Compendium
of Prospective Emerging Technologies for Mass Housing

Third Edition

Building Materials & Technology Promotion Council
Ministry of Housing & Urban Affairs
Government of India









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September 2018

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Government of India

सत्यमेव जयते

HARDEEP S PURI
Minister of State (I/C)
Housing and Urban Affairs
Government of India

Message

Under the leadership of the Hon'ble Prime Minister, India has embarked on the most comprehensive, planned programme of urbanisation undertaken anywhere in the world. This massive push involving huge projects will be green and resilient, according the highest priority to environmental concerns.

Conventional construction systems are typically slow paced, energy intensive, dependent on natural resources and have a large carbon footprint. They use low levels of mechanization and have high dependence on manual labour. The advent of new construction technologies in India has been gaining usage but the pace needs to be accelerated. A concerted effort is required to create mass awareness to enhance technology transition from conventional to new technologies.

Hon'ble Prime Minister of India has emphasized the need to accelerate the adoption of new construction technologies to improve the pace and quality of construction under the Pradhan Mantri Awas Yojana (U) in order to address the challenges of rapid urban growth and its attendant requirements. Nearly 1 crore houses are to be constructed by 2022. Construction of houses at this scale offers an opportunity for using new and alternative technologies from across the globe which may trigger a major transition through introduction of cutting-edge building materials, technologies and processes.

Building Materials and Technology Promotion Council (BMTPC) has been identifying, evaluating and certifying new technologies for mass housing. The first edition of a Compendium of eight prospective emerging technologies brought out at the time of launching of the Mission by the Hon'ble Prime Minister of India on 25 June 2015. The second edition of Compendium comprising of 16 technologies was published in March 2017. I am happy to know that BMTPC has now further evaluated and certified eight more new emerging technologies for mass housing.

The Compendium will be a useful resource for State Governments and other Authorities dealing with construction of mass housing.

I wish BMTPC all success in their efforts.

New Delhi
26 September 2018

(Hardeep S Puri)

सत्यमेव जयते

DURGA SHANKER MISHRA
Secretary
Ministry of Housing & Urban Affairs
Government of India

Message

Pradhan Mantri Awas Yojana (Urban), a flagship Mission of Government of India, reaching halfway stage and most of the States/UTs have completed their demand survey. The demand is around 1 crore houses across the country. I am glad to inform that over 55 lakh houses have been sanctioned till mid-September. States/UTs are fully geared up to implement the scheme and achieve their targets by 2022.

2. Construction of 1 crore houses by 2022 with conventional 'brick and mortar' construction approach is not an easily achievable target. Not only these traditional construction methods are slow paced but also have issues related to quality, maintenance and environment. Realizing this, Government of India has been constantly endeavoring to expedite the use of fast track innovative technologies for construction of houses. Evaluation and certification is one of the most critical steps in the acceptance and mainstreaming of these technologies.

3. Building Materials & Technology Promotion Council (BMTPC), an autonomous organization under this Ministry has been given the mandate of certification of innovative materials & technologies under its Performance Appraisal Certification Scheme (PACS).

4. In order to disseminate knowledge and technical information on new technologies, BMTPC prepared first compendium on eight such technologies in 2015 and updated it with sixteen technologies in 2017.

5. I am glad to learn that during last one year, more technologies have been identified and certified by BMTPC which have been included in this 2nd updated version. Now, 24 technologies are available to State Government agencies and other stakeholders for use in their housing projects. CPWD has issued Schedule of Rates (SoRs) for 11 of these technologies.

6. I appreciate the efforts made by the Council in preparing this compendium and hope that it will prove to be a useful resource for policy makers, technocrats and other concerned stake holders.

(Durga Shanker Mishra)

सत्यमेव जयते

AMRIT ABHIJAT
Joint Secretary & Mission Director (Housing for All)
Ministry of Housing & Urban Affairs
Government of India

Message

The “Housing for All by 2022” mission is now in advanced stage of implementation in urban areas, wherein out of 10 million estimated housing shortage in the Country, 5.5 million houses have been sanctioned, 0.88 million houses have been completed & 2.2 million houses are in various stages of construction. States & UTs are making concerted efforts to achieve its respective targets & greater focus is now being laid on early grounding & completion of the sanctioned housing projects.

Facing the issues with conventional construction system such as slow paced in-situ construction, and being resource, energy & labor intensive, various States/UTs have started using emerging technologies in housing projects, while some are in the process of exploring the same. The “Compendium of prospective emerging technologies for mass housing”, containing eight emerging technologies in its first edition was released by the Ministry during launch of the mission in June, 2015. Subsequently, 2nd edition of compendium with 16 technologies was released in April, 2017. The compendium containing technologies as identified, evaluated & certified by Building Materials & Technology Promotion Council (BMTPC), has primarily facilitated the States/UTs in adoption of new technologies. The inclusion of these technologies in generic form in National Building Code (NBC), 2016 & selected technologies in the Schedule of Rates of CPWD, has further boosted the confidence of States/ UTs in these technologies.

It is heartening to note that BMTPC has now included eight more emerging technologies in the third edition of the Compendium, & with this the present edition encompasses the technical details of 24 technologies. The eight newly added technologies have been evaluated & certified by BMTPC in last one & half year under its Performance Appraisal Certification Scheme (PACS). I also appreciate the efforts of BMTPC in providing technical help to States in selection & finalization of new technologies & conducting sensitization programmes in various States.

I am sure the States will be further benefited in its upcoming projects of Mass housing with more number of technological options available with present edition of the compendium.

(Amrit Abhijat)

Foreword

With the launch of Pradhan Mantri Awas Yojana (PMAY) - Urban & Rural, which envisions to provide pucca house to each household of India by 2022, a year when India will be celebrating its 75th year of Independence, it is incumbent on part of academic, research & other organizations involved in construction to bring innovation & thus paradigm shift in the prevailing construction practices so as to fast-track delivery of houses without compromising structural & functional performance. With this objective in mind, BMTPC initiated identifying, evaluating & certifying new emerging construction systems from all across the globe which can help in replacing the conventional cast-in-situ RCC construction. The first set of such 8 technologies were published in form of compendium in 2015 and its second edition with 16 new construction systems was published in April 2017. Since 2017, more number of technologies are knocking the door of Indian construction industry and it is heartening to mention here that with the concerted efforts put up by BMTPC, now, we have a set of 24 such new emerging technologies which can bring in speed, safety, sustainability in the construction sector and same are being published in this document as third edition.

The next biggest challenge is to mainstream these new systems in the construction sector and, therefore, there is need to create an enabling eco-system to facilitate use of these new systems. Under PMAY(U) mission, Ministry of Housing & Urban Affairs (MoHUA) has setup a Technology Sub-Mission which aims to encourage the use of sustainable & safe practices across states with the help of IITs/NITs/SPAs and other institutes of repute. It has always been BMTPC's endeavor to handhold State Governments so as to mainstream new technologies in the construction sector and with its dedicated efforts, there are around 9 lakhs houses being constructed by State Governments under PMAY(U) and other Sate Schemes using new construction technologies certified by BMTPC. There has always been questions regarding standards and schedule of rates of any innovative technologies and treated as impediment in promotion of any new product/system. Realizing the need, CPWD and BIS was roped in by the Ministry and as on date CPWD has published in DSR 2016, Schedule of Rates of almost all such technologies. There have been a few circulars from CPWD & Ministry which recommends mandatorily use of such systems and encourage turnkey approach instead of item rate contract for use of new technologies. Bureau of Indian Standards (BIS) has also included these systems in their recently published NBC-2016. Apart from this, MoHUA along with BMTPC is also constantly interacting with Defence, Railways & PSUs involved into construction such as NBCC, DDA etc. to make use of these emerging technologies in their own housing projects. The response has been very good. In fact, almost all states are coming forward to embrace these technologies for their upcoming social mass housing projects.

As of now, the only impediment in usage of these systems has been cost but given economies of scale, the cost comes comparable with conventional construction cost and there are host of additional benefits such as low maintenance, low life-cycle cost, better durability, improved thermal & acoustical performance, better hazard resistance, low wastages, less pollution & above all green & sustainable development, which are often neglected while drawing comparisons. I have been the great proponent of life-cycle cost and it is strongly recommended that whenever an innovation is being introduced in construction sector, instead of initial cost, the life-cycle cost need to be ascertained. With the tools available, the life-cycle assessment (LCA) can easily be done. The emerging technologies included in the Compendium have low life-cycle cost and thereby resource-efficient and environmentally-responsible.

The technical contributions made by BMTPC officers namely Shri S.K. Gupta, Shri C.N. Jha, Shri Pankaj Gupta, Shri A.K. Tiwari, Shri Y.D. Munjal & Shri Dalip Kumar in bringing this compendium are deeply appreciated and acknowledged. Through this publication, I sincerely hope that the all stakeholders involved into construction including state agencies will repose faith in the technologies and make use of the information available in right earnest and start using these innovative systems in their future housing projects so as to fulfil the dream of Govt. of India of providing housing to all without vitiating the environment & stressing the natural resources.

Date: September 12, 2018
Place: New Delhi

(Dr. Shailesh Kr. Agrawal)
Executive Director, BMTPC

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Background

The Pradhan Mantri Awas Yojana (Urban) launched on 25th day of June 2015, set the target of delivering approximately 10 million houses by 2022 and subsequently Pradhan Mantri Awas Yojna (Rural) launched on 1st day of April 2016 envisages 10 million houses in next three years. In order to achieve this gigantic task, the natural question comes to mind whether we have sufficient quantity of such building materials which do not impact the mother earth adversely and further do we have existing construction practices in vogue which can help fast delivery of houses? The answer to both the question is negative as if we look at the traditional building materials e.g. brick, cement, steel, aggregates, sand etc., they are either based on natural resources which are finite in nature or energy intensive or emit greenhouse gases during production. Thus, the entire proposition of using these materials as usual will not be sustainable and environment friendly. Further, the construction technologies being practiced in India, is cast-in-situ RCC beam-column construction which is primarily slow track methodology and is subjected to time & cost overruns. Also, these constructions are labour intensive, which further hamper fast delivery, as there is acute paucity of unskilled labour force in cities. Therefore, it is prudent to take a paradigm shift from brick & stick approach and look for alternate systems which overcome these limitations. There have been number of such construction systems available elsewhere in the world which are in use since decades successfully. Nevertheless, these systems ought to be promoted and adapted in Indian conditions. BMTPC have been identifying, evaluating and certifying these systems and also in order to showcase these technologies, demonstration housing projects are being executed in different states. Our endeavor has been to bring innovation, speed, safety & sustainability in the existing construction methodology without compromising structural & functional performance. Also, BMTPC has been conducting handholding programmes across India, in partnering with states, so as to educate practicing engineers & architects, students, policy makers, contractors and artisans about these technologies.

In order to give further impetus to these technologies, Ministry of Housing & Urban Affairs has assertively pursued CPWD, BIS and state departments to come out with notifications, circulars, SORs, specifications etc. which will authorize state governments to use these new construction technologies in housing projects. The various OMs of the Ministry and CPWD, and DSR items are included in Appendices. CPWD has included New Technology Items in Delhi Schedule of Rates (DSR) 2016 Volume-2 namely (a) Light Gauge Steel Framed System (Item No. 26.41 to 26.45), (b) Expanded Polystyrene Core Panel System (Item No. 26.46 to 26.47), and (c) Aluminum Formwork for Monolithic Construction (Item No. 26.48) and their detailed analysis is given in Delhi Analysis of Rates (DAR) 2016 (Volume-2). Further, CPWD, through Correction Slips, has also included (a) EPS cement sandwich light weight solid core panels (Item No.26.49), (b) Non asbestos fibre reinforced aerated cement sandwich wall/roof/floor light weight solid core panels (Item No.26.50), (c) GFRG Panel System (Item No.s 26.51 to 26.61), (d) Speed Floor System (Item No.26.62 to 26.64), (e) Factory Made Fast Track Modular Building System (Item No.26.65 to 26.66), and (d) Prefab Technology (Item No.5.50 to 5.57) along with their Analysis of Rates.

Further, in the recently published National Building Code 2016 by BIS, provisions have been updated to ensure utilization of number of new/alternative building materials and technologies so as to provide for innovation in the field of building construction. Updated provisions on new alternate technologies for speedier construction have also been included in Part-5 BUILDING MATERIALS; Part-6 STRUCTURAL DESIGN: Section 7 Prefabrication and Systems Building and Mixed/Composite Construction, 7A Prefabricated Concrete, 7B Systems Building and Mixed/ Composite Construction; and Part-7 CONSTRUCTION MANAGEMENT, PRACTICES AND SAFETY.

This third edition of compendium contains following 24 innovative construction systems, developed within the country & from aboard. These systems are recommended for use by the public and private agencies based on their technical suitability and certification.

FORMWORK SYSTEMS - Engineered Formwork Systems

1 Monolithic Concrete Construction System
– using Plastic - Aluminium Formwork
– using Aluminium Formwork

2. Modular Tunnel Form

FORMWORK SYSTEMS - Stay-in-Place Formwork Systems

3. Insulating Concrete Forms
4. Monolithic Insulated Concrete System
5. Structural Stay-in-place formwork system
6. Lost-in-place formwork system- Plaswall Panel system
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8. Sismo Building Technology

PRECAST SANDWICH PANEL SYSTEMS - EPS based Systems

9. Advanced Building System – Emmedue
10. Rapid Panels
11. Reinforced EPS Core Panel System
12. QuickBuild 3D Panels
13. Concrewall Panel System

PRECAST SANDWICH PANEL SYSTEMS - Other Systems

14. Glass Fibre Reinforced Gypsum Panel System
15. Prefabricated Fibre Reinforced Sandwich Panels
16. Rising EPS (Beads) Cement Panels

LIGHT GAUGE STEEL STRUCTURAL SYSTEMS

17. Light Gauge Steel Framed Structure (LGSF)
18. Light Gauge Steel Framed Structure with Infill Concrete Panel Technology

STEEL STRUCTURAL SYSTEMS

19. Factory Made Fast Track Modular Building System
20. Speed Floor System

PRECAST CONCRETE CONSTRUCTION SYSTEMS

21. SRPL Building System (Waffle-Crete)
22. Precast Large Concrete Panel System
23. Industrialized 3-S system using RCC precast with or without shear walls, columns, beams, Cellular Light Weight Concrete Slabs/Semi-Precast Solid Slab
24. Walltec Hollowcore Concrete Panel

One of the crucial components of technology transfer cycle is demonstration construction and therefore, in order to demonstrate these new systems in the field, BMTPC with the support of Ministry of Housing & Urban Affairs, Govt. of India has initiated several Demonstration housing projects as pilot projects in different states wherein around 40 houses are being constructed. The land is provided by the state govt. free of cost whereas the houses are constructed along with onsite infrastructure by BMTPC as per the Operational Guidelines of Demonstration Housing Projects issued by the Ministry of Housing & Urban Affairs in April 2018. During the construction, the professionals, students, artisans, policy makers & residents of the area are sensitized & educated about these new technologies. Two projects at Nellore, AP using GFRG panel systems and at Bhubaneshwar, Odisha using EPS Core Panel system have already been completed. The other projects at Bihar Sharif, Bihar (using structural stay-in-place formwork system), Lucknow, UP (using double walled EPS Core Panel system), Hyderabad, Telangana (using light gauge steel structural system & structural stay-in-place formwork system) are in advanced stages of completion.

The details of the technologies evaluated and recommended, as contained in this Compendium, will help user agencies in getting informed choice of different innovative construction practices, which could be utilized for mass housing scheme.

BMTPC operates Performance Appraisal Certification Scheme (Gazette Notification No. I-16011/5/99 H-II in the Gazette of India No. 49 dated December 4, 1999). The emerging technologies for mass housing appearing in the Compendium have been evaluated and certified through Performance Appraisal Certification Scheme (PACS) of 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 & accoustic behaviour
- Ease of fixing services
- Quality assurance
- Durability / Service Life

The process flow chart for PACS is given in figure-1. 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 developed by BMTPC to provide a technical framework for selection of any new technology is given in Figure-2. It may be used by agencies for selection of any technology/construction system.

