^{o}C before shifting to storage area or the cutting table. The wall panels can be cut as per dimensions & requirements of the building planned.

It is an integrated composite building system using factory made prefab load bearing cage panels & monolithic cast-in situ RC infilled for walling & floor/roof slab, suitable for low rise to medium rise (single to 10 storeys) building.

CLASSIFICATION

Class – 1 – Water resistant grade – GFRG panel for external walls, in wet areas and / or as floor and wall formwork for concrete filling.

Class – 2 – General Grade – GFRG panels for structural application or non–structural application in dry areas. These panels are unsuitable for use as wall or floor formwork and

Class – 3 – Partition Grade – GFRG panel as non–structural internal partition walls in dry areas only.

APPLICATION

GFRG panels may generally be used in following ways:

i) As load Bearing Walling – With cavities filled with reinforced concrete is suitable for multi – storeyed housing. In single or two storeyed construction, the cavities can remain unfilled or suitably filled with non – structural core filling such as insulation, sand, quarry dust, polyurethane or light weight concrete.

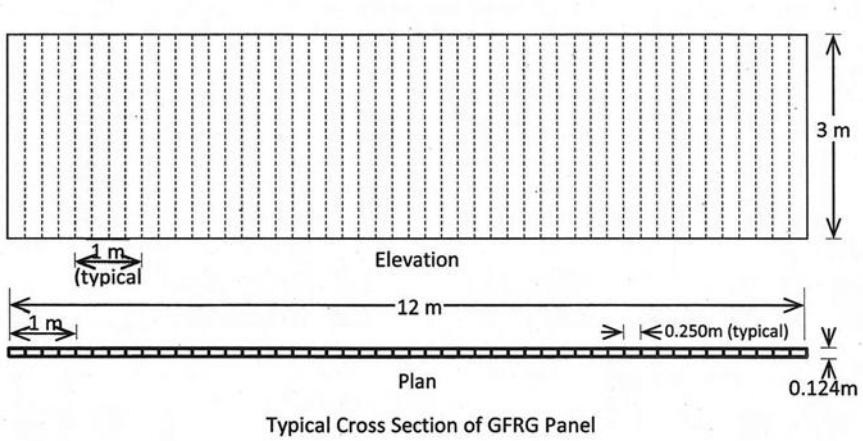
ii) As partition walls in multi storeyed frame buildings. Panels can also be filled suitably. Such walls can also be used as cladding for industrial buildings or sport facilities etc.

iii) As compound walls / security walls.

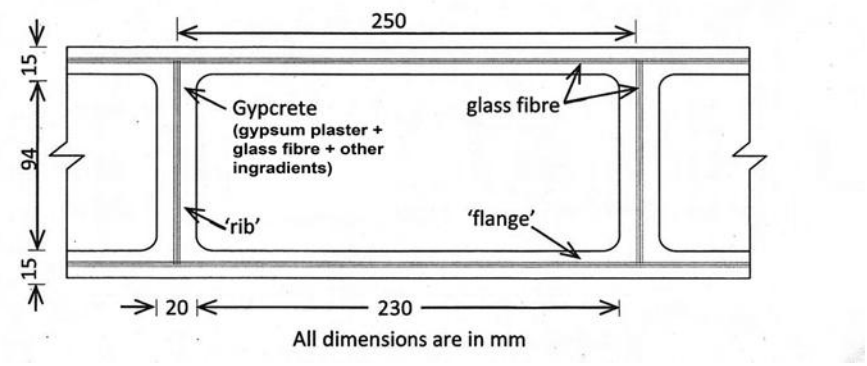
iv) As horizontal floor slabs / roof slabs with reinforced concrete micro beams and screed (T-beam action). This system can also be used in inclined configuration, such as staircase waist slab and pitched roofing.

