# Compendium of Prospective Emerging Technologies for Mass Housing (PART-1)

Ministry of Housing & Urban Poverty Alleviation
Government of India


CREDAI
AFFORDABLE HOUSING COMMITTEE PRESENTS

**Affordable Housing**
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# 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, durabil- ity, 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, METH- ODS 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 pro- posed 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.

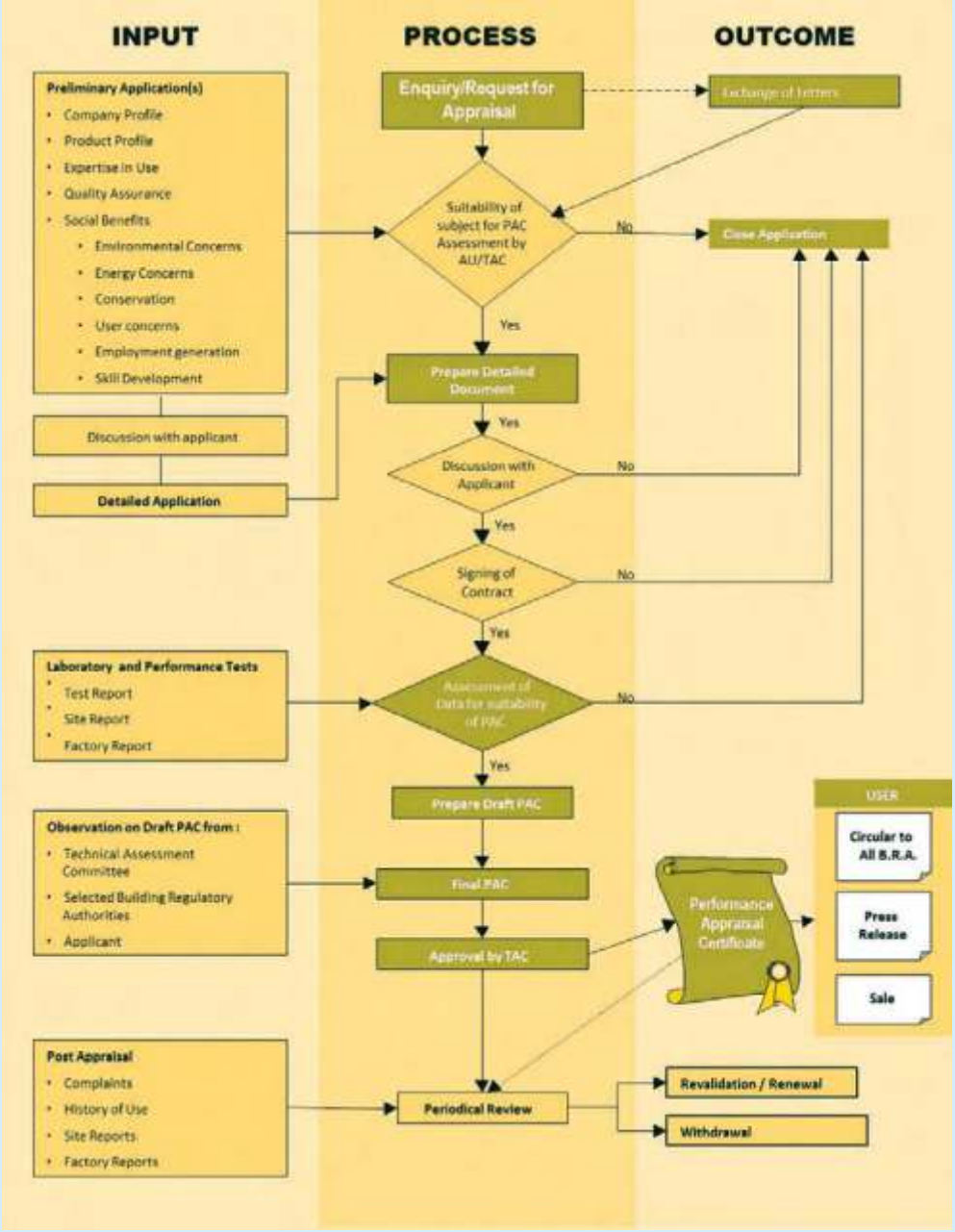
The Building Materials & Technology Promotion Council (BMTPC), Ministry of Housing & Urban Poverty Alleviation, Govt. of India is studying & evaluating prospective innovative Construction system, developed within the country and from aboard and based on their technical suitability, recommended following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