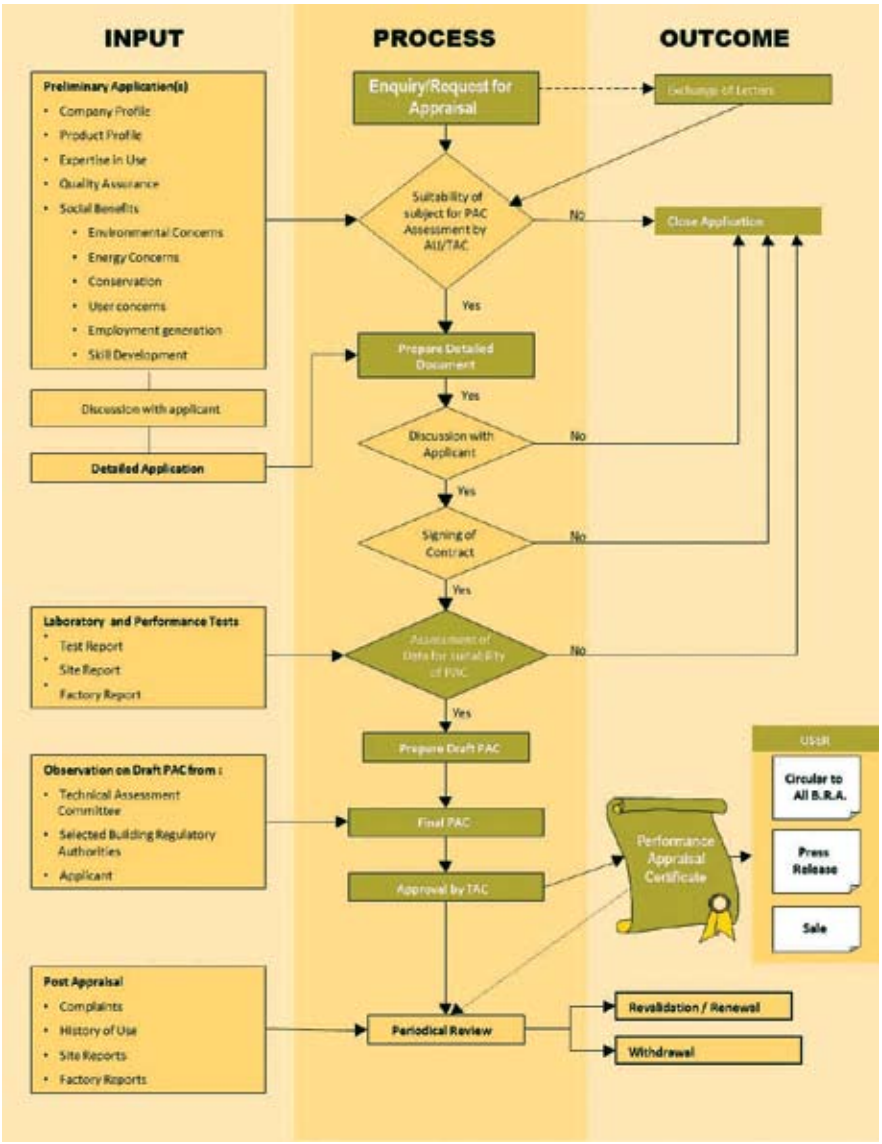


Figure-1: Performance Appraisal Certification System – Process Chart

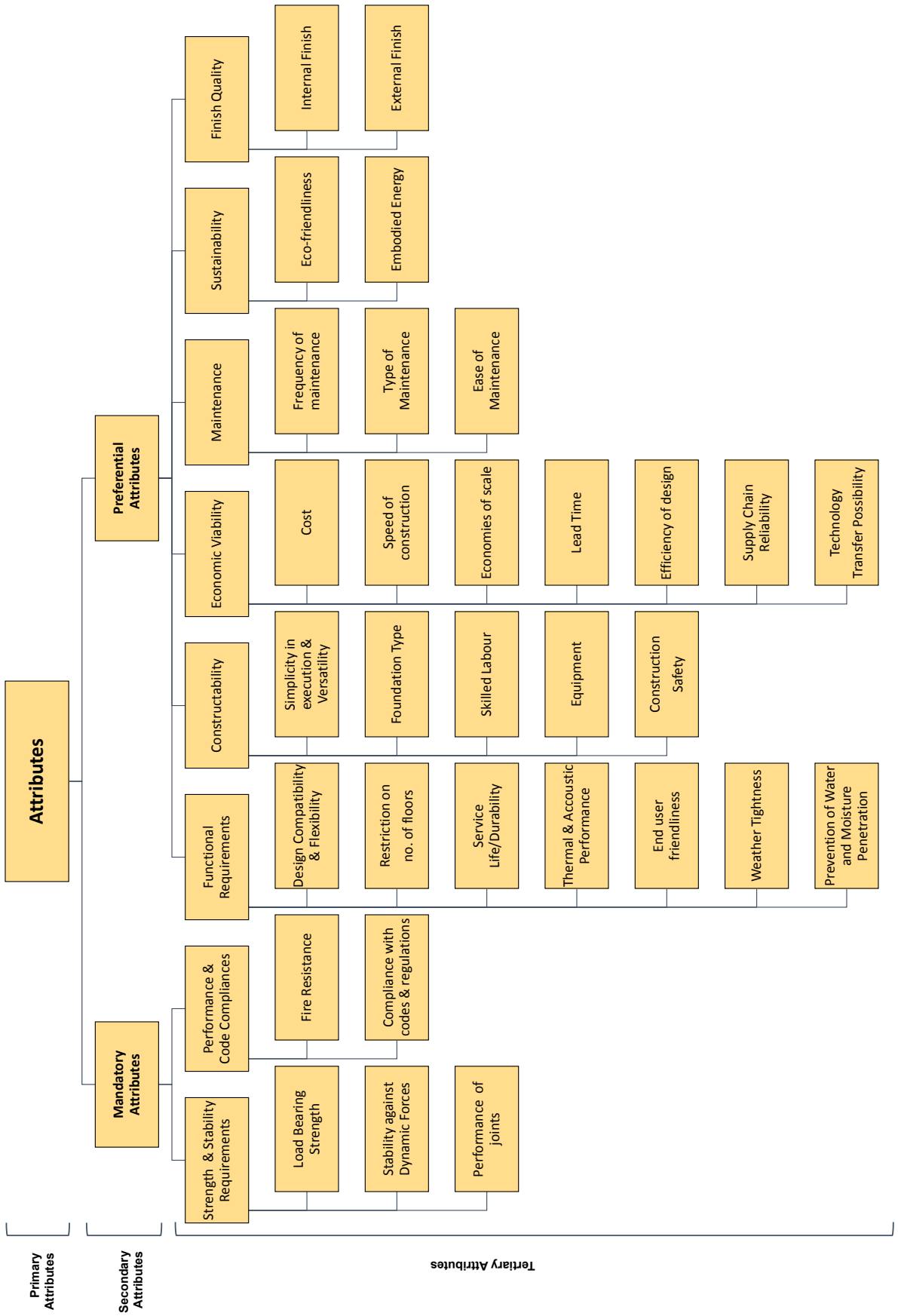


Figure-2: Multi-Attribute Evaluation System for New Technologies

Formwork Systems

Engineered Formwork Systems

Monolithic Concrete Construction System – using Plastic - Aluminium Formwork

(Suitable for Low Rise to High Rise Structures)

ABOUT THE TECHNOLOGY

The technology intents to replace the conventional steel/plywood shuttering (formwork) system with customised engineered formwork which is manufactuered in the factory set up under controlled conditions. In this system, in place of traditional RCC framed construction of columns and beams and infill walls; all floors, slabs, columns, beams, walls, 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 used for the purpose which facilitates easy handling with minimum labour & without use of any equipment. Being modular formwork system, it enable fast construction of multiple/mass modular units.

BASIC MATERIAL REQUIREMENTS

Formwork system

Formwork system is manufactured by various firms in India and abroad and shall have to be designed as per loading requirements of the structure. It must have adequate stiffness to weight ratio, yielding minimum deflection during concreting & operation. The panel formwork 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, however, it is being covered in NBC - 2016.

Concrete

Shall be of appropriate grade based on environment condition (exposure) 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 is 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 system 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 vertical 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):2015 and IS1893(Pt.1):2016 respectively. For out of plane loading, the walls 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 13920:2016 is referred for ductile detailing of reinforced concrete structure. Thickness of wall below plinth level should be minimum 200 mm with double layer 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, for higher durability.

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 is considered as reasonable acoustic insulation.

EASE OF FIXING SERVICES

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

ECONOMY OF SCALE

Economies of scale depend 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. However, now with number of formwork manufacturers available, the project with less number units may also be feasible.

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 to 4 days cycle is desirable.
3) It is flexible in design and can form any architectural or structural configuration, such as stairs, windows, etc.

LIMITATIONS

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/UNDER COMPLETION PROJECTS

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
5) 4,52,656 houses under PMAY (U) in various parts of Andhra Pradesh
6) 4,586 houses under PMAY(U) in Naya Raipur, Chhattisgarh
7) 30,000 houses under PMAY(U) in Maharashtra

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) : 2015	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) : 2016	Criteria for Earthquake Resistant Design of Structures - Part 1 : General Provisions and Buildings (Sixth Revision)
IS 1950 : 1962	Code of practice for sound insulation of non-industrial buildings (Reaffirmed 2010)
IS 3792 : 1978	Guide for heat insulation of non-industrial buildings (Reaffirmed 2013)
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 (First Revision) (Reaffirmed 2014)
IS 13920 : 2016	Ductile detailing of reinforced concrete structures subjected to seismic forces - Code of practice (First Revision)
IS 14687 : 1999	Falsework for Concrete Structures - Guidelines (Reaffirmed 2014)
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)

ABOUT THE TECHNOLOGY

The technology intents to replace the conventional steel/plywood shuttering (formwork) system with customised engineered formwork which is manufactuered in the factory set up under controlled conditions. In this system, in place of traditional RCC framed construction of columns and beams and infill walls; all floors, slabs, columns, beams, walls, 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 used for the purpose which facilitates easy handling with minimum labour & without use of any equipment. Being modular formwork system, it enable fast construction of multiple/mass modular units.

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):2015 and IS1893(Pt.1):2016 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 13920:2016 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.

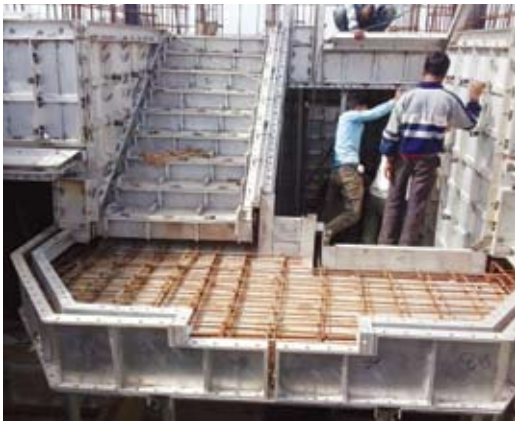
DURABILITY

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

Economies of scale depend 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. However, now with number of formwork manufacturers available, the project with less number units may also be feasible.

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.

LIMITATIONS

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 PROJECTS

1) Houses in Bangalore for Karnataka Slum Development Board.
2) Houses in Mysore for Karnataka Slum Development Board.
3) 2,112 houses under PMAY(U) in Tamil Nadu
4) 34,928 houses under PMAY(U) in Gujarat
5) 1,136 houses under PMAY(U) in Puducherry
6) Houses in Bangalore for Bangalore Development Authority & several other projects in major cities of India, 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) : 2015	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) : 2016	Criteria for Earthquake Resistant Design of Structures - Part 1 : General Provisions and Buildings (Sixth Revision)
IS 1950 : 1962	Code of practice for sound insulation of non-industrial buildings (Reaffirmed 2010)
IS 3792 : 1978	Guide for heat insulation of non-industrial buildings (Reaffirmed 2013)
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 (Reaffirmed 2014)
IS 13920 : 2016	Ductile detailing of reinforced concrete structures subjected to seismic forces - Code of practice
IS 14687 : 1999	Guidelines for Falsework for Concrete Structures (Reaffirmed 2014)
BMTPC Guidelines : 2011	Guidelines on Monolithic Concrete Construction
PAC No. 1006-A/2011	Performance Appraisal Certificate issued by BMTPC on Formwork for Monolithic Construction

Modular Tunnelform

(Suitable for Low Rise to High Rise Structures)

ABOUT THE TECHNOLOGY

Tunnel formwork is customized engineering formwork replacing conventional steel/plywood shuttering system. It is a mechanized system for cellular structures. It is based on two half shells which are placed together to form a room or cell. Several cells make an apartment. With tunnel forms, walls and slab are cast in a single day. The structure is divided into phases. Each phase consists of a section of the structure that will be cast in one day. The phasing is determined by the program and the amount of floor area that can be poured in one day. The formwork is set up for the day's pour in the morning. The reinforcement and services are positioned and concrete is poured in the afternoon. Once reinforcement is placed, concrete for walls and slabs shall be poured in one single operation. The formwork is stripped the early morning next day and positioned for the subsequent phases.

The formwork is manufactured in a fully automated plant. Presently, it is imported from France and there is no plant in India.

The on-site implementation of 24 hour cycle is divided into following operations.

1. Stripping of the formwork from the previous day.
2. Positioning of the formwork for the current day's phase, with the installation of mechanical, electrical and plumbing services.
3. Installation of reinforcement in the walls and slabs.
4. Concreting and if necessary, the heating equipment.

TYPES OF FORMWORK SYSTEM

TMPH Modular Tunnelform

Tunnel forms are room size formworks that allow walls and floors to be caste in a single pour. With multiple forms, the entire floor of a building can be done in a single pour. Tunnel forms require sufficient space exterior to the building for the entire form to be slipped out and lifted up to the next level.

This Tunnelform consists of inverted L-shaped half tunnels (one vertical panel and one horizontal panel) joined together to create a tunnel. Articulated struts brace the horizontal and vertical panels. These struts enable the adjustment of the horizontal level of the slab and simplify the stripping of the formwork. The vertical panel is equipped with adjustable jacking devices and a triangular stability system. Both devices are on wheels.

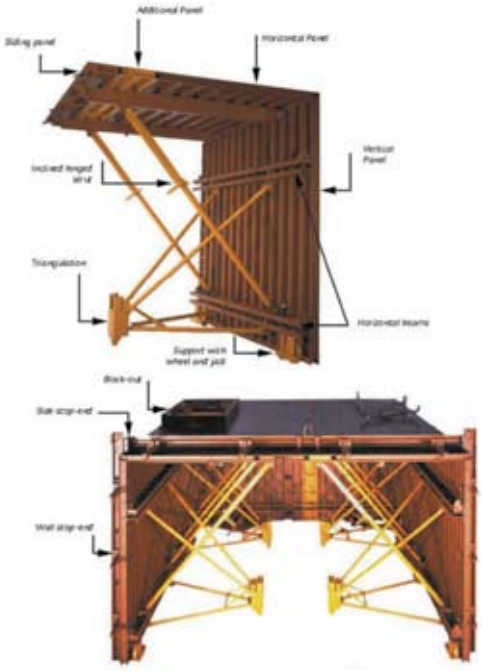
A range of spans is possible by altering the additional horizontal infill panel's dimensions. Due to the distribution of the horizontal beams on the vertical plank, the formwork also cast staggers and offsets in the layout of the walls as well as differing wall thicknesses. The half-tunnels shall be equipped with back panels to cast prependicular shear walls or corridor walls. Assembly and levelling devices ensure that the frormwork surfaces are completely plumbed and levelled.

Standard Characteristics

Standard dimensions: TMPH & Modular
Unit width : 2.40 m to 6.00 m
Type 1 horizontal panel : 1.20 m to 1.60 m
Type 2 horizontal panel: 1.80 m to 2.40 m
Type 3 horizontal panel: 2.40 m to 3.00 m
The span can be adjusted by fitting an additional panel measuring between 0.05 and 0.60 m
Package length: Up to 12.50 m in length as a function of the hoisting facilities and availability
Basic length: 1.25 m
Average weight: 90 Kg/m^2
Handling: Lifting triangle or sling
Transportation: 180 m^2 per truckload.

Wallforms

Wallforms are temporary moulds in which concrete is poured in order to build a structure. Once the concrete is poured into the formwork and has set, the formwork is stripped to expose perfect finished concrete. These forms constitute a system approach for construction and are particularly suited to build structural walls, columns, bridge piers, culverts etc. This system adopts well to daily work-phase of both repetitive and non-repetitive tasks. The equipment used each day is productive and is reused in subsequent phases. The four daily operations which outlines the daily production cycle for wall form equipment are identical to those for Tunnel form equipment with the exception that it is solely used for casting concrete walls. The slabs are cast as a secondary phase. The existing equipment can be adapted on a day-to-day basis by the addition of standard elements and corner-wall formwork to take into account different wall configurations on site. All safety and stability devices shall be fully integrated into the standard version of Wallform equipment.



B 8000 Wallforms

These Wallforms are tools specially designed to be used on specific buildings and structures. This vertical wallform panel is a multi-purpose formwork system. This system has been designed and developed to ensure that it is simple and quick to assemble and position the following:

- A full range of standard dimensioned components
- Multiple combination of panels for simple adoption to specific configurations
- Basic standard equipment incorporates complete safety, circulation and stability equipment
- Caliper–device opposing Wallform packages are craned into position in one lift.

Standard characteristics

Standard dimensions:
Standard height: 2.80 m
Upper extension: 0.50 m
Lower extension: 1.00 m-1.50 m
Average weight: 135 Kg/m^2
Assembly: 0.80 H/m^2 of formwork
Use: 0.15 to 0.30 H/m^2 of formwork, depending on complexity
Wind stability: by prop
Access: inner ladder accessed via hatch
Superposition: up to 22.5 m with specific engineering performed to determine hoisting and stability characteristics
Transportation: 24 wall forms per container/ truckload

Angle Formwork

Inner and outer angle configurations are designed to attach to 1.25 m wall forms to obtain a 160 mm wall. Spacers shall be installed for producing wall thicknesses.

Back Panel

The back panel allows pouring of cross walls, other walls, walls and slab in one operation.

Slab Stop End and Wall stop

These can be adjusted to fit the lengths of wall and slabs. These remain fixed to the form during all handling operations.

Kicker Form

In order to guide the walls of the upper floor precisely above the walls of the floor below, a kicker form is fixed to the tunnel form before pouring the concrete. Slab and starting walls are then poured during the same phase.

Box Out

During each phase, window box out, door box out and slab box out are mounted on the tunnel using a magnetized system.

MATERIAL REQUIREMENTS

i. Hot dip galvanized steel sheet – 3 mm thick shall conform to IS 277:2003
ii. Steel for Angle section – 80 mm x 80 mm x 6 mm shall conform to IS 2062:2011
iii. Cold rolled U-sections – 60 mm x 30 mm shall conform to IS 2062:2011.

Mechanical properties:

Yield stress : ≥ 23.5 daN/mm^2
Breaking load : ≥ 36 daN/mm^2
Elongation : ≥ 20%
Steel for spacer pins – Apart from the requirements given above, the steel used for the manufacture of the spacer pins, the gripping mechanisms, anchoring points for the rear stabilizing and adjusting mechanisms shall guarantee a KCV resilience at –20ºC of at least 28J.

CHARACTERISTICS OF THE SYSTEM

- Maximum span between walls shall be 5.60 m without accessory units and 7.00 m with accessory units.

- Height of the formwork – The forms are designed for floor to ceiling height of 2.51 m minimum with the possibility to increase this by action of the leg jacks or with the use of movable panels in the event of extra heights.
- Appearances of the faces after form removal – The surfaces obtained allow direct application of finishing paint or wallpaper after sanding off the fins at the joints connecting the units and smoothing with paint filler.
- Working rhythm using the system – Under average temperature conditions, with the use of ordinary cement, the normal rhythm is two days per cycle with one day and two nights for drying and setting of the concrete.
- Time period required for execution of the process – The time required for execution shall vary according to the cell plan. For a type cell consisting of two formed wall surfaces and a floor surface, the average time is less than one & one half hours per square meter of building. This time includes the form removal, oiling, displacement of the units, formwork and adjustment.