DIMENSION

Typical Dimension of GFRG building panel are 12.0m x 3.0m x 0.124m
Each 1.0m segment of the panel contains four cells. Each cell is 250mm wide and 124mm thick (as shown below)



Typical Cross Section of GFRG Panel



Enlarged view of a Typical Cell of GFRG Panel

MECHANICAL PROPERTIES (UNFILLED PANELS) : TEST RESULTS

Mechanical Properties	Nominal Value	Remarks
Unit weight	0.433 kN/m^2	
Modulus of elasticity, **E_G**	7500 N/mm^2	
Uni-axial compressive strength, P_{uc}	160 kN/m (4.77 MPa)	Strength obtained from longitudinal compression / tension tests with ribs extending in the longitudinal direction.
Uni-axial tensile strength, T_{uc}	34 – 37 kN/m	
Ultimate shear strength, V_{uc}	21.6 kN/m	
Out-of-plane moment capacity, Rib parallel to span, M_{uc}	2.1 kNm/m	
Out-of-plane moment capacity, Rib perpendicular to span, M_{uc}, perp	0.88 kNm/m	
Mohr hardness	1.6	
Out-of-plane flexural rigidity, **EI**, Rib parallel to span	3.5 x 10^{11} Nmm^2/m	
Out-of-plane flexural rigidity, **EI**, Rib perpendicular to span	1.7x10^{11}Nmm^2/m	
Coefficient of thermal expansion, Cm	12x10^{-6}mm/mm/^{o}C	
Water absorption	1.0% : 1 hr 3.85% : 24 hrs	Average water absorption by weight % after certain hours of immersion.
Fire resistance : Structural adequacy / integrity / insulation	140/140/140 minutes	CSIRO, Australia/ IS 3809:1979
Sound transmission class (STC)	40 dB	ISO 10140-3:2010*

** ISO 10140-3:2010 - Acoustics -- Laboratory measurement of sound insulation of building elements -- Part 3: Measurement of impact sound insulation*

Source: GFRG/Rapidwall Building Structural Design Manual

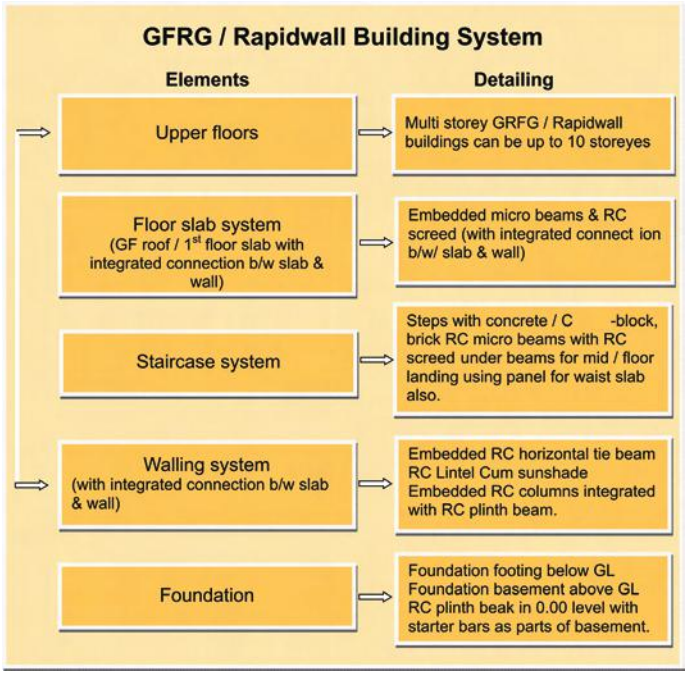
DESIGN

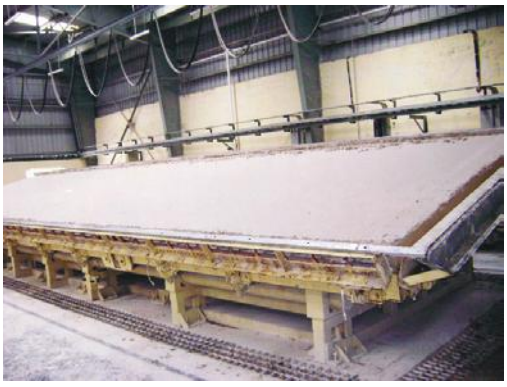
The design capacities of GFRG panel is based on limit state design procedures, considering the ultimate limit state for strength design, treating the 3.0 m high GFRG panel as the unit material and considering the strength capacity as obtained from the test results. The design shall be carried out by considering all possible loads (as per relevant Indian Standards) to which the structure is likely to be exposed in its service life. It shall also satisfy the serviceability requirements, such as limitations of deflection and cracking. In general the structure shall be designed on the basis of the most critical limit state and shall be checked for other limit states.