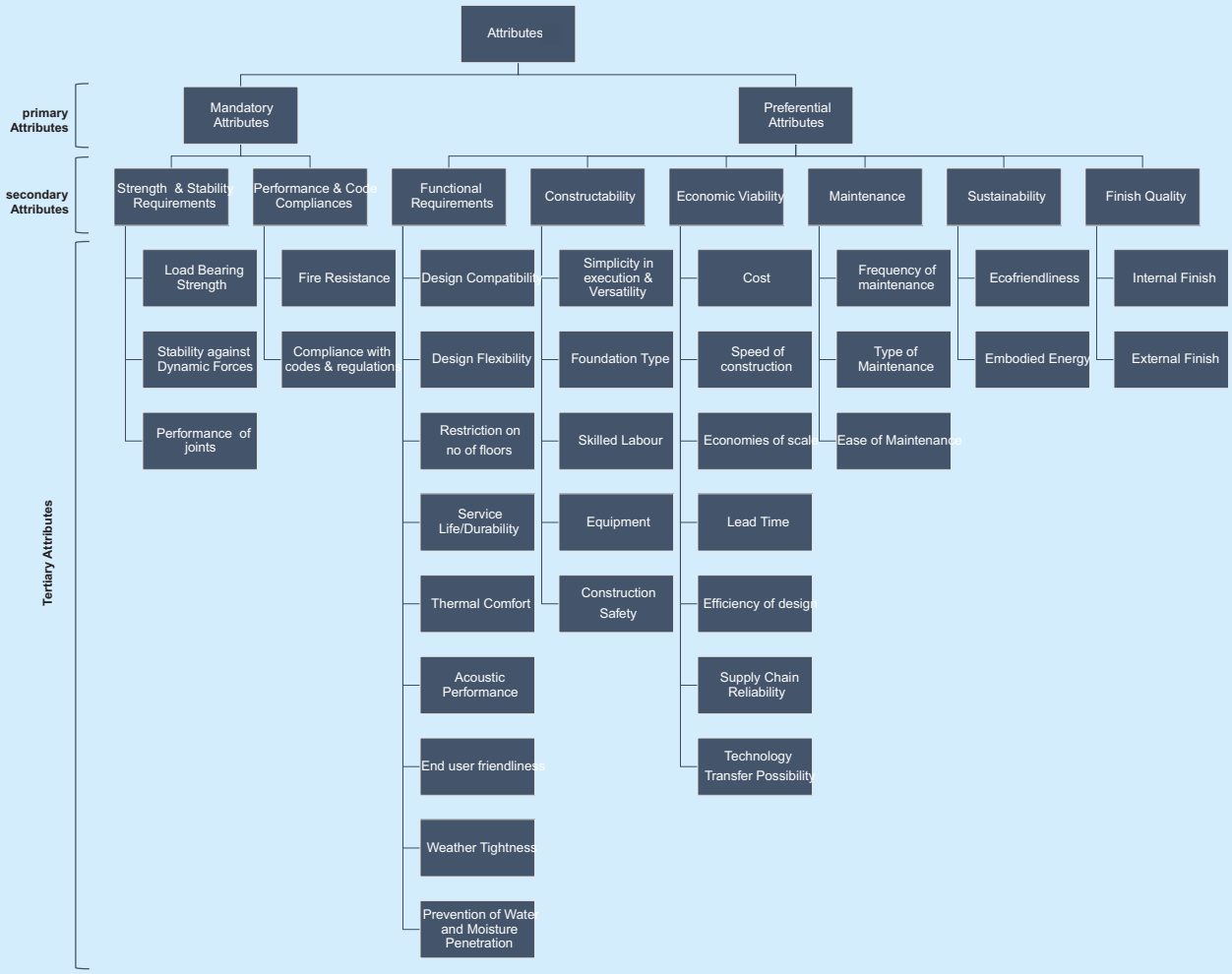
The PACS is a third party assurance system based on laboratory and field tests of the required performance criteria of the any system / building materials on which there is no Indian Standard. The broad parameters, based on which the evaluation is done inter-alia include:

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




*Performance Appraisal Certiication System*

Whereas PACS takes care of verifying technical suitability of the system; other pa- rameters 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 con- struction 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

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.

### 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.

## 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.

## OTHER FEATURES

1) Pre designed formwork acts as assembly line production and enables rapid construction of multiple/mass scale units of repetitive type.
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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 |
| IS 14687:1999 | Guidelines for Falsework for Concrete Structures |
| BMTPC Guidelines : 2011 | Guidelines on Monolithic Concrete Construction |
| PAC No. 1006-A/2011 | Performance Appraisal Certificate issued by BMTPC on Formwork for Monolithic Construction |

# Monolithic Concrete Construction System using Aluminium Formwork (Suitable for Low Rise to High Rise Structures)

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.

## 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 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

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.

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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/m2K) (as per IS 3792:1978). As, it is more than the normal plastered brick masonry walls (thermal transmittance (U) 2.13 W/m2K), 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 (IS1950:1962), 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.For very small project of less than 500 units, this system may not prove to be economical.