UTILIZATION OF THE FORMWORK SYSTEM

At each stage, utilization of the system requires the following successive operations:

i. The placing of the vertical wall reinforcement of the floor and possibly the door frames provided for in the erection drawing;

ii. Dismantling of the movable form units of the preceding storey. This shall be carried out in two stages:
   a) Loosening of the normal units (half-shells), by removal of the spacers passing through the walls, by unlocking the tunnel keys and disassembly of the sections. This work is executed in principle by two non-specializes maneuvers.
   b) Striking and removal of the forms. This shall be carried out by using the special dolly and two maneuvers in the tunnel and by two other maneuvers at the new location (usually on the storey above). This suite of operations shall be carried out by bringing the dolly under the half-shell to be removed and then working the different jacks for the striking operation itself. The leg jacks are lifted first, then a slight deformation of the half-shell is provoked by working the diagonal bracing jacks (shortening). This deformation is sufficient to strip the form progressively. It drops down automatically onto the dolly. The dolly half-shell assembly shall then be rolled across the service platform where the form is cleaned and oiled with a sprayer, then picked up with a crane and hoisted to its new location site, the dolly remaining in place. The half-shell design makes it possible to remove the whole side of a tunnel, then to prop the slab near the key before removing the other half, permitting if necessary, a faster rotation of the equipment.

iii) Reassembly of the units on the floor above. This assembly consists of the following operations:
   a) A half-shell shall be positioned on its leg jacks and knee brace, and adjustment shall be squared by blocking the diagonal bracing jacks, then adjustment of the height and plumb by working the leg jacks and the knee brace jack.
   b) The half-shells shall be assembled together.
   c) The opposite half-shells shall be positioned, and adjacent half-shells of the ‘tunnel’ half-shells shall also be positioned using the same procedure.
   d) The half-shells shall be blocked by constituting the two faces of the wall on the ‘starters’ with the help of the lower spacers; the upper spacers shall be tightened without being forced, only after verification of the general adjustment; positioning of the butt end forms of the walls and floors.
   e) The key-locks solidifying the opposite half-shells shall be positioned and blocked. If necessary, a light action on the knee brace and diagonal bracing jacks shall be used to bring the locking units into line.
   f) The starter forms shall be positioned and blockouts, if necessary for anticipated door and window frames.
   g) The overall adjustment and finish making–up shall be verified, if necessary, after lifting of the knee braces.
   h) The suspended floor shall be reinforced and concrete shall be poured in the walls and slab.

iv) The service platform shall be removed and this platform shall be installed on the storey above.

APPLICATIONS

Designed to cast concrete load-bearing walls and slabs in a single monolithic pour, tunnel forms are suited for the construction of following structures:

- Multiple residential dwellings
- Housing projects
- Garden apartments
- Town homes
- Condomiums
- Hotels etc.

SPECIAL FEATURES

Behavior in earthquake

Formwork shall be designed to meet the requirement of permanent structures using specified Indian Standards for material used. The design should take into account the conditions of materials to be actually used for the formwork, environment, site condition loads on formwork and combination of loads shall be taken in accordance with the clause 7.3 of IS 14687:1999.

Behavior under high winds

The design for wind loads shall be in accordance with the provisions given in IS 875 (Part 3):2015 and IS 14687:1999.

Productive

The equipment used each day is productive and is reused in subsequent phases.

Day-to-day basis

The existing equipment can be adapted on a day-to-day basis by the addition of standard elements and corner-wall formwork to take into account different wall configurations on site.

LIMITATIONS

- The floor spans executed with movable forms shall not be more than 5.60 m, unless accessory units are used.
- The thickness of vertical in-situ walls shall not be more than 120 mm, unless justified by special provisions.

MAJOR WORKS COMPLETED USING THE FORMWORK

- Apartments by M/s Runwal Group at Mumbai in 2000
- Apartments complexes by M/s B G Shirke Construction Technology Pvt. Ltd., Pune at Navi Mumbai, and Tirupati in 2001
- Apartments by M/s L&T South City Projects Ltd., at Chennai in 2008
- Slum Rehabilitation by M/s Pawar Patkar Construction Pvt. Ltd., at Nasik in 2014

CERTIFICATION

Performance Appraisal Certificate No. 1018-S/2015 issued to M/s Outinord Formworks Pvt. Ltd., Pune by BMTPC.

STANDARDS/REFERENCES

Agreement No. 2569 relating to New Materials and Non-traditional Construction Processes between Cashiers of the C.S.T.B, Paris, France and Outinord, Company, S.A.	
Case studies of the projects carried out by various agencies throughout the world including India using Outinord Formwork.	
Design of the Formwork submitted by the manufacturer	
Quality Management Manual and Maintenance Manual followed by the manufacturer	
Application of accelerated curing to Apartment Formwork System – Advisory Note from British Cement Corporation	
IS 277 : 2003	Specifications for plain and corrugated galvanized steel sheets (sixth revision)
IS 456 : 2000	Code of practice for plain and reinforced concrete (fourth revision)
IS 875 (Part 3) : 2015	Code of Practice for Design Loads (Other than Earthquake) for Buildings and Structures - Part 3 : Wind Loads
IS 2062 : 1999	Hot rolled medium and high tensile structural steel
IS 14687 : 1999	Falsework for concrete structures

Formwork Systems

Stay-in-Place Formwork Systems

Insulating Concrete Forms (ICF) & Monolithic Insulated Concrete Systems (MICS)

(Suitabvle for Low Rise Structures)

ABOUT THE TECHNOLOGY

Insulating Concrete Forms (ICF) & Monolithic Insulated Concrete Systems (MICS) comprise of panels of two walls of Expandable Polystyrene (EPS) separated by a nominal distance of 150mm by hard plastic ties. These are assembled on site to hold reinforced concrete. The forms are open ended hollow polystyrene blocks which fit tightly together to form a shuttering system. Concrete is poured into the hollow space to form a continuous wall. When cured, this wall supports the structural loads from floors and roofs, and the shuttering provides thermal insulation. Reinforcing steel shall be as required from design. Upper and lower surfaces of the polystyrene panels are castellated and the vertical mating surfaces are tongue-and-groove to form a tight fit when joined together. The rigid formwork does not require supporting false work. The inner surfaces have tapered grooves running vertically and have offset on opposite faces to ensure uniform concrete thickness. They also form locks for end stops. The outer surfaces are grooved vertically at 50mm centers to aid cutting and trimming.

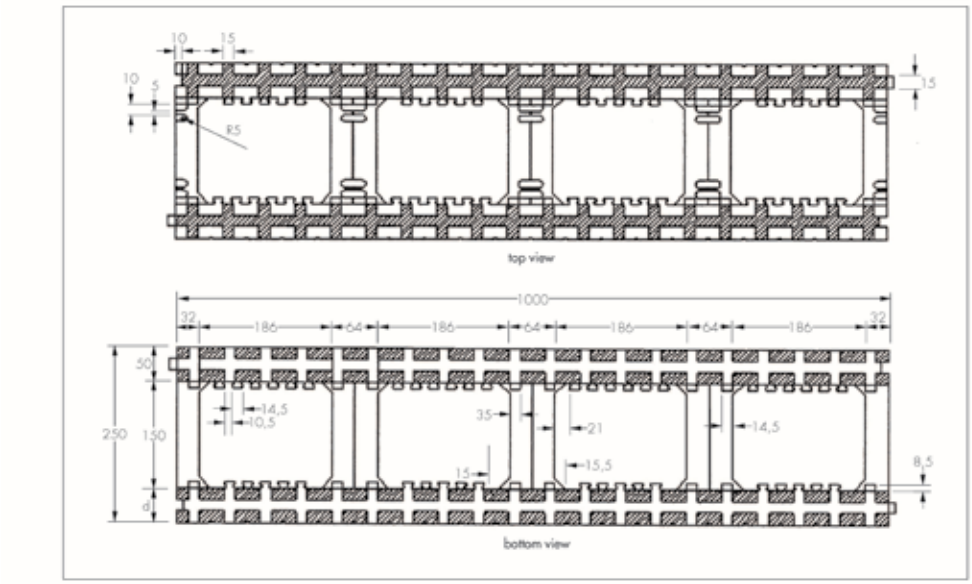


Fig. 1 Plan View

CLASSIFICATION AND TYPES OF FORMS

Standard Forms – These form bulk of the forms and have 50mm EPS panels on both sides with 8 nos. hard plastic ties holding the panels. Dimensions of these forms are 1000 x 250 x 250mm. (See Fig. 2)

Half Height Forms – Together with the lintel, these form the top layer of all gaps in the wall and hold the required steel reinforcement. Dimensions of these forms are 1000 x 150 x 250mm. (See Fig. 3)

Lintel Forms – In combination with Half Height forms, these form the top layer of all wall gaps and hold the concrete thus preventing thermal leaks. Dimensions of these forms are 1000 x 125 x 250mm. (See Fig. 4)

Floor Edge Forms – These form the top most layer, where the wall ends and floor begins. This envelopes the floor slab and thus prevents thermal bridging. Dimensions of these forms are 1000 x 375/125 x 250mm. (See Fig. 5)

Corner Forms – These constitute 90º corner of the building. The two sides are 50mm EPS panels held together with 8 nos. hard ties. Dimensions of these forms are 750/500 x 250 x 250mm. (See Fig. 6)

End Forms – These create wall ending by fitting in inside the Standard or Corner form and provide a smooth and thermal bridge ending to the wall. Dimensions of these forms are 150 x 125 x 50mm. (See Fig. 7)

Fig. 2 Standard

Fig. 3 Half Height

Fig. 4 Lintel

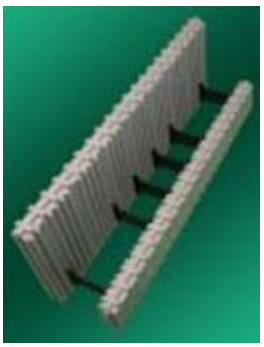


Fig. 5 Floor Edge

Fig. 6 Corner

Fig. 7 End

RAW MATERIALS

- Expanded Polystyrene (EPS): Self-extinguishing type EPS shall conform to IS 4671: 1984 having density not less than 25 kg/m^3 and valid Restriction of Hazardous Substance (ROHS) test certification.
- Polyurethane (PU) Foam Adhesive: Shall have Skin Formation of 8 min, Density 25 kg/m^3, Sound insulation 58 dB, Insulation factor 35 mW/mK, Shrinkage< 2%, Fire rating B3, Insulation factor 35 mW/m.K and Water absorption of 1 % volume
- Plasticizer: Slump retaining super plasticizer for self-compacting plastic concrete (CEMWET SP-3000) shall conform to IS 9103:1999
- Hard Plastic Tie: Shall be made with High density polyethylene and shall be as per manufacturer's specifications.
- Cast-in-place concrete: The ingredients, grade of concrete & slump for walls, floors and roofs shall be used as per IS 456:2000.

STRUCTURAL

The Insulating Concrete Forms (ICF) & Monolithic Insulated Concrete Systems (MICS) may be designed using the appropriate design software. The buildings constructed with EPS shall be studied and designed as reinforced concrete structure since the parameters required for their design are the same as needed for traditional reinforced concrete. In the calculation model, the building shall be designed in accordance with IS 456:2000, as applicable, as structure composed of load bearing walls with a box-like structure.

The system is intended for use where architectural drawings are available and satisfy the various requirements. The system shall be designed to provide the required performance against the loads to be taken into account in accordance with IS 875 (Parts 1,2,4&5):1987 and the data given by manufacturer for various panels. It shall also provide the required bearing resistance for earthquake and wind forces as per IS 875 (Part 3):2015 and IS 1893 (Part 1):2016, wherever applicable.

Foundation shall be specifically designed in accordance with provision given in IS 1904:1986. The design concept is same as that of the conventional building design. The safe bearing capacity and soil properties (soil investigation report)) shall be provided from the site after soil investigations. Foundation shall be designed based on the soil investigation report. Both single and double panels should have starter bars from either foundation or ground floor slab. All foundations should be designed by experienced engineer with appropriate reference. In addition, any other requirement regarding safety against earthquake need to be ensured by the designer as per prevailing codal requirements.

Typical construction

Construction process

The construction of most Insulating Concrete Forms (ICF) & Monolithic Insulated Concrete Systems (MICS) buildings is fundamentally a process of stacking lightweight blocks together in a similar manner to building bricks, laying reinforcement where necessary and pouring concrete into the voids of the block work. It does not call for the same skill set as solid brick or brick veneer construction.

Footings
The footings for Insulating Concrete Forms (ICF) & Monolithic Insulated Concrete Systems (MICS) buildings are usually reinforced concrete rafts or strips that are flat and even enough to enable stacking of the form blocks, with reinforcement starter bars set ready to connect with the concrete when poured into the formwork.

Load bearing walls
Any Insulated Concrete System/Forms wall can be designed to be load bearing.

Joints and connections
Joints and connections with other building elements are kept to a minimum, especially when the flooring or roofing elements are also made from Insulated Concrete System/Forms.

Fixings
The foam block work or formwork forms a poor basis for any fixings. Light loads are generally carried by the lining or facing materials, such as plasterboard, and heavier loads can be carried by supporting points drilled into the concrete that forms the inner material of the Insulated Concrete System/Forms.

Openings
Major openings for doors, windows, etc., need to be set out in the formwork as it is relatively difficult to make changes later, owing to the fundamentally monolithic nature of the structural elements. Once openings have been made, they can accommodate window and door frames of any type. A typical kind of fixing uses timber blocks set into the ends of the form blocks around the opening.
Electrical conduit and plumbing is generally run in chasing in the depth of the form blocks.

Finishes
Finishes are dependent on the materials used to face the Insulated Concrete System/Forms units. Typically, the main finish is a render or render-equivalent covering or paint. Any additional cladding can be added to the Insulating Concrete Forms (ICF) & Monolithic Insulated Concrete Systems (MICS) walls subject to making appropriate supports for it, although many sheet finishes, such as plasterboard, can be glued directly to the surface of the formwork. External renders require a base or skim coat embedded with fibreglass mesh, followed by a second coat and then a texture coating, finally finished with an ‘armour coat’.

BASE: Insulated Concrete System/Forms can be built on footings similar to conventional masonry footings, slabs-on-grade or piles or can also be built on step footings & shallow foundation systems.

FORMWORK: Walls built by assembly of interlocking, moulded hollow forms.

REBARS: Fixing reinforcement steel bars with hard ties inside formwork as per calculated structural requirement.

TRESTLES: Fixed for plumb straight walls & support during concrete pour

SCAFFOLD: Platform on trestles for access & assembly of high walls
PROPPING: Fixing framework as props around Doorways & window frames.

CONDUITS & PIPES: Inside chased lines



CONCRETE: High slump concrete poured inside formwork


SPECIAL FEATURES

- Cost Effective - Saves 70% or more in energy equipment & consumption bills for maintaining cooling temperatures
- Quicker - Commissioned in nearly half the normal time period, with less manpower & no heavy machines
- Resource Conserving - No water for curing, hence time & labour also saved at site
- Load bearing external walls - With minimized need for columns or beams

- Minimal on site waste - Modular form work enables any wall height or design complexity with ease,
- 100% insulation - With zero thermal leaks (R-Value = 19, higher than any other new or traditional constructions
- Durable - Monolithic structure for highest degree of fire & disaster resistance 3 hours of fire rating, can withstand earthquakes of Magnitude +7
- Sound Insulation - Up to 60 Db
- Maintenance free - Fibre glass mesh reinforced, crack resistant plaster on walls
- Heat resistant external roof - With interlocking insulation tiles of uniformly high R-Value
- Code Compliance - System designed to meet International Standards & Building Codes

ADVANTAGES

- Not just Walls: But multiple building steps with one product
- Form system -- light weight, interlocking
- Wall structure -- strong, load bearing, disaster proof
- Insulation -- thermal & acoustic, on both sides
- Air barrier -- no drafts with monolithic insulation
- Vapour barrier -- moisture & condensation kept out
- Smooth, straight surface -- less finishing time for Interior/exterior Render

USES AND LIMITATIONS OF ICF/MICS

Insulating Concrete Forms (ICF) & Monolithic Insulated Concrete Systems (MICS) may be used as a load bearing and non-load bearing internal or external walls to build residential and other buildings. This construction technology may be used for wide variety of buildings including apartments, villas, low-rise buildings, commercial complexes, hotels, industrial buildings, etc.

LIMITATIONS

1. Door and window position can't be changed after pouring of concrete
2. Forms are not reusable as compared to conventional materials

EXECUTED PROJECT

S. No.	Name of Project	Location	Period of Supply
1.	Construction of Farmhouse of approx. 110 sqm area	Manesar (Haryana)	January 2015
2.	Construction of G+3 showroom of total area of approx. 1600 sqm	Indore (MP)	Mar-April 2015
3.	Construction of G+1 Hillside Cottage of approx. 250 sqm area	Theog, Shimla (H P)	June – Aug., 2015
4.	Construction of G+5 Multi storey residence of total area 900 sqm	New Delhi	Nov. – April 2016
5.	Construction of G+1 Office & godown of 590 sqm area each	Greater Noida (UP)	2014-15
6.	Construction of a single storey Prototype house	VDOS Colony, Khammam (Telangana)	2016

CERTIFICATION

i) Under Performance Appraisal Certification Scheme, the present formwork system with patent name 'Insulating Concrete Forms' vide Performance Appraisal Certificate No. 1029 -S/2018 issued to M/S RELIABLE INSUPACKS (P) LTD, Greater Noida by BMTPC.

ii) Under Performance Appraisal Certification Scheme, the present formwork system with patent name 'Monolithic Insulated Concrete System' vide Performance Appraisal Certificate No. 1036-S/2018 is awarded to M/s Maiwir Ecotech Pvt. Ltd., Khammam (Telangana) by BMTPC.