Detailed design Guidelines are available in “Use of Glass Fibre Reinforced Gypsum (GFRG) Panels in Buildings - Structural Design Manual” prepared by IIT Madras and published by BMTPC. It may be obtained on request from BMTPC.

Experimental studies and research have shown that GFRG Panels, suitably filled with reinforced concrete, possess substantial strength to act not only as load bearing elements, but also as shear wall, capable of resisting lateral loads due to earthquake and wind. It is possible to design such buildings upto 10 storeys in low seismic zone. (and to lesser height in high seismic zone). However, the structure needs to be properly designed by a competent structural engineer. Manufacture of GRFG Panels with increased thickness (150 mm – 200 mm) with suitable flange thickness can facilitate design and construction of taller buildings.

The basis arrangement of GFRG Panel Building System is as follow:





TRANSPORTATION

The GFRG panels are transported from factory to site, generally through trucks or trailers. The panels are kept in a vertical position using “stillages” so as to avoid any damage during transportation. The panels after reaching the site are taken out from trucks using cranes. Forklifts can be used for easier movement of panels.

CONSTRUCTION

The foundation used for the construction is conventional and is designed generally as strip footing depending upon the soil condition.

For superstructure – plinth beams are cast all around the floor, where walls have to be erected. The superstructure is entirely based on prefabricated panels. The procedure mainly include fixing of wall panels and roof panels using mechanical means, preferably a crane and filling the required joint with reinforced cement concrete as per structural design.

Waterproofing is an essential requirement of the construction at different stages. Detailed guidelines for waterproofing are required to be followed during construction.

LIMITATION

- The shorter span of slab (floor / roof) should be restricted to maximum of 5 m.

- The system is ideal if the same floor / roof is replicated for all floors in multi storeyed structure. For any variations, a structural designer needs to be consulted.
- The panels are not suitable for curved walls or domes. In case it is essential, use masonry / concrete for that particular area.
- The electrical / plumbing system should be such that most of the pipes go through the cavities (in order to facilitate minimum cutting of panel)

OTHER FEATURES

Green Technology

It makes use of industrial waste gypsum, does not need any plastering, uses much less cement, sand, steel and water than conventional building materials. It consumes much less embodied energy and less carbon footprint.

Reduced built area

Panels being only 124 mm thick, for the same carpet area, the built up area and the building footprint is much less than conventional buildings. This is particularly advantageous in multi storeyed mass housing.

Versatility

Panels can be used not only as walls but also as floors, roofs and staircase.

Speed of Construction

Using the system, the construction of a building is relatively faster as compared to the conventional building. One building of two storeyed (total 185 sqm with four flats) was constructed in IIT Madras in one month.

Lightness of structures bringing safety against earthquake forces

These panels are very light weight (43 kg/m^2). Even after filling some of the cavities with concrete, the overall building weight is much less, contributing to significant reduction in design earthquake forces and savings in foundation and overall buildings cost especially in multi – storeyed buildings.

FEW BUILDING CONSTRUCTED IN INDIA

- Residential buildings at Udipti Karnataka owner Mr. Satish Rao, built by Harsha Pvt. Ltd., Udipi, Bangalore.
- Utility Building for Konark Railways at Madgao, South Goa, built by Harsha Pvt. Ltd., Udipti, Bangalore.
- Residential building at Udipti by Harsha Pvt. Ltd.
- 3 storey residential building at Calicut by NMS Rapidwall Construction Company, Calicut (2014).
- Two storeyed building at IIT Madras.
- Residential building at RCF Mumbai.
- Model house at Cochin.