## OTHER FEATURES

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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) 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...

## STANDARDS/GUIDELINES REFERRED

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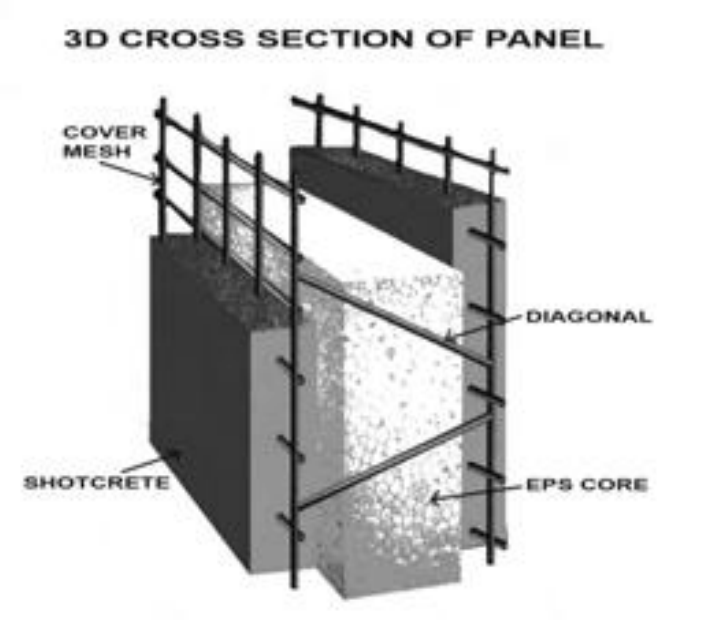
| BMTPC Guidelines : 2011 | Guidelines on Monolithic Concrete Construction |
| PAC No. 1006-A/2011 | Performance Appraisal Certificate issued by BMTPC on Formwork for Monolithic Construction |

# 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/m3, 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.

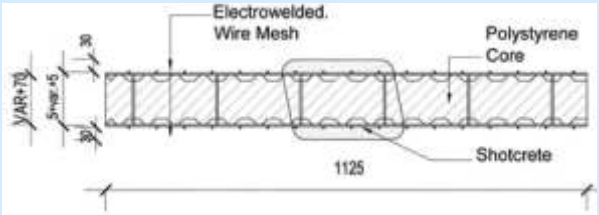
The technology (developed about 30 years back) is in use successfully in many countries like Morocco, Algeria, South Africa, Kenya, Austria, Malasiya, Ireland, Romania & Australia with involvement of different agencies and brand names.

## 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:

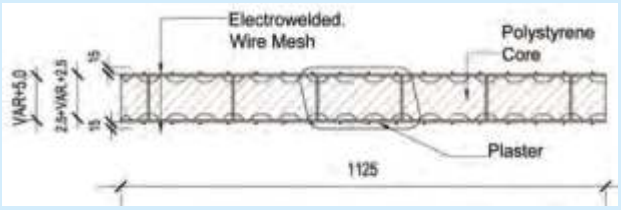
## SINGLE PANEL FOR STRUCTURAL USES

| | |
|---|---|
| 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 |



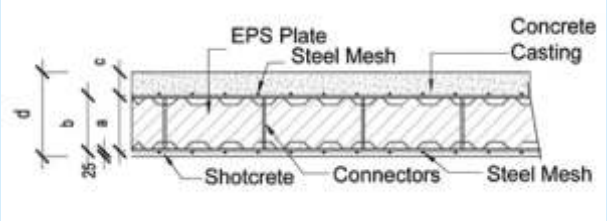
## single panel for internal partition, external walls and insulation

| | |
|---|---|
| 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. / $m^2$ |
| polystyren e 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 |

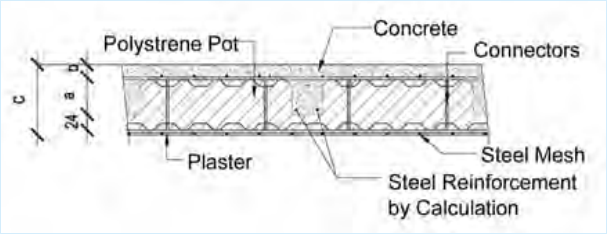



a = EPS Nominal Thickness (variable between 80 mm to 160 mm); b = Distance between thickness steel meshes (a + 10 mm);
c = Shotcrete thickness (average ? 25 mm); d = Total thickness (2xc+a)