STANDARDS

Following Standards are referred:

IS 383:2016	Specifications for coarse and fine aggregate for concrete (Third Revision)
IS 456:2000	Code of practice for plain and reinforced concrete (Reaffirmed 2016)
IS 875 (Parts 1,2,4&5):1987 IS 875 (Part 3):2015	Code of Practice for Design Loads (Other than Earthquake) for Buildings & Structures (Parts 1,2,4&5 – Reaffirmed 2013)
IS 1346:1991	Code of practice for waterproofing of roofs with bitumen felts (Reaffirmed 2016)
IS 1542:1992	Specifications for sand for plaster (Reaffirmed 2014)
IS 1786:2008	Specifications for high strength deformed steel bars and wires for concrete reinforcement (Reaffirmed 2013)
IS 1893 (Part 1):2016	Criteria for Earthquake Resistant Design of Structure - Part 1 : General Provisions and Buildings (Sixth Revision)
IS 1904: 1986	Code of practice for design and construction of foundations in soils: General requirements (Reaffirmed 2015)
IS 3346:1980	Method of determination of thermal conductivity for thermal insulation materials
IS 4326:2013	Code of Practice for Earthquake Resistant Design and Construction of Buildings (Third Revision)
IS 4671:1984	Specifications for expanded polystyrene for thermal insulation purposes
IS 4759:1996	Hot Dip Zinc Coating on Structural Steel Products
IS 8112:2013	Specifications for 43 grade Ordinary Portland Cement (Second Revision)
IS 9103:1999	Specifications for concrete admixtures (Reaffirmed 2013)
ISO 9705:1983	Fire tests for evaluating contribution of wall & ceiling interior finish to room fire growth
ACI 318:2014	Building code requirements for structural concrete, structural design for flat wall ICF systems
ASTM C 578:2015	Standard specifications for rigid, cellular polystyrene thermal insulation
ASTM E 119:2014	Standard test methods for fire tests of building construction and materials
ASTM E 2634:2011	Standard specifications for flat wall ICF systems

Structural Stay-in-Place Formwork System (Coffor Technology)

(Suitable for Low Rise to Medium Rise)

ABOUT THE TECHNOLOGY

It is a patented structural stay in place formwork system known as 'Coffor' to build load bearing monolithic concrete wall structures based on shear wall concept.

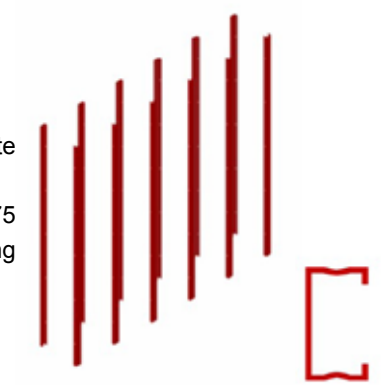
The formwork system comprises of two filtering grids made of rib mesh reinforced by 'C' channel vertical stiffeners. The grids are connected by rebar which act as horizontal stiffeners and connector which act as a shear link. The grids on both faces act as sacrificial formwork in which concrete is poured in-situ.

After the erection of formwork panels in alignment, corners, edges of doors and windows frame are closed with rebar positioning & concrete of required grade is poured in the panels. The concreting may be done with a pump, bucket or with a shovel loader. The inside and outside walls are finished with cement plaster of suitable grade.

The panels are prefabricated according to a structural plan (based on client's architectural plans) designed by structural engineers.

Product assembly Components in Coffor Panel:

The various parts of Coffor panel are explained briefly below:

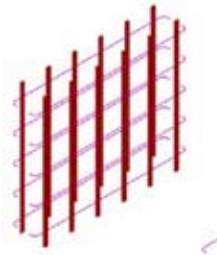


Part – 1: C-Chanel

– These are vertical stiffeners, work as vertical steel in Reinforced Concrete wall
– It is made up of 0.6 mm thick galvanized sheet. The 180 GSM to 275 GSM zinc coating is used based on geological location to prevent rusting of steel.
– Area of profile is 60.6 mm^2 (i.e > 8 mm dia bar)
– Placed at every 200 mm distance along the width

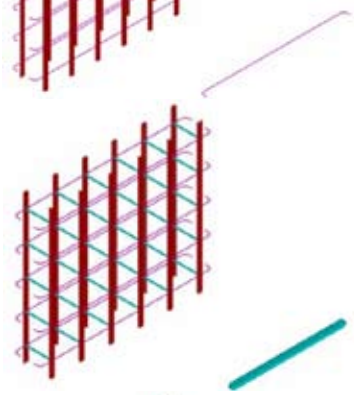
Part – 2: Rebar

– Rebar's are horizontal stiffeners at every 200 mm or 100 mm centre to centre
– It is 5 mm dia MS bars and work as distribution bar.
– Made up of Fe 415 Grade steel



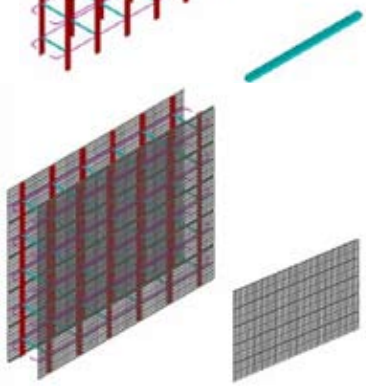
Part – 3: Connector

– Connects C profile & Rebar.
– It is made up of 1.6 thick Cold Rolled Cold Annealed (CRCA) plates of 120 gm/m^2 zinc coated sheet to prevent rusting
– Works as shear link to connect steel on both face of form work.
– Also helps to avoid bulging of formwork during concrete pouring.



Part – 4: Rib Mesh

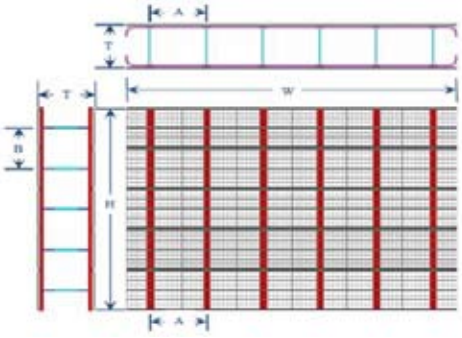
– Rib meshes are filtering grids.
– They are made up of 0.42 mm thick high galvanized sheet with 180 GSM to 275 GSM zinc coating used as per geological location to prevent rusting of steel
– It works as reinforcement to plaster to prevent crack generated due to contraction and expansion.
– Also provide good bonding to plaster.



Size and Types of Panels

Panels are normally produced in sizes as given below (See Fig. 2):

Width (W): 300mm, 500mm, 700mm, 900mm & 1100mm
Height (H): 500mm to 5000mm in multiples of 100 mm.
Thickness (T): 100mm, 140mm, 160mm, 200mm & 250mm.
However, customized sizes also be made available on demand.



Panel Type	T mm	A mm	B mm	W mm	H mm
C10	100	200	100, 200	300,	Min.
C14	140	200	100, 200	500,	500
C16	160	200	100, 200	700,	then
C20	200	200	100, 200	900,	in multiples
C25	250	200	100, 200	1100	of 100

Fig.2

Types of panels are given below:

i. Standard single panels – These panels shall be used for slab shuttering but may also be used as shuttering option for RCC wall having thickness of more than 350mm. (Fig. 3)
ii. Double panels – Double panels shall have inbuilt steel and not require extra reinforcement. In double panels, the grids shall be connected by articulated rebar loops and connectors that fold.
These panels are of two types:
(a) Standard double panels shall be of fixed size and need to be cut on site for openings etc.
(b) Customized double panels from the factory shall have required cutting for openings as per drawing and there is no need for cutting on site.
(c) These panels create a monolithic structure as it allows pouring of walls and slab together.
These panels shall be used for load bearing walls, retaining walls and shear walls. (Fig. 4)

iii. Insulated Double panel – These panels shall have an integrated insulation on the exterior side. The insulated material shall be of polystyrene or polyurethane of required thickness as per design.(Fig. 5)

iv. Fiber Cement Double panel – These panels shall have its interior face as fibre cement board which has smooth surface and avoid plastering of walls. (Fig. 6). These panels may be used for water retaining structures.

Fig.3 Standard Single Panel

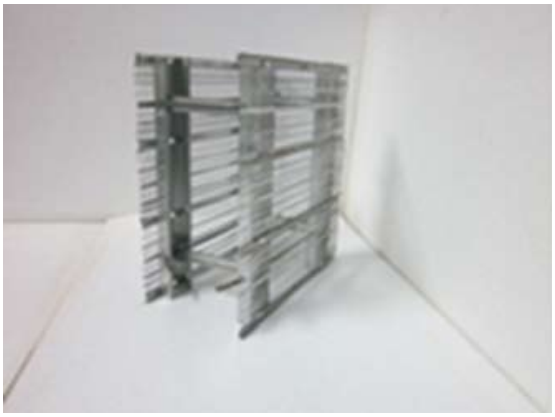


Fig.4 Standard Double Panel

Fig.5 Insulated Panel

Fig.6 Fiber Cement Panel

BASIC STEPS TO CONSTRUCT WITH COFFOR PANELS

Foundation

Strip Footing or normal column and beam structure up to Plinth level based on soil condition.
In case of Strip footing, Coffor panels will start from foundation and on the top of strip concrete raft which increase speed to come out from the ground.

Installation of Panel:

Layout and Blocking

- The alignment shall be traced with chalk on the two sides. Boards/battens shall be nailed on the ground to indicate the positioning of one face of the panels.

Positioning the Panel

- The Structural formwork panels shall be fitted over projecting vertical reinforcing rods. Each panel shall be held vertically with wood pieces (boards/battens) or metal pieces (L-sections/tubes). The minimum length of these bracing elements shall not be less than 1.80m. The panels shall preferably be positioned beginning from the angles and from the doors. Whenever length of the wall does not correspond to a multiple of width of the panels, the last panel shall be cut with a rotary saw to adjust to length of the wall. The horizontal

battens shall be installed on a single side. The verticality shall be checked using a plumb line or level.

- Shuttering of Slab: after completion of Coffor panel installation of the wall, slab shuttering will start either with use of Coffor single panels or normal conventional shuttering for RCC or any other slab.
- Plumbing and Electrification: After installation of slab shuttering, electrical and plumbing conduits can be placed in between panels. For installing the electrical box, panels can be cut with small grinder machine.
- Panel alignment & slab steel needs to be checked & ensured prior to concreting.
- Concrete Pouring: The placing of concrete of specified grade is done in wall and slab in one go with either with Boom placer, stationary pump or manually. As all concreting is done in one go, a monolithic reinforced concrete structure is created.

STRUCTURAL REQUIREMENTS OF THE CONSTRUCTION

The design strategy is to utilize concrete and formwork steel to the ultimate and to provide standard solutions for minimum reinforcement to be used, wherever required, depending on the application and will be determined by structural calculations performed according to the IS 456:2000. In seismic prone areas requiring seismic resistant construction, relevant provisions of IS 875 (Part 1, 2, 4 & 5):1987, IS 875 (Part 3):2015, IS 1893 (Part 1):2016, IS 4326:2013 and IS 13920:2016 shall apply.

Design analysis of the Structural formwork walls, panels, floor slabs etc. shall be done using Staad Pro Software or equivalent. The Optimal result is obtained when walls shall be designed as braced construction elements whose horizontal loads are supported by other bracing elements belonging to the same construction e.g. shear walls. The panels with concrete shall act as “lightly reinforced RCC walls” as per clause 32 of IS 456:2000 and as “prefabricated concrete load bearing walls” as per IS 15916:2010 & IS 15917:2010 & amp; IS 15971:2010.

Structural design and analysis of the formwork shall be based on relevant Indian and International standards. The panel construction assembly shall be used for free standing walls when designed and anchored as cantilever walls. Panels shall be reinforced and tied at vertical joints to maintain alignment. Additional reinforcement and cement plaster shall be provided as required by the design.

The technology is intended for use where Architectural drawings are available. The Architect and Engineer designer team of the concerned developer/owner (client) is responsible for the drawings and overall building design to comply with the various regulatory requirements applicable to the area.

Foundation shall be specifically designed in accordance with provisions given in IS 1904:2005. All foundations should be designed by structural engineer with appropriate reference.

DURABILITY

Since concrete is main constituent material in this system, durability of the structure can be achieved by using proper ingredients, grade of concrete as per IS 456:2000 and mix design in accordance with IS 10262:2009.
Thickness of the wall is minimum 120 mm thick, with 100 mm concrete thickness & 10-12 mm plaster on both sides.

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 this system uses 10-12 mm plaster on both sides of the walling unit, the thermal transmittance value is going to be slightly lower than 100 mm thick RCC wall. Further, in G+3/G+4 building units, the panel thickness used is generally 140 mm, which will have still lower thermal transmittance value. However, it is more than the normal plastered 9" brick masonry walls (thermal transmittance (U) 2.13 W/m²K), hence it is advised to 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 is reasonable acoustic insulation.

EASE OF SERVICES

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

MAIN ADVANTAGES OF THE SYSTEM

- Creates good quality monolithic earthquake resistant structure.
- Ensures significant reduction in construction time, labour requirement, overheads, etc.
- Easy to use system with no need for heavy machinery, Cranes, etc.
- Simplifies the construction process
- No need of skilled labor, the labor can easily be trained in a short span of time
- Maintenance free building as the outer surface having mesh provides good bonding to plaster and helps to prevent cracks, water seepage, etc.

THE APPLICATION OF THE SYSTEM & ITS LIMITATIONS

This sacrificial Formwork System is used for load bearing walls/ retaining walls/shear walls for residential buildings upto G+4 storey, Industrial buildings, Underground Tanks, Water retaining, structures, Storm water drains, Compound walls etc. and as shuttering material for slabs. The limitations of the system are;

- For construction of high rise buildings beyond G+ 4 storeys, extra steel in walls shall be required.
- Post construction alterations are difficult.
- All the service lines are to be pre-planned in advance.

EXECUTION OF PROJECTS

- Coffor France SNC, France for construction of various projects, with total built-up area of approx 17839 sqmt during 2008 -15
- Coffor France SNC, France for construction of Swimming pools, with total built-up area of approx 22770 sqmt during 2008-15
- West Coast Contractors Pvt. Ltd., Vadodra, Gujarat for construction of P+4 apartments, with total built-up area of approx 1596 sqmt during 2012-13
- Sandeep Shah & Associates, Surendranagar, Gujarat for construction of G+4 structure, with total built-up area of approx 1251 sqmt, during 2013-14
- Lubi Pump Pvt. Ltd., Ahmedabad, Gujarat for construction of Retaining wall, with total built-up area of approx 1400 sqmt during 2013-14
- The demonstration housing project under PMAY as being executed by BMTPC with 36 DUs (G+2) at Biharsharif, Bihar & 16 DUs (G+3) at Hyderabad, Telangana. The proof checking of design for both the projects is available with BMTPC.

The projects other than demonstration housing projects, are as per the details provided by PAC holder.

CERTIFICATION

Under Performance Appraisal Certification Scheme, Structural Stay-in-place Formwork System has been evaluated and certified by BMTPC **PAC No.: 1035-S/2018 is awarded to M/s Coffor Construction Technology Pvt. Ltd., Vadodra (Gujarat).**

STANDARDS & REFERENCES

IS 456:2000	Code of Practice for plain & reinforced concrete (Reaffirmed 2016)
IS 15916:2010	Code of practice for Building design and erection using prefabricated concrete
IS 15917:2010	Code of practice for Building design and erection using mixed/composite construction (Reaffirmed 2014)
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) (Reaffirmed 2013)
IS 875 (Parts 2,4&5):1987 IS 875 (Part 3):2015	Code of practice for design loads (other than earthquake) for buildings and structurres: Imposed Loads, Wind Loads, Snow Loads and Special loads & combinations
IS 1893 (Part 1):2016	Criteria for Earthquake resistance design of structure
IS 10262:2009	Concrete mix proportioning - Guidelines (Reaffirmed 2014)
IS 13920:2016	Code of practice for Ductile detailing of reinforced concrete structures subjected to seismic force
IS 4759:1996	Hot Dip Zinc coating on structural steel products.
Technical Assessment No. 16/10-607 of Coffor Structural Formwork by CSTB, Paris, France	
Structural Evaluation of Prefabricated Concrete Wall System made of Coffor Steel panels comprising tests of Lateral load, Flexural strength and Axial load of the Panels by IIT Bombay	
Project Report of Flexural, Compression, Shear & Deflection tests by Geo Test House, Vadodra	
Quality Assurance Procedure Manual	
Operating Manual giving details of Installation and Execution of the panels	

Lost-in-Place Formwork System – Plaswall Panel System

(For Structural Applications)

(Suitable for Low Rise to Medium Rise Structures)

ABOUT THE TECHNOLOGY

Plaswall Panel System is a lost in place formwork, where two fiber cement boards (FCB) of 6mm thickness each and HIMI spacers (High Impact Molded Inserts) bonded between two sheets of FCB (in- situ) are erected to produce straight-to-finish panels. A monolithic structure is then created by filling the entire structure with M20 or higher grade of concrete as per the design. Additional load capacity can be obtained by providing extra reinforcing bars and/or by increasing grade of the concrete.

At present, the firm imports the fibre cement board (FCB) manufactured by Hume Cemboard Industries, Malaysia for use in the construction of structures.