CERTIFICATION REFERENCES

- Performance Appraisal Certification PACs No. 1008-S/2011 issued to M/s Rashtriya Chemicals and Fertilizers Limited, “Priyadarshini”, Sion, Mumbai.
- Performance Appraisal Certification PACs No. 1009-S/2012 issued by FACT – RCF Building Products Ltd., FACT Cochin Division Campus, Ambalamedu, Kochi.
- GFRG / Rapidwall Building Structural Design Manual, prepared by IIT Madras, published by BMTPC, New Delhi.
- Schedule of Item & Rate Analysis for GFRG Construction, BMTPC, New Delhi *(to be published)*.
- IS 3809:1979 – Fire Resistant Test of Structures

Factory Made Fast Track Modular Building System

(Suitable for Low Rise to High Rise Structures)

ABOUT THE TECHNOLOGY

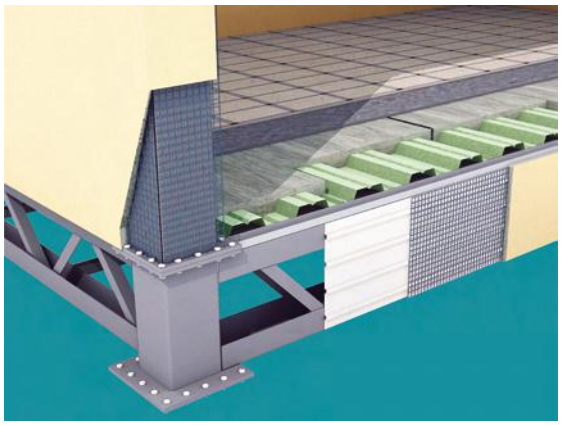
Factory Made Fast Track Modular Building System comprises of prefabricated steel structure with different walling components. About 70 percent of the work is done in the factory with minimal usage of concrete, which enables system to deliver the building within a few days of work at site. The steel moduled are pre-fitted with flooring, ceiling tiles, electrical and plumbing fittings. The assembled steel modules are transported to the site for installation which is done using crane and other required machineries. Once all the components are assembled and erected at site, factory made 3–D Expanded Polystyrene (EPS) wall panels are fixed and shotcreting is done from both sides.

The uniqueness of system is the efficient and simultaneous activities of site preparation and building construction in factory, rather than two phased customary process.

DETAILS OF STRUCTURE

Foundation

Foundation shall be either strip or raft as per site conditions. The design and construction of foundation shall be carried out as per IS 1904:1986 and other related Indian Standards, as applicable.



Steel Structure

The structure consists of steel pillars, modules and other components designed for worst loading conditions as per IS 800:2007 and IS 801:1975. In addition, the structure shall be designed in accordance with IS 1893(Part 1):2002 & IS 875:1987 for seismic and wind load considerations, both individually and in combination, as applicable. Steel pillars shall be made by welding MS plate of 16mm thickness and steel tubes of size 200mm x 200mm having wall thickness varying from 3mm to 16mm depending upon the number of floors. The smaller pillar is fixed with sub-assemblies for modules. All the columns shall be checked for their safety and computations shall be done for the same for satisfying requirements of IS 800:2007 and IS 801:1975.

Steel Staircase

Steel staircase shall be designed and fabricated using HR steel sheet of thickness 3mm / 4mm with MIG welding process. Staircase is pretreated for surface cleaning using steel cleaning agent and painted with two coats of anti-corrosion primer and fire proof paint.

Flooring

The floor is made up of deck sheet and wire mesh of size 100mm x 100mm x 3mm thickness. The deck sheet is fixed on the modules ready after providing with utilities like plumbing and electrical etc. Flooring, roofing and ceramic tiles are fixed as per relevant specifications.

Walling

Walling is completed by using factory made EPS based wire mesh welded 3D panels. The panels are easy to install and manufactured using insulated polystyrene core covered on both sides by hot GI coated round wire square mesh, duly connected by 33 connectors per m^2.