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 $kg/m^3$ |

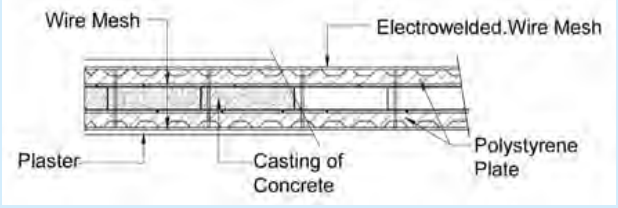



a = thickness of core; b = thickness of concrete; c = overall thickness

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 |



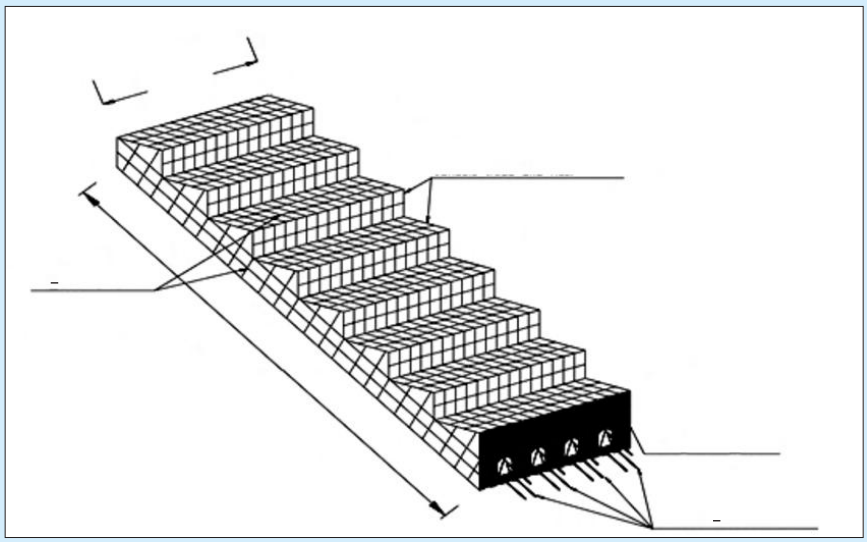
## Internal mesh

| | | |
|---|---|---|
| Longitudinal wire | 5 mm ø spaced @ 100 mm | 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. |
| Transverse Wire | 5 mm ø spaced @ 260 mm | |
| Polystyrene Core | Density 25kg/m3 thickness 50 mm to 80 mm | |

## 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° above and below corners of the opening. |
| Consecutive Floors | Using the same dowels utilized to connect the walls of the first floor to thefoundation.<br>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/m3 |

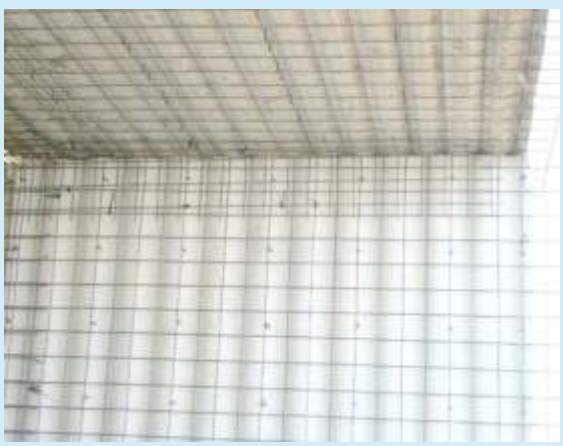
## FEATURES OF PANEL SYSTEM

### 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 panelwith 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/m2 to 5 kg/m2 which means that a single worker can easily handle a 3 m2 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/m2.

**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 Certifi- cate 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, Ire- land.
- Technical Report on Experimental Evaluation of Building System M2 by Structure Lab. Department of Engi-neering, 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

## 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/moc of AAC blocks*.

### ACOUSTIC COMFORT TEST

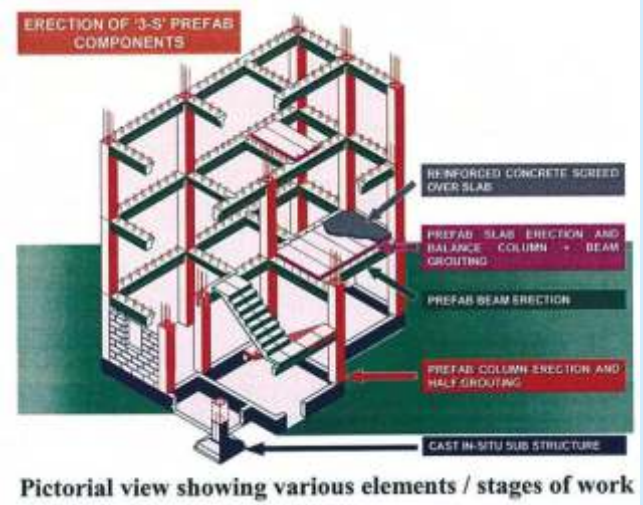
For 100 mm ACC Wall, Sound absorption is 38 – 40 db*

### 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 takingup any field work. Close co-ordination between design crew, fieldstaff 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 |

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