An Isometric View of the Plaswall is shown in Fig. 1 below:

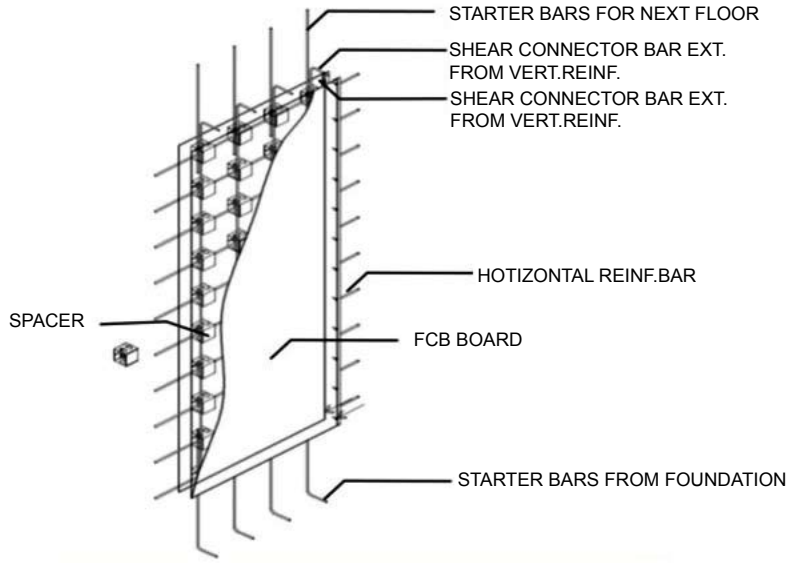


Fig. 1 Isometric View

SIZE OF PANELS

Panels are normally produced in sizes and dimensions as below:

Length:	2400mm/3000 mm
Width:	1200 mm
Thickness:	87 mm, 112 mm, 137 mm, 162 mm & 230 mm including two fiber cement boards of 6mm thickness each and infill of concrete of 75mm, 100mm, 125mm, 150mm and 218mm.

The dimensional sketches are shown in Fig. 2

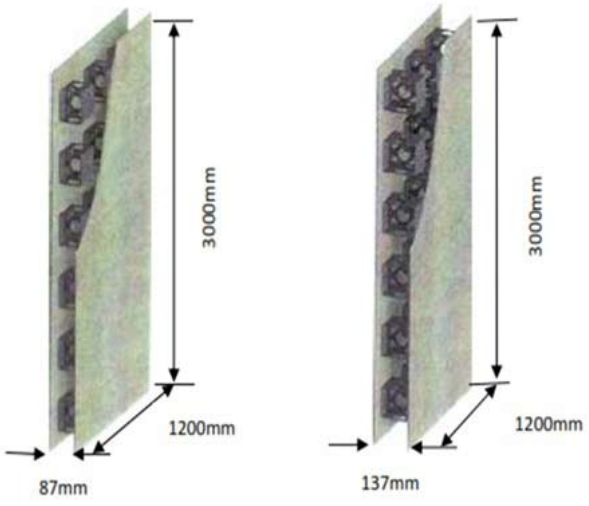


Fig. 2 Dimensional sketches

RAW MATERIALS

- Fibre cement board shall be 100% asbestos free and conform to Type A, Category 3 min. as stipulated in IS 14862:2000.
- Recycled plastic spacers made of High Impact Molded Inserts shall conform to the specifications of the manufacturer.
- PU Adhesive Glue shall conform to the specifications of the manufacturer.
- Putty shall conform to IS 419:1967.
- Cement, sand, aggregate and reinforcement steel shall be as per the relevant Indian Standards.

USES AND LIMITATIONS

Uses:

Plaswall panels may be used upto G+3 storey residential and commercial buildings, villas, apartments, factories and malls, etc.

Limitations:

- Nails should be inserted in walls by first making a hole by drilling and fixing a plastic sleeves or rawl plugs.
- Chisel shall not be used to chase directly on the wall for providing additional services. Instead 100 mm grinder machine shall be used to cut out exact portion of wall and then rendering of the wall with mortar and putty.
- If wall tiles are to be changed, walls shall not be hacked for fixing new tiles. Instead, a cementitious tile adhesive should be for fixing new tiles.
- Post construction alternations are difficult. All the service lines are to be pre-planned in advance.

DESIGN PARAMETERS

- All concreting work shall be done in accordance with IS 456:2000 with regard to workmanship and materials. M20 or higher grade of concrete as per the design shall be used for construction and mix should be prepared in accordance with Clause 9.2 of IS 456:2000.
- The Reinforcement shall be placed according to the specifications, depending on the application and shall be determined by structural calculations performed according to the IS 456:2000.
- The lateral forces as applicable shall be taken into account based on relevant Indian Standards.

PANEL FABRICATION

Fibre cement edge recessing

After cutting fibre cement sheets to the desired dimensions, the edge of the sheets shall be recessed using recessing machine.

Panel Lamination

- Plastic pallets and jigs shall be arranged perpendicular to each other
- Fibre sheet shall be laid in alignment with respect to pallet and jig setup
- Marking of spacer with use of specific stencil positions shall be done on the sheet
- Glue @ 250gm min. is the standard consumption. Reusable bottom angles shall be laid as per alignment of walls where panels are to be installed.
- Desired number of plastic spacers (32 nos. of spacers for panel of size 1200 mm x 2400 mm) shall be placed on the top of the fibre sheet, where glue is applied and kept in linear manner for 4 to 5 hours.
- Glue shall be applied on upper faces of spacers and upper sheet is laid perfectly in line with lower sheet. (Fig. 3 & 4)
- Ten number of panels shall be fabricated on each side of jig and stacked on pallets. (Fig. 5)
- These panels then shall be cut as per the specified dimensions and sizes such as rectangular, square, curves etc.

Fig. 3

Fig. 4

Fig. 5

Joint Splicing

Joints between two panels shall be fixed by using FCB strips 50 mm wide inside the panel with help of glue, screws and tacking pins. (Fig. 6).

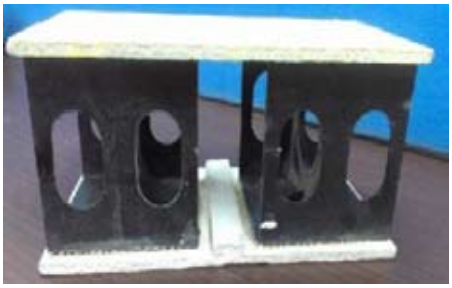


Fig. 6 Splicing

CONSTRUCTION, INSTALLATION AND JOINTING PROCEDURE OF PLASWALL

Foundation

The foundation type as raft, strip, isolated footing shall be decided based on bearing capacity of the soil, site condition, etc. However, the provision for starter bars for walls shall be ensured in all foundation scenarios. Typical sketch for starter bars from foundation are given below (Fig.7).

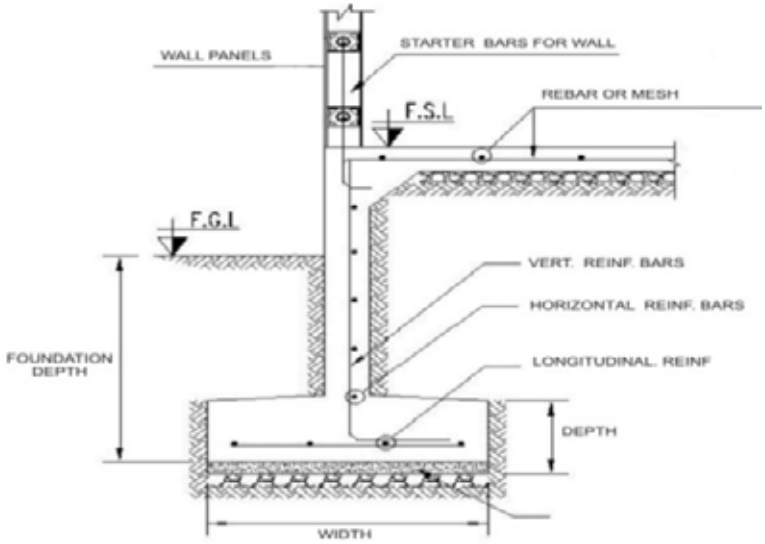


Fig. 7 Typical Strip footing

Panel Installation

Installation

The panel shall be lifted slightly and then placed along the bottom angles. The panel shall be plumbed at edge and face sides with provision of shims, if needed.

- The panel shall be screwed both sides at bottom at 250 mm center to center, while glue is applied & tacky. If glue is not available, spacing shall be kept at 200mm center to center.
- Support the temporarily angle installed on other side of panel to hold it in position for concreting (Fig. 8)
- Corner connection details shall be followed as shown in Fig. 9.

Fig. 8 Diagonal bracing

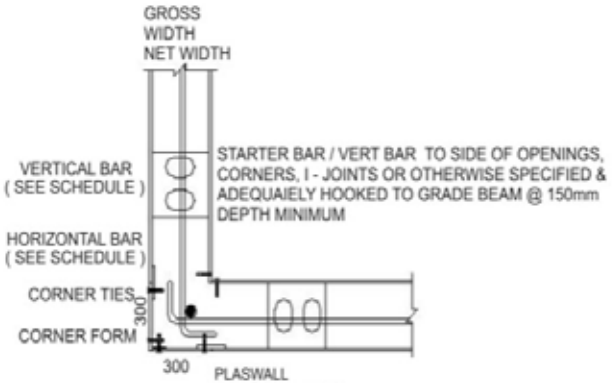


Fig. 9 Corner connection

T-Section

- After installing the primary walls, mark the place where corner will be constructed.
- The joiner stud shall be placed and marked by pencil to have a vertical line reference.
- The joiner stud shall be moved up by 60mm from slab to bottom of joiner stud. The stud hole shall be marked by pencil.
- The marked slots shall be cut by 100mm angle grinder with dry type diamond blade.
- Reinforced dowels shall be prepared, inserted & tied just after screwing the joiner stud corner connection. (Fig.9)
- In case, the holes intersect with panel stud of the primary wall, the portion of primary stud shall be cut to accommodate the marked holes for T-connection. One 12mm vertical bar shall be provided as replacement.
- In case of cross-connection, horizontal bars shall be provided.

Nib End Wall Detail

- For nib, end cap shall be provided.
- Glue shall be applied on end cap stud which shall be inserted to correct position and screwed. (Fig. 10)

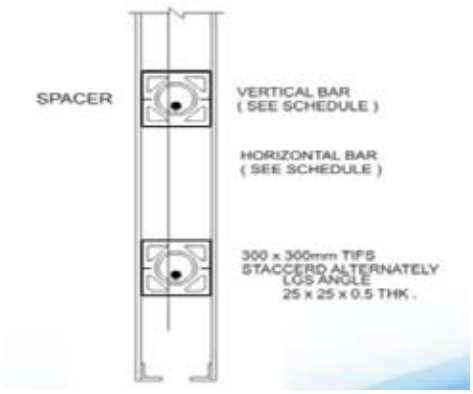


Fig. 10 Nib End Wall Detail

Fig. 11 Door & Window Jambs

Door & Window Jambs Installation

- Light gauge door & window jambs shall be provided for the panels
- Door jambs shall be installed along with the panel. (Fig. 11)
- Window jambs shall be installed (not fixed) to accommodate concrete at window sills. This will eliminate honey-comb and ease pouring of concrete.
- The window sill shall be overflowed by concrete and then push down window frame. The lintel panel shall be screwed to press down the window frame. Spacing of screws shall be the same.

Embedment of Services

After installation of the panels, electrical and plumbing pipes shall be inserted into the panel as per the drawings.

Concreting

After placing of reinforcement and services in the panel, designed grade/mix of concrete shall be poured manually or by Pumping system. The concrete shall be poured from top of the wall or by cutting slit and attaching chute in the panel.

Joint Treatment

After walls are completely filled and mix dried, joint treatment shall be done using fibre mesh tape and putty. (See Figs. 12 & 13)

Fig.12 Yellow Putty with Fibre mesh tape

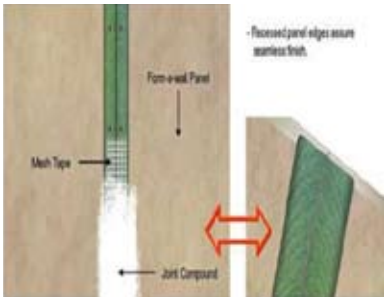


Fig.13 Joint Treatment

Construction of Slab

Once construction of panels is completed, slab construction shall be done as per the structural drawings with wall reinforcement and connection with slab reinforcement.

KEY FEATURES OF "PLASWALL" LOAD BEARING SYSTEM

- It is significantly faster than conventional technology.
- Brick work & plastering is eliminated
- Curing of concrete is not required & hence considerable water is saved
- Inlaid plumbing & electrical lines, superior quality finish.
- Better Acoustic Insulation
- Termite & Algae Resistant.
- Applicable in Humid conditions.
- HIMI is manufactured from 100% recycled plastics.
- Fire Resistance: PLASWALL™ is non-combustible and has fire resistance for one hour as determined by ASTM E 119 tests. Its excellent thermal insulation acts as a thermal shield. A 112mm thick wall will withstand fire for 2 hours 20 minutes and a 162mm thick wall has fire resistance for 3 hours.
- Acoustic Insulation: Its inbuilt sound reduction properties make it excellent for sound absorption and noise isolation. Concrete walls carry sounds, thus hampering privacy.

MAJOR PROJECTS EXECUTED

- Construction of Row Houses (Area= 675 sq.mts) at Boisar.
- Sales Gallery at Vaisind for Tata Housing, Mumbai.
- Construction of Villas at Cupertino, Bangalore for M/s Concorde Group, Bangalore
- Construction of 4 Villas at Goa (Area= 1085 sq.mts) for M/s Naiknaware Developers, Pune.
- Construction of 113 no .of Villas (G+1 configuration) at Sawantwadi, Maharashtra(Area= 6200 sq.mts) for M/s Ranco Reality, Mumbai
- Construction of Villas & School at Ooty for M/s Ground Reality, Bangalore

CERTIFICATION

Performance Appraisal Certificate No. 1034-S/2018 issued to M/s FTS Buildtech Pvt. Ltd., Mumbai by BMTPC. (Download from website (www.bmtpc.org.).

LIST OF STANDARDS AND CODES USED IN ASSESSMENT

Standards: These Standards are referred for carrying out a particular test only and do not specify the requirement for the whole product as such.

IS 383:2016	Specifications for coarse and fine aggregates (Third Revision)
IS 419:1967	Specifications for putty.
IS 456:2000	Code of practice for plain and reinforced concrete (Reaffirmed 2016)
IS 516:1959	Method of test for strength of concrete (Reaffirmed 2013)
IS 2380 (Part 14):1977	Methods of test for wood particle board and other Ligno cellulosic materials – screw & nail withdrawal test (Reaffirmed 2013)
IS 3809:1979	Fire Resistance Test for Structures
IS 8112:2013	Specifications for 43 grade Ordinary Portland Cement
IS 13920:2016	Ductile detailing of reinforced concrete structures subjected to seismic forces - code of practice
IS 14862:2000	Specifications for Fibre Cement Flat Sheets (Reaffirmed 2015)
ASTM C 518-02	Standard test method for steady state thermal transmission properties by means of heat flow meter apparatus
ASTM C779	Standard test method for abrasion resistance of horizontal concrete surfaces
ASTM C873	Standard test method for compression strength of concrete cylinders
ASTM C900	Standard test method for pullout strength of hardened concrete
ASTM 322:09	Standard test method for thermal conductivity
ASTM E119	Standard test method for fire tests of building construction and materials
ASTM E 152-58	Non-combustibility test for materials and heat emissions from building materials
ASTM E413	Classification of rating of sound insulation and field transmission class
ASTM E2179	Standard test method for lab measurement of effectiveness of floor coverings
BS 476 (Part4):1970	Fire tests on building materials and structures—Method of test to determine classification of surface spread of flame

References:

1.	Evaluation of Structural Design of G+2 storey 30m x 40m Villa Project at Cupertino, Bangalore using Plaswall Technology by IIT Bombay.
2.	Design of a G+2 storey with Roof Deck Residential Villa Project at Djibouti, Africa by Senior Consultant Engineer
3.	BBA Agreement Certificate No. 16/5380 pertaining to Greenspan Permanent Shuttering Systems on which Plaswall Technology is based
4.	Report on Thermal Transmission Properties of Plaswall (Load bearing walls) by calculation method by Material Lab, Dubai, UAE
5.	Small –Scale Fire Resistance Test on a 110mm thick panel by Firelab, Glenstantia, South Africa
6.	Tests performed on Plaswall Panel for Fire Resistance at the Forest Products Research & Development Institute Fire Testing Laboratory, Philippines as per ASTM E152-58.
7.	Tests performed on samples of spacers i.e. High Impact Moulded Inserts (HIMI) of size 125mm collected by the IO for carrying out the following tests by Central Institute of Plastics Engineering and Technology (CIPET), Ahmedabad
8.	Tests Performed on samples of Fibre Cement Board and Panels by Indian Institute of Technology Bombay, Mumbai.

Lost-in-Place Formwork System – Plasmolite Wall Panel

(Suitable for Non Load Bearing Structures)

ABOUT THE TECHNOLOGY

Plasmolite Panels are lost in place formwork system comprising of two fibre cement boards (FCB) of 6 mm thickness and High Impact Molded Inserts (HIMI) bonded between two sheets which also acts as spacers. The panel is erected to produce straight to finish walls which are filled with light weight foam concrete. The system may be integrated with conventional column and beam and also with pre-engineered buildings. The panels may be used as non load bearing walls for external and internal applications.

The firm imports the fibre cement board (FCB) manufactured by Hume Cemboard Industries, Malaysia for use in the technology. An Isometric View of the Plasmolite panel is shown in Fig. 1 below;

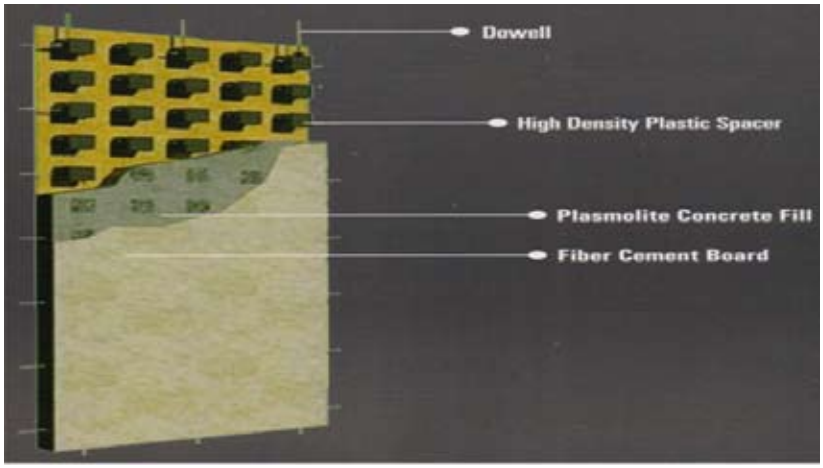


Fig. 1 Isometric View of Plasmolite Panel

SIZE OF PANELS

Size: Panels are normally produced in sizes and dimensions as given below:

Length:	2400/3000 mm
Width:	1200 mm
Thickness:	87 mm, 112 mm, 137 mm, 162 mm & 230 mm including two fibre cement boards of 6mm thickness each.