Door and Window

The structure can accommodate any types of door and window frames and panels. Metal door frame pressed from 1.2/1.5mm thick galvanized steel sheet with mitered and welded construction may also be fixed. The doors used, however, should satisfy the performance requirements as per relevant Indian Standards. For doors not covered by any Indian Standards, third party certification may be adopted. Performance characteristics for dimensions & squareness, general flatness, impact indentation, flexure test, edge loading, shock absorption, buckling resistance, slamming and misuse as per relevant parts of IS 4020:1998 shall be required before accepting any doors for use.

Utilities

i) Once the steel structure module is ready for electrical and plumbing work as per the drawings, these utilities are planned & executed based on the services/utilities layout design and requirement of the floor area.

ii) After completion of services/utilities, the module is covered with deck sheet. Wire mesh and MS studs of required size are fixed on the deck sheet before laying of PCC flooring. After decking, PCC of M25 grade is laid for a total depth of 76mm and flooring tiles are fixed wherever required depending upon utilization of area. With all fittings the module is ready for shifting to the site.

TRANSPORT OF MODULES AND PILLARS ALONG WITH ACCESSORIES

All the handling/transportation at site for erection are done by means of mechanical equipments such as tower & mobile cranes and trucks etc. Due care should be taken to avoid any damage to these modules, pillar and other elements. Special lifting points are provided in these modules so that handling stresses are kept to a minimum. Transportation are carried out in mainly two stages:

i) From manufacturing plant to stacking yard.

ii) From stacking yard to erection site. The transportation is carried out by using trucks of desired capacity and length. Erection are carried out by cranes of suitable capacity at site.

PERFORMANCE EVALUATION

Structure

Seismic Performance Evaluation of a G+7 CRC framed structure model for ground motion compatible to Seismic Zone V was performed at SERC, Chennai and found to be satisfactory.

Walling Component

Evaluation on the behavior of reinforced EPS Panel under flexural and Axial Compression load on 100 mm and 150 mm thick panels were satisfactory. Other performance characteristics are:

Thermal transmittance of Single Panel	0.537 w/m^{2}k
Acoustic Behavior	37 dB (noise reduction)
Water Penetration	No penetration after 3h
Resistance to impact with softbody and hardbody	Impacts of 90 & 1200 J –No crack

CERTIFICATION

Under Performance Appraisal Certification Scheme, PAC No. 1011-S/2013 has been issued for the system to M/s Synergy Thrislington, A1 Phase- I, Industrial Area, Mohali. (Available for download from BMTPC website : www.bmtpc.org).

REFERENCES

- Performance Appraisal Certificate PAC No. 1011-S/2013, issued by BMTPC, New Delhi
- Inspection Report of the visit for Performance Appraisal Certification.
- Report of Seismic Evaluation of Model of G+7 CRC framed structure for a ground motion compatible to zone V spectrum by SERC, Chennai.
- IS 800:2007 - General Construction In Steel - Code of Practice
- IS 801:1975 - Code of Practice for Use of Cold Formed Light Gauge Steel Structural Members In General Building Construction
- IS 875(Part 1):1987 - Code of Practice For Design Loads (Other Than Earthquake)For Buildings And Structures Part 1 Dead Loads - Unit Weights of Building Material And Stored Materials (Incorporating IS 1911 : 1967)
- IS 875(Part 2):1987 - Code of Practice for Design Loads (Other Than Earthquake) For Buildings And Structures: Part 2 Imposed Loads
- IS 1893(Part 1):2002 - Criteria for Earthquake Resistant Design of Structures - Part 1 : General Provisions and Buildings
- IS 4020(Part 1 to 16): 1998 - Door Shutters - Methods of Tests
- SP 7:2005 - National Building Code of India 2005.

Light Gauge Steel Framed Structures (LGSF)

(Suitable for Low Rise to Medium Rise Structures)

ABOUT THE TECHNOLOGY

Light Gauge Steel Framed Structures (LGSF) is based on factory made galvanized light gauge steel components, designed as per codal requirements. The system is produced by cold forming method and assembled as panels at site forming structural steel framework of a building of varying sizes of wall and floor.

The basic building elements of light gauge steel framing are cold formed sections which can be prefabricated at site using various methods of connection. The assembly is done using special types of screws and bolts.

Cold formed sections are widely used in construction including residential floors, industrial buildings, commercial buildings, hotels and are gaining greater acceptance in the residential sector. LGSF is a well established technology for residential construction in North America, Australia and Japan and is gaining ground in India.

LGSF is typically ideal for one to three storey high buildings, especially for residential and commercial buildings. Due to its flexibility fast construction and durability, this technology has great potential for counties like India.

LGSF can be combined with composite steel / concrete deck resting on light steel framing stud walls. Apart from having potential for mass housing, modular buildings can be used for long term temporary or permanent structures such as schools and classroom, military and civil housing needs, post – disaster relief structures and industrial buildings. Advisable maximum span for LGSF buildings should be 7.5 m.

SPECIFICATIONS FOR THE SYSTEM

Structural Section

Main Section are Studs & Track Studs serve as a general all purpose framing component used in a variety of applications including external curtain walls, load bearing walls, headers floors & roof joists, soffits and frame components.

Track is used as closure to stud and joists end as well as head and sill conditions. It is also used for blocking and bridging conditions.

Load bearing steel framing members shall be cold – formed to shape from structural quality sheet steel complying with the requirements of one of the following:

i) ASTM A 653 / A 653 M -13 Grade 33, 37, 40 & 50 (Class 1 and 3) or
ii) ASTM A 792 / A 792 M -13 Grade 33, 37, 40 & 50; or
iii) ASTM A 875 / A 875 M – 13 Grade 33, 37, 40 & 50; or
iv) Sheets, that comply with ASTM A 653 except for tensile and elongation with requirements, shall be permitted, provided, the ratio of tensile strength to yield point is at least 108 and the total elongation is at least 10 percent for a 5 mm gauge length or 7 percent for a 20 mm gauge length.

Wall frame

Consists of top track (U shape configuration) with a depth compatible with that of the studs of the same nominal size. Minimum height of track flanges shall be 19 mm.

Load Bearing Walls

C section studs with depth of 90 and 200 mm and thickness between 2.7 mm and 2.0 mm shall be provided at a distance of 300 mm / 400 mm / 610 mm to ensure efficient use of cladding material. Multiple studs are used at heavily loaded application such as adjacent to openings or in braced panels. C section with 94 x 50 mm is used for noggins.

Alteration shall be required for the local details at the head & the base of the wall to ensure that loads are adequately transferred without local deformation of the joists & studs.

Non Load Bearing Walls

It is similar to that of load bearing walls except that noggins and diagonal bracing are not required to stabilize the studs.

Deflection Limit of Walls

Suggested deflection limit for external walls subject to wind loading are as follow:

Full height glazing	Height / 600
Masonry wall	Height / 500
Board / reduced finish	Height / 360
Steel cladding	Height / 250
Other flexible Cladding	Height / 360

Wall cladding

Wall cladding shall be designed to resist wind load. Sheet has to be screwed to the joist / purlin with maximum spacing of 300 mm c/c. All the joints of sheet in longitudinal direction require a minimum lap of 150 mm in order to make them leak proof.

Following materials are generally used on wall cladding:

- Gypsum board conforming to IS 2095 (Pt. 1): 2011
- Heavy duty cement particle board conforming to IS 14862:2000.

Bracing

Bracing and bridging shall have configuration and steel thickness to provide secondary support for the studs in accordance with the relevant specification for the design of Cold – formed steel structure of members.

Floor frame

For speed of construction, floor joist may be pre-assembled to form floor cassettes. This works well for regular floor places but care shall be taken when the geometry of the building requires the cassettes to vary in size with location or when non – right angel corners are required. Resistant may be provided to the top flange of the joists by the flooring board. The floor should be designed for the combined effect of dead and imposed load.

The construction of a suspended floor comprising cold formed steel floor joists is similar to that for a floor using timber joists. The strength to weight ratio of light steel joist is higher than that of other material. Steel joists are stable and do not suffer, the long term problems of drying out, creep and Shrinkage. Joists are generally positioned at 300, 400 & 600 mm centres, depending on the spacing capabilities of the floor materials used.