Typical dimensional diagrams are shown in Fig. 2.

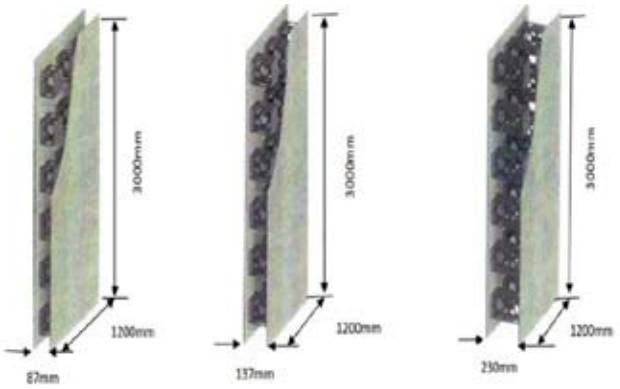


Fig.2 Dimensional Diagrams

RAW MATERIALS

- Fibre cement board shall be 100% asbestos free and conform to Type A, Category 3 min. as stipulated in IS 14862:2000.
- Recycled plastic spacers made of High Impact Molded Inserts shall conform to the specifications of the manufacturer.
- PU Adhesive Glue shall conform to the specifications of the manufacturer.
- Foaming agent shall conform to the specifications of the manufacturer.
- Putty shall conform to IS 419:1967.
- Cement, sand, aggregate and reinforcement steel shall be as per the relevant Indian Standards.

USES AND LIMITATIONS

Uses: Plasmolite Panels may be used as partition walls for external and internal applications for residential and commercial buildings, schools, hospitals, factories and malls etc.

Limitations:

- Nails/screws should not be inserted directly on the walls by using hammer. Instead, a hole shall be drilled by using drilling machine and then plastic sleeves or rawl plugs be inserted for fixing the nails/screws.
- Chisel shall not be used to chase directly on the wall for providing additional services. Instead, 100 mm grinder machine shall be used to cut out exact portion of wall and then rendering of the wall with mortar and putty.
- If wall tiles are to be changed, walls shall not be hacked for fixing new tiles. Instead, a cementitious tile adhesive should be for fixing new tiles.

PANEL FABRICATION

Fibre Cement Edge Recessing

After cutting fibre cement sheet to the desired dimensions, the edge of the sheet shall be recessed using recessing machine.

Panel Lamination (Fig. 3)

- Using the panel jig, one fibre cement sheet 6mm thick shall be placed on top of jig with the smooth face touching the jig flat form.
- Desired number of HIMI spacers shall be placed on top of fibre cement sheet and PU adhesive applied on the stud flanges (32 pieces for full panel 1200mm x 2400mm). HIMI spacers shall be aligned using pattern board.

Fig. 3 Marking & fixing of Spacers, formation of successive layers of panels

- Another 6mm thick fibre cement sheet shall be placed on top of the studs to close the first panel.
- The same process as above shall be repeated until jig is filled with panels.
- Flat plywood covers shall be laid to compress the panel for 4 to 5 hours.

PANEL INSTALLATION

Dowelling

- Holes shall be drilled & dowels shall be grouted by using epoxy resins in the holes.
- Centre to centre spacing between dowels shall be 300 mm as per design
- Dowels shall be installed on beams, columns and slab (Fig. 4)

Fig. 4 Dowelling

Installation

- The panel shall be lifted slightly and then placed along the bottom angles. The panel shall be plumbed at edge and face sides with provision of shims, if needed.
- It is essential that panels be first installed starting from face of supporting column
- The panel shall be screwed both sides at bottom at 250 mm center to center, while glue is applied & Stacy. If glue is not available, spacing shall be kept at 200mm center to center. (Figs. 5, 6 & 7)
- Support the temporarily angle installed on other side of panel to hold it in position for concreting (Fig. 8)

Fig. 5

Fig. 6

Fig. 7

Fig. 8

Joint Splicing

Joints between two panels shall be fixed by using FCB strips 50 mm wide inside the panel with help of glue, screws and tacking pins. (Fig. 9)

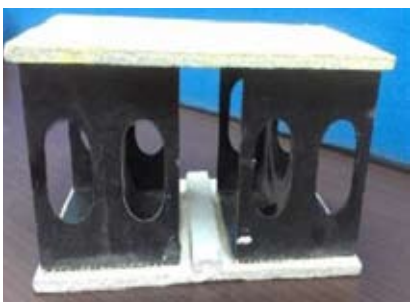


Fig. 9 Tongue and Groove Systems

Embedment of Services

After installation of panel, electrical and plumbing pipes shall be inserted into the panel as per the drawings.

Concrete mix

Plasmolite foam generator and mixer shall be used for this purpose. An elaborated mix of cement, sand/fly ash and water shall be prepared, quantities of which vary depending upon required density and strength of foam concrete.

Pouring of Concrete

Concrete can be poured in the panel by pumping or manually directly from top or intermediate position depending on floor to floor height and site conditions.

Fig. 10 Plasmolite set for pouring

Fig. 11 Gap Filling

Joint Treatment

- After walls are completely filled and mix dried, joint treatment shall be done using fibre mesh tape and putty.
- Mesh tape shall be sandwiched between first & second coats to have a hold over the wall. (Fig. 12)
- Wall is now ready to accept primer & paint.

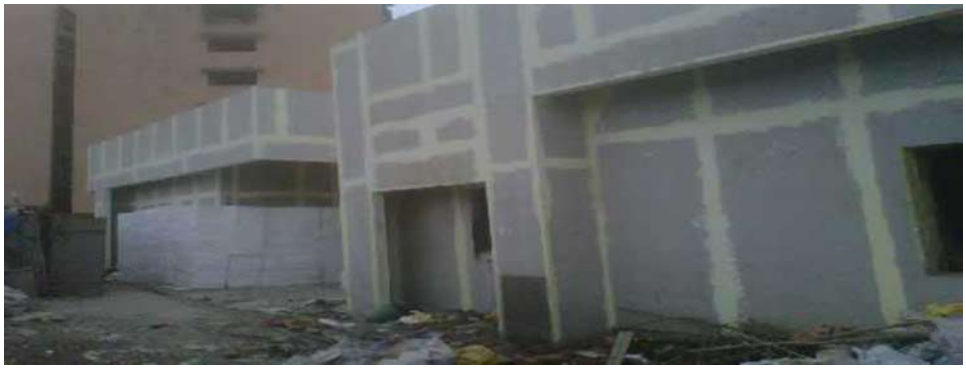


Fig. 12 Yellow Putty with Fibre Mesh Tape

DESIGN PARAMETERS

The technology provider shall provide design data for good practices and as ready reckoner for users.Typical design sketches for non-load bearing walls are shown in Figs. 13 & 14.

PROJECT EXECUTED

1. Supply, Fabrication & Installation of wall panels at Goa for construction of a high rise building for M/s JVS Infrastructure & Environment, Goa
2. Supply, Fabrication & Installation of panels at TCS Sahyadri Park, Hinjawadi, Pune for M/s Shapoorji Pallonji, Pune
3. Supply, Fabrication & Installation of wall panels at Dahej, Gujarat for M/s Indo Baijin Chem Pvt. Ltd., Bharuch, Gujarat

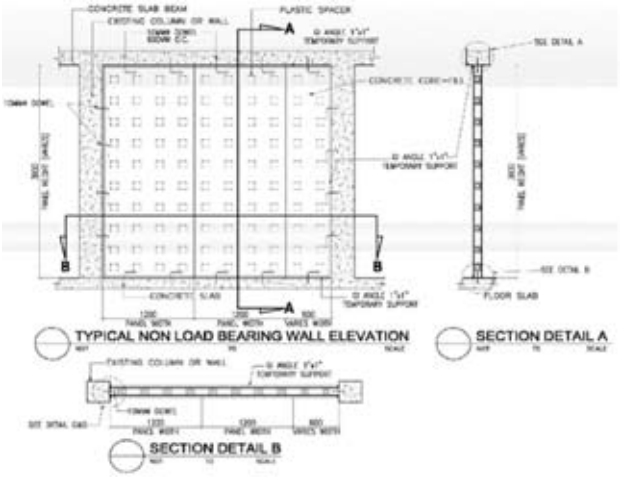


Fig. 13

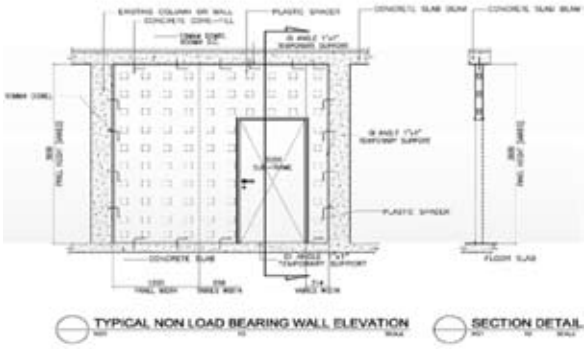


Fig. 14

4. Supply, Fabrication & Installation of panels at Future Towers, Amanora Park Town, Pune for Amanora, Pune
5. Design, Supply & Installation of panels at residential building at Vikhroli, Mumbai for Shubam Dynamic, Mumbai
6. Supply, fabrication & installation of wall panels at Pune for construction of IT Park for M/s Tata Consultancy Ltd., Pune.

ADVANTAGES

- Faster construction
- Eco-friendly
- Good thermal & acoustics insulation

CERTIFICATION

Performance Appraisal Certificate No. 1033-S/2018 issued to M/s FTS Buildtech Pvt. Ltd., Mumbai by BMTPC (Download from website - www.bmtpc.org)

LIST OF STANDARDS, REFERENCES USED IN ASSESSMENT

Indian Standards

IS 383:2016	Specifications for coarse and fine aggregates (Third Revision)
IS 419:1967	Specifications for putty.
IS 456:2000	Code of practice for plain and reinforced concrete (Reaffirmed 2016)
IS 516:1959	Method of test for strength of concrete (Reaffirmed 2013)
IS 2380 (Part 14):1977	Methods of test for wood particle board and other Ligno cellulosic materials – screw & nail withdrawal test (Reaffirmed 2013)
IS 3809:1979	Fire Resistance Test for Structures
IS 8112:2013	Specifications for 43 grade Ordinary Portland Cement
IS 14862:2000	Specifications for Fibre Cement Flat Sheets (Reaffirmed 2015)
ASTM C900	Standard test method for pullout strength of hardened concrete
ASTM 322:09	Standard test method for thermal conductivity
ASTM E119	Standard test method for fire tests of building construction and materials

References

1.	Tests Performed on samples of Fibre Cement Board and Panels by Indian Institute of Technology Bombay, Mumbai
2.	Tests Performed on Panels by Civil-Aid Technoclinic Pvt. Ltd., Bangalore
3.	Test Performed on samples of spacers i.e. High Impact Moulded Inserts (HIMI) of size 125mm collected by the Inspection Officer for carrying out the tests by Central Institute of Plastics Engineering and Technology (CIPET), Ahmedabad

Sismo Building Technology

(Suitable for Low Rise to High Rise Structures)

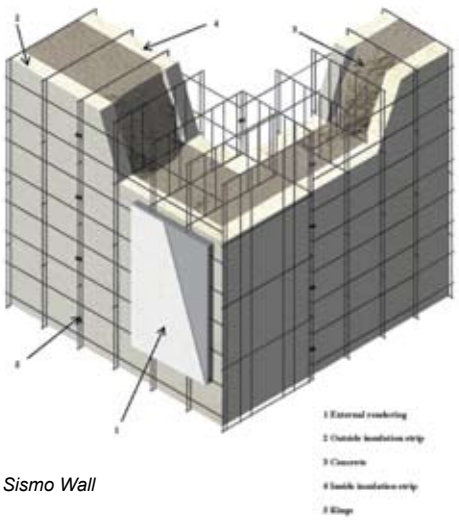
ABOUT THE TECHNOLOGY

Sismo Building Technology is an insulating shuttering kit for whole building based on a three-dimensional lattice made of galvanized steel wire. The lattice is filled with materials of different nature to serve as formwork. The basic structure of the Sismo building module is steel wire lattice. At the exterior sides of the lattice, infill panels are inserted, which transform the lattice into a closed structure that can be filled with concrete. The type of infill panels used depends on the purpose of the wall: load bearing or not, insulated or otherwise, etc. The steel wire also acts as armature and anchoring for the finished material and it holds reinforcement bars in place during concrete filling.

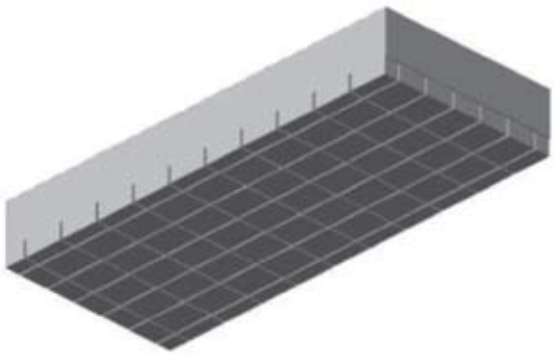
This technology was initially developed in Belgium and the firm in India has a collaboration with n. v. Desmo-Home “Sismo” Ltd., Belgium.

Description of the components is as follows:

- 3D lattice (2.2 mm Ø galvanized steel wire)
- Infill panels (EPS, rock wool, mineral board)
- Structural filler (concrete)
- Finishing (plastering, natural stone, paneling etc.)



Sismo Wall



One-way girder-slab floor

MODULES

Type of Modules

Depending on the internal and external material, the walls may be divided into following types:

(i) Inside & outside insulation (EPS) strips symmetrical and asymmetrical

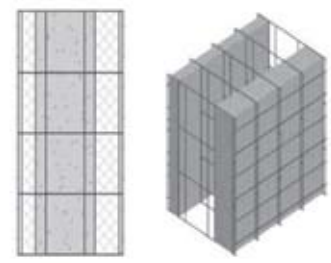
(ii) Inside board and outside insulation (EPS) strips

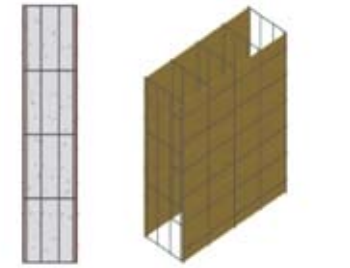
(iii) Inside & outside board strips

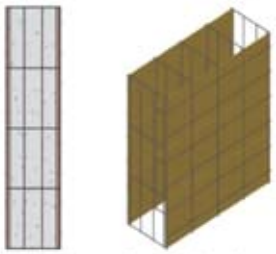
(iv) Inside & outside insulation strips

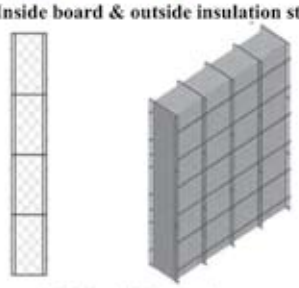
(v) 2 Sismo walls decoupled and insulated for an optimized acoustic performance. This type is typically used as separating wall between apartment and houses.

(vi) Module with insulation strips as core material Sismo floors and roofs may be plain, one and two-way slabs; as per requirement.


Inside & outside insulation strips


Inside board & outside insulation strips


Inside & outside board strips


Module with insulation as core

DESCRIPTION OF THE COMPONENTS

Steel Lattice

The steel wire frame, lattice formwork for the walls, are available in panels of different dimensions as follows:

- Height: in multiples of 150 mm, with a max. of 12 m
- Length: in multiples of 100 mm, with a max. of 1.2 m
- Thickness: Max. 500 mm, depending on the type of wall /roof required

Functions of steel lattice

The steel wire lattice has the following basic functions:

(i) To resist hydraulic pressure of fresh concrete during pouring and first hours of hardening

(ii) To keep reinforcement bars in place during pouring of concrete

(iii) To ensure adhesion (and reinforcement) of finishing when using mineral based renders

Insulation strips and Interjoists

The insulation strips have following functions:

- Maintain fresh concrete during the provisional phase of pouring
- Thermal insulation in final phase
- Support of interior and exterior finishing

The strips have fixed dimensions and shall be fixed with tongue and groove: 15 mm x 20 mm for EPS strips of thickness 38 mm to 118 mm and 10 mm x 15 mm (h x w) for other strips of thickness 38 mm.

The interjoists have following functions:

- Creation of ribs in order to have a one or two-way girder-slab floor
- Thermal insulation in final phase

The inter joists have fixed dimensions (length 1200 mm & width 450 mm) but may be cut in length in multiples of 100 mm and width in multiples of 150 mm. These shall be available in various thicknesses from 100 mm to 350 mm. These shall have a 'waffle' structure (100 mm x 75 mm) and the groove has depth of 30 mm and a width of 10 mm. Their shape ensures a good grip on the metal frame of the floor modules.

The details of one-way girder-slab floor are as follows:

- The center to center distance between the ribs is in multiples of 150 mm
- The width of the ribs is 150 mm or in multiples thereof.

The details of two-way girder-slab floor are as follows:

- The center to center distance between the ribs is in multiples of 150 mm on one side and 10cm on the otherside
- The width of the ribs is 150 mm or in multiples thereof on one side and 100 mm on the other side.

MATERIAL REQUIREMENTS

Hot galvanized steel wire shall conform to the specifications as given below:

- Zinc coating shall not be less than 60 g/m^2
- The dia. of the wires and rings shall be 2.2 mm ± 0.03 mm.
- Tensile strength: 680 N/mm^2 min.
- Chemical composition: C = 0.020 % min., Mn = 0.150 % min, Si = 0.250% max., P = 0.030 % max., S = 0.030 % max.