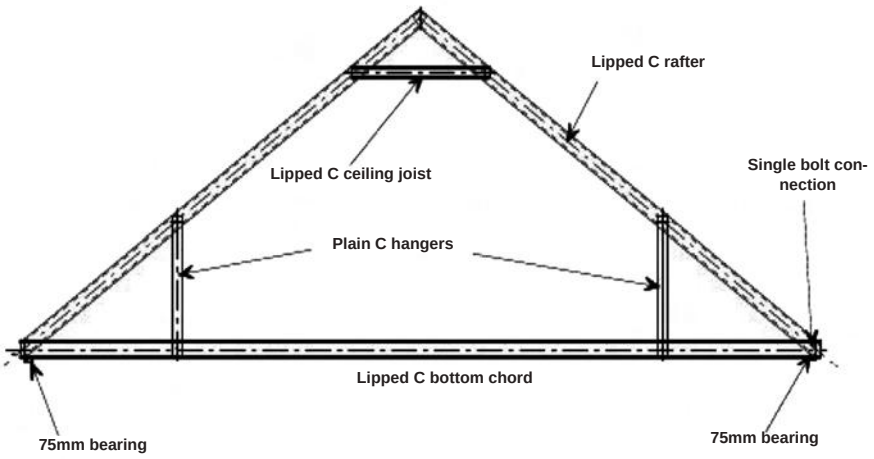
Roof frame

Flat roof is made up of joists, where steel decking form a flat roof, a minimum fall of 1:4 should be introduced to ensure that any moisture runs off. To avoid local ponding to rain water, the pitch may need to be increased to overcome the effective reduction in roof angle caused by the deflection of long span roof purlin or decking.

Roof truss

Use of Light Steel roof truss is economical for larger span building. In attic or open roof truss creates usable roof space, uses fewer components than Fink truss and provides an economical solution, since it utilizes the high strength of the steel members.

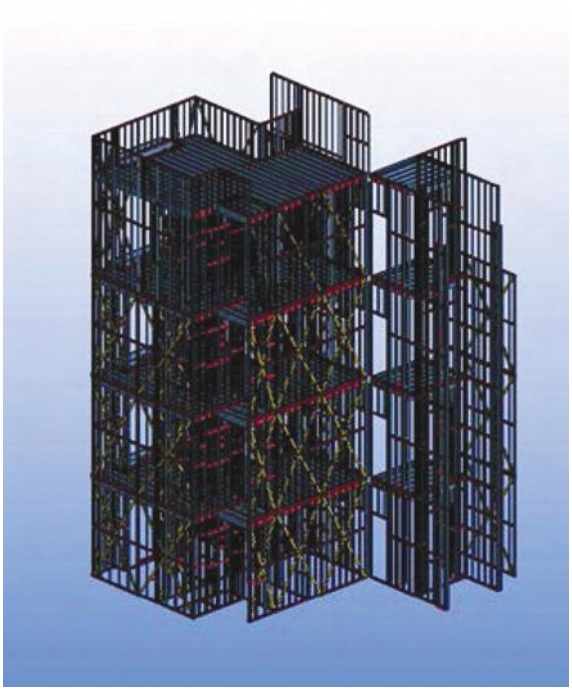
The trusses are placed at 600 mm maximum spacing and are battened and tiled in a conventional manner.



Screws

Screws as per the details given below shall be used:

- Panel Assembly – Low profile screws
- LGS-LGS Wall panel to roof cassette – 12-14x15mm
- LGS to concrete – Tapcon screw 14-12x60mm Hex head
- Wire mesh = EPS board – SDS Hex head with Ceresin without washer
- HRS-LGS – Hex heat
- CP board 6mm – WT 8 CSK Phillips
- Gypsum board – Flat heat self-driven type
- Deck sheet/Wire mesh – SDS WT, CSK, Flat head



Extended Polystyrene Panel

Shall be of minimum density of 15 kg/m^3.

Wire Mesh

Shall be made of 4 mm dia wire of UTs 480 MPa with spacing 150 mm x 150 mm or 1.4 m dia of spacing 40 mm x 40 mm.