Rings: Rings shall be used to hold the panels together during installation phase.

Insulation strips and panels:

- Expanded polystyrene (EPS): shall conform to IS 4671:1984 and shall have density not less than 15 kg/m^3.
- Fibre cement board (FCB) 5 mm thick: shall conform to IS 14862:2000.

Cast-in-place concrete: The ingredients, grade of concrete & slump for walls, floors and roofs shall be used as per IS 456:2000.

APPLICATIONS

The technology shall be used for construction of structures consisting of load bearing walls, foundations, cellars, floors and roof etc. for residential, commercial and industrial purposes.

PRODUCTION PROCESS

The production of the modules is carried out in the Sismo Production Station (SPS). The main stages of production include:

- Unwinding of steel wire rolls
- Cutting and straightening of steel wire
- Assembly and welding of two-dimensional lattices
- Assembly and welding of three-dimensional lattices
- Cutting of insulation strips and interjoists
- Insertion of the insulation strips into three-dimensional lattice at the lateral intervals intended for this purpose.

The fixing of the panels and placing of interjoists on respective walls and floors is done at site. Panels are installed after hardening of concrete.

The production is carried out according to an internal factory production control plan.

Conformity checks are done on incoming materials and at regular stages throughout the production sequence to ensure the fitness of the components.

Accessories

The accessories required for erection of the walls in construction site shall be as follows:

- *Struts:* to support the panels during installation and pouring of concrete (max. distance of 2 m between two panels).
- *Strut for stanchion*: to support stanchion for guard rail and used to align and support the top of panels at floor level during installation and pouring of concrete.

- *Hollow profiles*: to support the panels during installation and pouring of concrete (max. distance of 2 m between two panels).
- *U-profiles*: to connect the hollow profiles with horizontal steel wire supporting the panels during pouring of concrete.
- *Stapler & Rings*: to connect the panels (7 rings per linear meter, on each side of the wall, back and front).
- *Lop ties and Tie twister*: to secure the reinforcement bars to the metal frame.
- *Cutter*: to cut the steel wire at the openings (doors, ceilings etc.) after hardening of the concrete.
- *Boards*: (30 mm/120 mm) for proper alignment of the walls.
- *Props and Shuttering boards* : as support for floors to spread the concentrated loads of the vertical props. The number of vertical props may be reducing by using load spread beams.

IMPLEMENTATION

Handling, transportation and storage of panels

- The handling of panels on site shall be done with gloves and protective glasses as they have sharp points.
- Loading and unloading of modules shall be done either manually or by machine.
- The modules shall be transported and stored sideways, standing or in a horizontal position. When stored and transported in horizontal position, extra care should be taken to limit stress because bottom panels of a pile horizontal staked modules have a higher risk of deformation.

Erection of Panels

- The panels shall be placed on the foundation or on the floors. They shall be held together by rings longitudinally placed every 150 mm on both sides of the wall.
- In the initial phase, the panels shall be supported on one of their sides by struts specially developed for this purpose. They shall provide lateral support to the panels till hardening of the concrete. The maximum distance between lateral supports should not exceed 2 m. It should be possible to transform the struts to scaffolding to allow access at the top of the casing to monitor pouring of the concrete.
- The free end of the panels (in case of openings, windows, doors or ceilings) shall be closed in the same manner as the common parts to ensure holding of fresh concrete.
- The verticality of the walls shall be checked before and during casting.
- The floor modules shall be temporarily, till hardening of the concrete, be supported by shuttering panels, beams and props. When props are used only for supporting the weight of fresh concrete, circulation and curing platform shall be used.

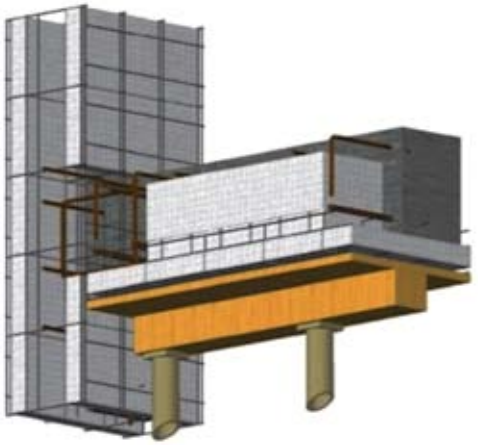
Placing of reinforcement

- The modulated dimensions of the lattice shall be 100 mm horizontally and 150 mm vertically and in multiples thereof. The securing of the bars through the lattice, shall ensure a correct positioning of the reinforcement after pouring of concrete.
- Stirrups, straight, L and U shaped bars shall be placed during mounting of the modules. The lattice should not be combined with welded reinforcement mesh.
- The placing of vertical bars shall be done through the top of panels and shall progress together with the mounting of the panels.
- Horizontal bars for ties, lintels etc. shall be inserted sideways and progresses together with the mounting of the walls. It is sometimes required to remove the insulating strips used as formwork at the edge of the panels to be able to insert the horizontal reinforcement bars and then slide them back into position.
- Length of U-shaped horizontal bars used shall be 1 m for straight length and 300 mm for bend portion, wherever required.

i. Corner –connection

- U-shaped horizontal reinforced bars
- U-shaped horizontal reinforced bars in the second wall
- Common vertical reinforced bars

ii. T-connection



- U-shaped horizontal reinforced bars in the wall to join
- Installation of the wall in T-connection
- Horizontal reinforced bars of a wall
- Common vertical reinforced bars

iii. Beam

- Vertical stirrups
- Horizontal reinforced bars

iv. Wall-floor connection

v. Starter bars

vi. Floor

Pouring of concrete

The pouring of concrete shall be done with a pump device or a tipper. The following requirements shall be adhered to:

- The speed of concrete filling shall be limited to 1000 mm per hour. Concrete is filled in layers up to 500 mm and shall be filled up to a maximum height of 6 m in a day.
- If filling is done with a pump device, suitable measures should be taken to cut the dynamic pressure of concrete. A flexible rubber sleeve is secured with retaining rings to the pipe of the pump device in order to limit the pressure of concrete by compressing the hose manually.

In order to ensure the geometrical and mechanical properties of the finished wall, the following checks are carried out during concrete filling:

- Control and possible correction of verticality of the wall before hardening of concrete
- Visual verification of penetration of cement concrete in joints between the strips so that all gaps are completely filled. Cores shall be taken through the insulation at critical positions, such as below windows and at corners, to establish integrity of concrete.

Roofs with pitch below and over 30º shall be constructed with open and closed lattices respectively.
Insulating strips shall be cleaned with a water jet or brushed after pouring of concrete to remove light leakage of laitance.

Finishing

Rendering

As there are significant regional differences due to availability of local materials and climatic conditions, the recommendations of the manufacturer of the material should generally be followed and good trade practice regarding installation and sealing should be observed. Renders should contact the local supplier to ascertain the product best suited for finishing of the modules. If plastering with cement mortar is to be done, the thickness of plaster shall be 15-20 mm.

Imbedding of ducts

- In self-extinguishing polystyrene panel conduits path shall be made.
- When thin hard panels are used for shuttering, conduits may either be surface mounted or inserted before the concrete is poured.
- Alternatively, polystyrene strips may be inserted allowing the conduits to be installed at a later stage.

Fixing of objects

- It is possible to fix objects up to 80 kg per fixing device in the insulation strips.
- For other cases, the fixing devices should be inserted in the concrete.

SPECIAL FEATURES

Structural Stability

The technology used is to exploit concrete to the ultimate and standard solutions for reinforcement are used, wherever required. Reinforcement, shall be placed according to the specifications, depending on the application and shall be determined by structural calculations performed according to the IS 456:2000. In seismic prone areas requiring seismic resistant construction, relevant provisions of IS 1893 (Part 1):2016, IS 4326:2013 and IS 13920:2016 shall apply.

Durability

The modules provide maximum strength during concrete placement. Once complete, structures reach an incredible structural integrity. When concrete is hardened, durability of steel wire is necessary in only those applications where the adhesion of finishing depends on it, in addition to the adhesion between concrete and insulation and between insulation and rendering.

Behavior in earthquake

The structure can be made earthquake resistant by applying provisions of IS 1893 and IS 13920.

Fire Safety

The assembled system is a continuous monolithic concrete system, thus without fire leakage through the assembled system. The required rating is achieved with proper thickness of concrete and polystyrene/other strips.

Thermal Performance

Depending on the climate, a variety of infill materials that completely and permanently insulate the building without thermal bridges, can be chosen

Behavior in wind/hurricane

A Sismo building is extremely resistant to the complex strains and thrusts due to the force emitted by wind, hurricanes and cyclones.

Light weight

Sismo modules weigh between 2 & 7 kg, eliminating the need for heavy and expensive building equipment on site. These can easily be handled and assembled manually.

Fast implementation

The time required to raise buildings using this technology is significantly shorter than any conventional building method.

MAJOR WORKS COMPLETED/UNDER COMPLETION

Sismo Building Technology, Belgium has constructed numerous residential and utility projects mostly in Belgium, France, Portugal, Italy, Turkey, Korea and Middle East etc. The Indian firm is constructing about 70 (G to G+2) housing units at Kashipur (Uttarakhand) by using this technology. The project is likely to be completed by 2017. Police Barracks (2500 sqft.) has been constructed at Siliguri. A project of construction of District Magistrate Office (7000 sqft.) at Cooch Behar, West Bengal is under progress. A Demonstration Housing Project of BMTPC at Lucknow comprising of 40 houses in G+1 configuration is under construction.

CERTIFICATION

Performance Appraisal Certificate No. 1025-S/2016 issued to M/s M K S Infosolutions Pvt. Ltd., Manesar (Haryana) by BMTPC.

STANDARDS/REFERENCES

European Assessment Technical Regulation	
Sismo technology: Plain concrete in high rise buildings by Sismo Engineering, Belgium	
Guideline for European Technical Approval of 'Non-load bearing permanent shuttering systems based on hollow blocks or panels of insulating materials' by EOTA, Brussels, Belgium	
Experimental Research in 92-93 & 93-94 by Sismo Engineering & CE Deptt., University of Leunen, Belgium	
IS 456:2000	Code of practice for plain and reinforced concrete (Reaffirmed 2016)
IS 875 (Parts 1,2, 4 & 5) :1987	Code of Practice for Design Loads (other than earthquake) for Buildings & Structures (Part 3 : 2015)
IS 1893 (Part 1):2016	Criteria for Earthquake Resistant Design of Structure
IS 4326:2013	Code of Practice for Earthquake Resistant Design and Construction of Buildings
IS 4671:1984	Specifications for expanded polystyrene for thermal insulation purposes
IS 14862:2000	Specifications for Fibre Cement Flat Sheets (Reaffirmed 2015)

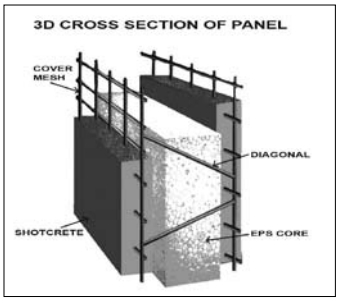
Precast Sandwich Panel Systems

EPS based Systems

Advanced Building System - EMMEDUE

(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 15 Kg/m^3, thickness not less than 60 mm, sandwiched 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 steel welded wire fabric mesh.

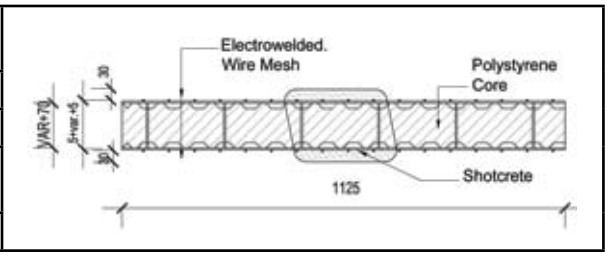
The technology (developed about 30 years back) has been successfully used in many countries like Morocco, Algeria, South Africa, Kenya, Austria, Malasiya, Ireland, Romania & Australia with involvement of different agencies and brand names.

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:

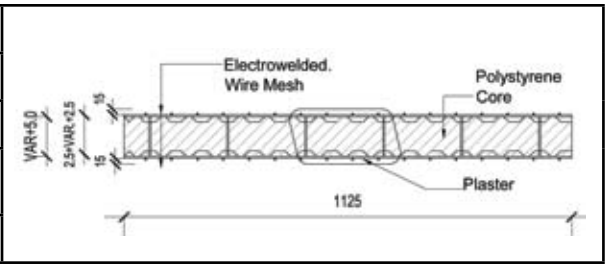
Single Panel for structural uses

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

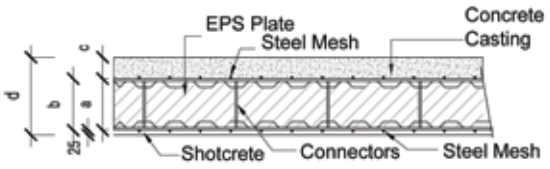


Single Panel for Internal partition, external walls and insulation

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



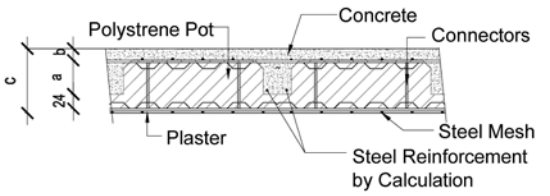
Single Panel for horizontal structure for floor/ roof

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

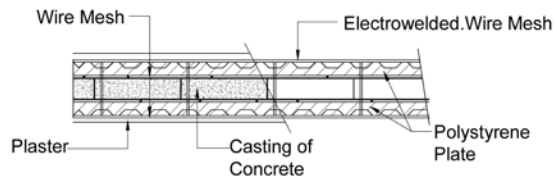
Longitudinal wire	2.5 mm ø spaced @ 70 mm	
Transverse Wire	2.5 mm spaced @ 70 mm	
Cross Steel Wire	3.0 mm ø approx. 68nos. /m^2	
Polystyrene Core	Density ≥ 15 kg/m^3	

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	

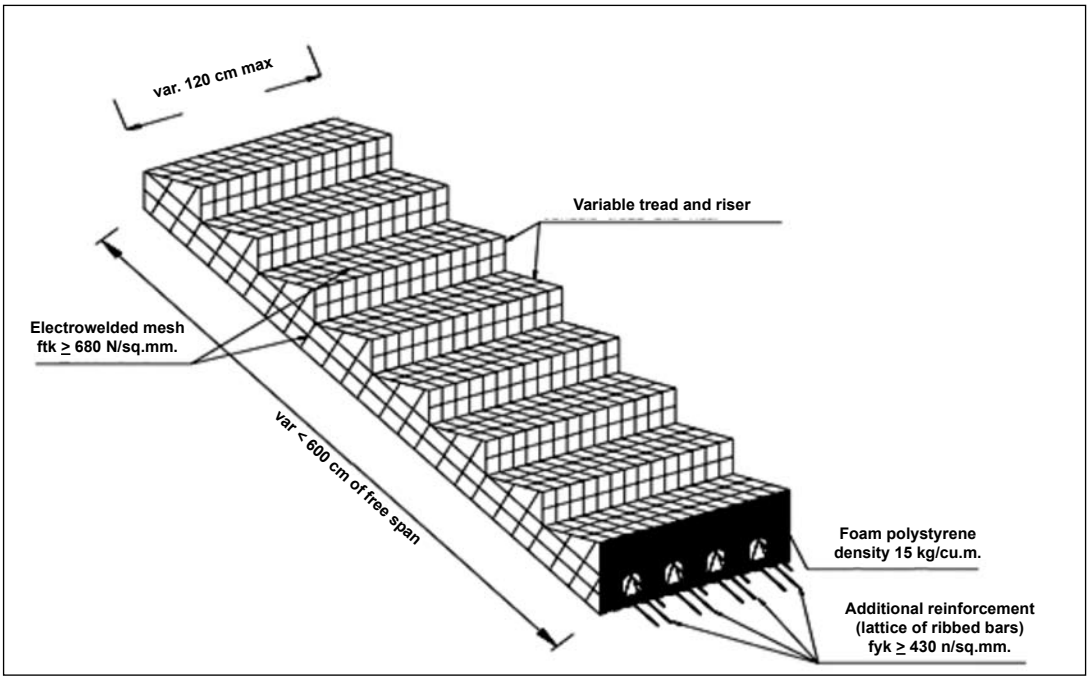
Internal mesh

Longitudinal wire	5 mm ø spaced @ 100 mm	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/m^3 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 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 carrying capacities 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.

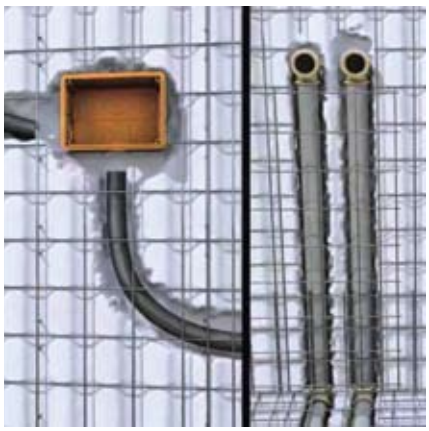
Versatility

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. The systems by any other agency may required to be verified, appropriately.

STANDARDS/REFERENCES

•	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.

Rapid Panels

(Suitable for Low Rise to Medium Rise Structures)

ABOUT THE TECHNOLOGY

The Rapid Panel is a prefabricated assembly of high-strength steel wire forming a panel with a core of expanded polystyrene (EPS). During construction, Rapid Panels are installed as walls and/or slabs. Specified mixtures of mortar or concrete are applied to the surfaces of the panels to complete the structure.

The basic unit of the Rapid Panel is the zig-zag truss. Steel wire is bent into a zig-zag shape to form a continuous chain of web members. This bent wire is then welded to continuous chord wires at every node to form the complete truss. *(See Figs. 1 & 2)*

The Rapid panels are manufactured in a fully automated plant. This technology was initially developed in USA and the Indian firm has a collaboration with WorldHaus, California, USA. These panels are manufactured in Mexico and there is no plant in India at present.