Shotcrete

Shortcrete when used shall be of minimum grade M 25 Grade of concrete.

DESIGN

The LGSS is designed based on provision of the following standards:

- Indian Standard IS 801: 1975 Code of Practices for use of cold formed and welded section and light gauge steel structural members in general building construction.
- British Standard BS 5950 (Part 5):1998 – Structural use of steel in Building Part 5 – Code of Practice for design of cold formed thin gauge structure.
- British Standard BS 5950 (Part 1): 2000 Structure use of steel work in Building Part 1 with loading requirement as per IS 875 (Part 1)
- Indian Standard IS 875 : 1987 Code of Practice for design loads
  Part 1 - Dead Loads - Unit Weights of Building Material and Stored Materials
  Part 2 - Imposed Loads
  Part 3 - Wind Loads
- IS 1893 (Part 1):2002 Criteria for Earthquake Resistant Design of Structures - Part 1 : General Provisions and Buildings

MANUFACTURING

The sections are manufactured using Centrally Numerical Control (CNC) automatic four Pinnacle Roll Forming machine having production speed of 450-900 m/hr with very high precision.

CONSTRUCTION

Foundations for light steel framing are essentially the same as for any form of construction, although dead loads applied by the light steel frame will be much lower than in the concrete or masonry construction.

Construction phases of steel buildings resembles the phases of conventional reinforced concrete buildings. The sections manufactured as per design are numbered properly. The profiles are sent to site either as profile or panellized parts, considering the distance of the construction site and transportation conditions. Profiles are assembled by trained assembly team at the construction site in line with the architectural plan. Only special studs are used during assembly, no welding is done. Once the assembly is done, the frame is filled with insulation materials (fibreglass, rockwool etc). Walls are then covered with standard boards or similar approved materials.

The sequence of construction comprises of foundation laying, fixing of tracks, fixing of wall panels with bracings as required, fixing of floor panels, fixing of roof panels, decking sheet, fixing of electrical & plumbing services and finally fixing of insulation material & walling panels.

Electrical Gas and plumbing, services are installed through pre-punched service holes in the web of the steel forms. Plastic grommets and silicon seals are used to fasten and protect wiring and pipes from corrosion and damage arising from vibrations

Electrical cables running within floor insulation layer in the separating floor construction should be protected with cartridge fuses or mini circuit breaker.

Wall panels are generally made by using heavy duty Cement Particle Board and Gypsum board. It can also be made using high density extended polystyrene core plastered from outside using wire mesh and chicken mesh. Galvolume sheet of appropriate thickness can also be used as cladding. This technology is being evaluated by BMTPC under PACS.

ADVANTAGE

LGSF is based on established system of light gauge steel structures and designed as per codal provisions with loading requirements as per Indian Standards. The merits of the system encompasses:

High Precision

- Fully integrated computerised system with CNC machine provides very high accuracy upto 1 mm.

Structural

- High strength to weight ratio. Due to low weight, significant reduction in design earthquake forces. Chance of progressive collapse are marginal due to highly ductile and load carrying nature of closely spaced studs/joists.

Speed in Construction

- Construction speed is very high. A typical four storeyed building can be constructed within one month.

Saving in foundation

- Structure being light, does not require heavy foundation.

Mobility

- Structural element can be transported any place including hilly places to remote places easily and structure can be erected fast.
- Structure can be shifted from one location to other without wastage of materials.

Environment friendly

- Steel used can be recycled when required.

CERTIFICATION - OTHER REFERRED STANDARD

IS 2095 (Part 1) : 2011	Specification for Gypsum Plaster Boards - Part 1 Plain Gypsum Plaster Boards
IS 14862 : 2000	Specification for Fibre Cement Flat Sheets
ASTM – A653/ A 653 M -13	Specification for steel sheet, zinc coated (galvanized) on zinc – iron alloy coated by hot dip process.
ASTM – A 792/792 M -13	Specification for steel sheet, 55% aluminium zinc alloy coated by hot dip process
ASTM – A 875/875 M -13	Specification for steel sheet, zinc 5% aluminium alloy coated by hot dip process.

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