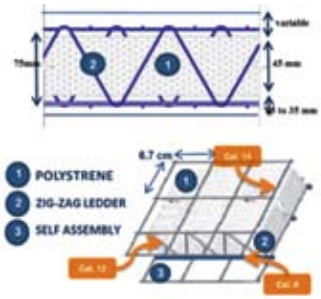


Fig. 1 Rapid Panel

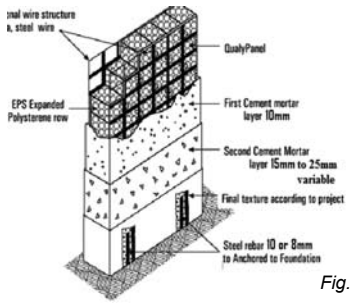
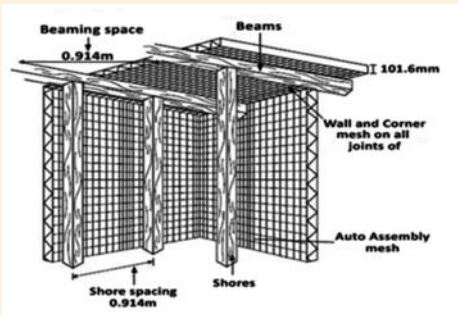


Fig. 2 Panel System Wall

PANEL TYPES

Wall panel

Top Wire	2.65 mm Ø
Top distribution wire	1.90 mm Ø
Truss wire	2.65 mm Ø
Bottom wire	2.65 mm Ø
Bottom distribution wire:	1.90 mm Ø
Chemical Composition	C < 0.153%, P < 0.016% S < 0.015%, Mn < 0.893%, Si % < 0.134
Galvanizing	Zinc coating of 60 gm/m^2 ± 5 gm/m^2
Mechanical characteristics: *1.9 mm dia* Yield stress Breaking load Elongation *2.65 mm dia* Yield strength Breaking load Elongation	 > 680 N/ mm^2, > 687 N/mm^2, > 4.8% >618 N/mm^2 >632 N/mm^2 > 6.1 %

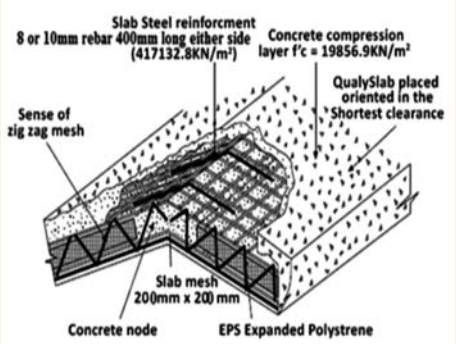


Wall Panel

Polystyrene Core	Density > 15 kg/m^3, Flammability: Non Flammable, Moisture Continent at 50ºC: <1.1% Thickness: not < 50 mm Bead size: shall be > 95% between 0.5 – 1.12 mm as per ASTM C 578	
Cast-in-place concrete	The min. grade of concrete is M20 and slump for walls, floors and roofs shall be as per IS 456:2000	
Cement Plaster	Shall have a minimum 28-day compressive strength	

Roof Panel

Top Wire	2.65 mm Ø	
Top distribution wire	1.90 mm Ø	
Truss wire	2.65 mm Ø	
Bottom wire	5.00 mm Ø	
Bottom distribution wire:	1.90 mm Ø	
Chemical Composition	C < 24%, P < 0.055% S < 0.055%, Ceq< 0.52%	
Galvanizing	Zinc coating of 60 gm/ m2 ± 5 gm/m^2	
Mechanical characteristics: *1.9 mm dia* Yield stress Breaking load Elongation *2.65 mm dia* Yield strength Breaking load Elongation 5.00 mm dia	 > 680 N/ mm^2, > 687 N/mm^2, > 4.8% >618 N/mm^2 >632 N/mm^2 > 6.1 %	
Yield strength Breaking load Elongation	670 N/ mm^2, 816 N/mm^2, > 14%	
Polystyrene Core	Density > 15 kg/m^3, Flammability: Non Flammable, Moisture Continent at 50ºC: <1.1% Thickness: not < 50 mm	



Roof Panel

MATERIAL REQUIREMENTS

Galvanised high strength steel wire: Fe 500 & Fe 550 as per IS 1786: 2008

Ordinary Portland Cement: 43 grade as per IS 269:2015.

Fine aggregate: 4.7 mm size for concrete as per IS 383:2016 and plaster of sand 150 micron – 2.36 mm as per IS 1542:1992

Coarse Aggregate: of 20 mm & 40 mm size as per IS 383:2016

Steel reinforcement: as per IS 1786:2008.

Gypsum Plaster board: as per IS 2095 (Part 1):2011.

Adhesive: as per ASTM C 881

Plasticizers: as per IS 9103:1999

Waterproofing compound: as per IS 2645:2003

Fibers: Polypropylene fiber mesh as per EN 14889-2:2006

Ledger Bolt: Consists of 12.7 mm diameter L-shaped bolt with washers and nuts as per ASTM A 307. It shall be fastened to the panel wire sand plastered.

Hartco clips: Formed from 11.11mm-wide, No. 20 gauge cold-rolled steel and manufactured by Stanley Hartco or Spenax Flex-C-Rings, No. 516 G100.

CONSTRUCTION PROCESS

The construction process of the panels is as follows:
The shop-fabricated panels consist of welded wire zig-zag trusses and a foam plastic core to which structure plaster shall be applied on each side. The panels have vertical 75 mm deep 14 gauge (1.63 mm) wire trusses spaced at 50 mm centers with preformed 57 mm thick expanded polystyrene (EPS) foam strips between. The assembly is held together with 14 gauge horizontal wires on each face at 50 mm centers electro welded to the truss chords. The horizontal wires and vertical truss chords shall project 10 mm approx. beyond each foam plastic face to permit wire embedment within cement and gypsum plaster finish applied to each face after erection on the site.

The panels are manufactured in 1.22 m widths and varying heights from 1.52 m to 3.55 m in increments of 100 mm. The nominal thickness of the panel is 75 mm resulting in a finished wall thickness, after plastering, of 100 mm or more.

Manufacturing Process of Rapid Panels

APPLICATIONS

The panels shall be used for construction of buildings consisting of frame structures, load bearing walls, floors and roof etc. for residential purposes up to G+3 storey.

IMPLEMENTATION

Panel System

Raft foundation

For only ground floor and G+1 unit constructions. When the soil is strong or when the soil is improved, this is done by using a slab/raft foundation.

Strip foundation

For only ground floor and G+1 unit constructions. When the surface soil is in a terrain with vegetation or lime, and it is required to locate the foundation in a stronger and deeper layer, this is done by using a strip footing.

Existing foundation

When a foundation already exists or when something is being constructed over existing construction, steps given below shall be followed:

(i) Holes of 8 or 10 mm dia. of 100 mm depth every 400 mm shall be drilled and lined up with inside of the wall.

(ii) High strength steel bars of 8 or 10 mm dia. shall be placed in every hole leaving 400 mm of height above the foundation.

(iii) The wall panel shall be tied with bars of 8 or 10 mm dia. on the outside of the mesh with steel wire, with a minimum of 3 ties per bar.

Boundary Wall

Following procedure shall be followed for construction of boundary walls:

(i) Bars of 8 or 10 mm dia shall be placed on top of the foundation, alternating one on the outside of the foundation and the other on the inside every 400 mm.

(ii) The bars that are placed on the inside shall be bent in such a way that they are rooted in the foundation.

(iii) The wall panel shall be located on the soil and plastered on the bordering side. They shall be placed in groups of two or three.

(iv) The mortar layer shall be dried, and the wall panel erected while straightening the interior bars.

(v) Finally, the wall panels shall be tied to the bars on both sides perfectly and plastered on the interior.

Wall Panels

Exterior wall panels shall be set with a minimum 6 mm clearance between the concrete slab edge and the panel reinforcement. The slab shall be attached with perimeter 63 mm-long by 3 mm thick steel hold-down connector channels and 13 mm diameter foundation bolts placed at a distance of 1.22 m max. centers along width and at each panel end. Panel reinforcement and connector channels shall be attached with 305 mm long, 12 gauge (2.06 mm) wires extending approximately 45 degrees upward along each panel face from each channel end. The upper end of the diagonal wires shall be attached to the panel reinforcement. Panels shall be joined along vertical edges with 203 mm wide strips of 14 gauge 51 square mm welded wire mesh on each face centered on the panel joint. The mesh shall be attached to the vertical panel wire reinforcement with Hartco clips spaced 305 mm on center at the edge wires and 610 mm on center at interior wire Panels shall also be joined on both sides with 14 gauge wire trusses).

Interior wall panels shall be set and attached to hold-down connector channels with 12 gauge wires in the same manner as exterior panels. Approved powder-actuated anchors shall be used, provided they are adequate for applicable uplift loads. A nonstructural plaster ground shall be attached at the base of the interior panels if desired.

Roof and Floor Panels

The panels shall not be permitted to bear on wood-frame walls. Horizontal diaphragms shall be permitted the same shear values as vertical racking shear, provided the panels are fastened to each other and to walls as described here.

Installation of Panels

The procedure for installing the panels shall be as follows:

i. The panels shall be put in place according to the building plan as follows:
   - It must be ensured that the rebar is on the bottom of the panel.
   - Each panel shall have a portion of wire mesh on the end without polystyrene.
   - The adjacent panel shall be inserted into this area thereby locking them together. The overlapping wire mesh should be tied together.
   - The vertical rebar in the wall shall be allowed to go through the polystyrene in the panels.
   - It shall be necessary to cut some of the wire mesh to allow this. The rebar on the bottom of the panel shall not be cut.

ii. The polystyrene in the areas directly over the walls shall be removed.

iii. The rebar that bends into the panels shall be placed according to the wall reinforcement and this bar shall be tied to the wire mesh on top of the panel. The vertical rebar shall be extended as necessary.

iv. The edge molds shall be placed around the perimeter of the panel as follows:
   - Each set of holes in the edge molds shall be tied tightly to the panel
   - It must be ensured that the edge molds are level and straight.
   - It must also be ensured that there is more than 50 mm clearance between the top of panels and top of edge molds.

vi. A minimum M20 grade of concrete shall be used.

Supports and Cambers

Slabs for roofs and floors shall be made with slab panels and supported during erection with temporary beams with props spaced at 900 mm, leaving a camber. The support beams shall be located on the bottom of the panel, always perpendicular to the direction of the zigzag trusses in the panel.

Connections

All the connections for walls and slabs shall use the self-connection system, where the mesh on the end of the panel shall be used to join the panels in different situations.

Door and Window

These shall be made by marking and cutting the mesh of the wall panel with a circular saw, reciprocating saw, or with wire cutters, and reinforcing the edges on both sides with zigzag mesh. The zigzag mesh should extend 300 mm from the edges of the doors and windows. Afterwards, diagonal zigzag mesh shall be installed on every corner of 400 mm.

Where edges and corners are reinforced, the polystyrene along the perimeter of the opening shall be removed and the space is filled with mortar or concrete to form a rigid boundary. In the area on top of the opening, the polystyrene shall be removed and reinforcing steel placed to form a lintel beam.

Plumbing and Electrical Fixtures

Water pipes and electrical conduits shall be placed within the panels as shown in the building plans by removing polystyrene from the portion. For layers pipes wire mesh shall be cut. Good practices of electrical and plumbing services shall be adopted.

Plumb and Alignment

It shall be assured that the wall panel is plumb and in line, and to maintain right angles between them, tension wire and metal rulers shall be used. The polystyrene in the center of the panel shall be toothed on the surface to ensure better mortar connection and less wastage.

Finishing

i. Floor finishing

- It must be ensured that the floor area is completely clear of any debris, dust and soil etc.
- It must be ensured that the floor surface is damp prior to finishing and it should be fully moist without any water stagnating on it.
- Cement mortar of mix 1 cement: 3 sand shall be prepared and required quantity of mortar shall be applied to the floor to provide a smooth finish.

ii. Ceiling finishing

- A stiff mix of 1 cement: 3 sand mortar shall be prepared and applied to the ceiling, providing a level but rough surface.
- It must be ensured that the first layer of plaster is damp prior to applying the finish layer.
- Cement mortar of mix 1 cement: 4 sand shall be prepared and required quantity of mortar shall be applied to the ceiling to provide a smooth finish.
- The total thickness of the ceiling finish should not exceed 19 mm below the panel wire mesh.

iii. Wall finishing

- Cement mortar of mix 1 cement: 4 sand shall be prepared and 25 mm plaster shall be applied to the predamp wall to give a finish surface.
- Wall plaster should be allowed to be cured for at least 7 days after placement.

Handling of Panels

These panels are composed of two layers of steel wire mesh with a layer of polystyrene in the middle. The bottom side of each panel has rebar welded in which provides the strength that allows the panel to be used as a slab. The wire mesh on the top and bottom are connected to each other with a 'zig-zag truss' of wire running between the two meshes, welded at each joint. Good practices for handling of the panels shall be followed.

Cutting of Panels

As the panels are manufactured in a few fixed sizes, it shall be necessary to cut the panels to a smaller size. The procedure for cutting of the panels shall be as follows:

- The length of the panel to be cut shall be measured and the measurement extended to the far-side of the nearest cross-wire.
- Bolt cutters shall be used to cut the wires along the measured length on one side of the panel.
- Panels shall be flipped to the other side and bolt cutters used to cut the wires along the measured length on the other side of the panel.
- Panels shall be allowed to stand on its end and bended to 90^{o} to expose the 'zig-zag truss'. The bolt cutter shall be used to cut the exposed wires.

SPECIAL FEATURES

Structural Stability

IIT Madras has certified that RapidPanel Roofing slab system is found satisfactory for use in buildings, for imposed loads (live loads) defined in IS 875 (Part 2):1987 on the basis of static tests under gravity loading.

Durability

On the basis of test conducted, the wall panel is capable of taking the min. load of 12.0 ton and no crack observed on the surface of the wall panel

Behavior in earthquake

Load bearing wall panel system acts as a continuous shear wall system. It is analyzed as per box section and additional vertical bars are fixed to the panels according to lateral analysis. Load bearing/shear wall panel system is being used for structures upto G+5 in high seismic areas (zone v) having poor soil conditions to provide an economical and robust structure that meets codal seismic design requirements.

Fire Safety

For one hour fire-resistive wall assembly, the panels are covered with 29 mm thick cement plaster on both sides. For two hour fire-resistive wall assembly, the panels are covered with 25 mm thick cement plaster followed by 12 mm thick light weight gypsum plaster or light weight cement plaster on both sides.

Thermal Performance

As per the tests conducted, the thermal transmittance U works out to 0.503 W/mK.

Shuttering

Rapid panel slab does not require conventional shuttering/formwork, as the EPS filler acts in this capacity.

Limitations of Use

- Panel lengths shall be up to 5 m, simply supported on beams or bearing walls not less than 125 mm in width.
- Panels shall be installed with min. M20 grade of concrete and 1:3 cement plaster.
- Total dead load (including panel self-weight) shall not exceed 3.3 kN/m^2
- Total imposed load (live load) shall not exceed 3.0 kN/m^2.

WORKS COMPLETED

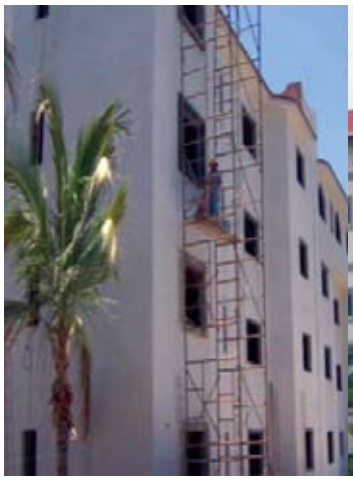
1. (GF) house at Sarjapura, Bangalore of 200 sqm area
2. (B+G) house at Coorg, Bangalore of 300 sqm area
3. (S+2) Nirmithi Kendra at Bangalore of 120 sqm area
4. (S+2+H) flat at Bangalore of 180 sqm area
5. (S+2) flat at Bangalore of 120 sqm area
6. CSI Church at Hosur, Bangalore of 350 sqm area
7. (G+2) flat at Bangalore of 120 sqm area
8. (G+3) flat at Bhubaneswar of 200 sqm area

CERTIFICATION

Performance Appraisal Certificate No. 1026-S/2016 issued to M/s Worldhaus Construction Pvt. Ltd., Bangalore by BMTPC.

STANDARDS/REFERENCES

• Legacy Report by ICC Evaluation Services Inc., USA	
• Construction Manual by WorldHaus Construction Ltd., USA	
IS 383:2016	Specifications for coarse and fine aggregates for concrete (Third Revision)
IS 456:2000	Code of practice for plain and reinforced concrete (Reaffirmed 2016)
IS 875 (Part 1&2):1987	Code of Practice for Design Loads (Other than Earthquake) for buildings & structures: Part 1 Dead Loads; Part 2 Imposed Loads (Reaffirmed 2013)
IS 1786:2008	Specifications for high strength deformed steel bars and wires for concrete reinforcement (Fourth Revision) (Reaffirmed 2013)
IS 1893 (Part 1):2016	Criteria for earthquake resistant design of structures (Part 1) - General Provisions and Buildings
IS 1904:1986	Code of practice for design and construction of foundations in soils: General requirements (Reaffirmed 2015)
IS 2095 (Part 1):2011	Specifications for gypsum plaster board (Part 1) - Plain gypsum plaster boards (Reaffirmed 2016)
IS 2645:2003	Specifications for integral water proofing compounds for cement, mortar and concrete (Reaffirmed 2016)



Reinforced EPS Core Panel System

(Suitable for Low Rise to Medium Rise Structures)

ABOUT THE TECHNOLOGY

Reinforced Expanded Polystyrene Core (EPC) Panel System is a factory produced panel system for the construction of low rise buildings upto G+3 and as filler walls in high rise RCC and steel frame buildings. In this technique, a core of undulated polystyrene is covered with interconnected zinc coated welded wire mesh on both sided reinforcement and shortcrete concrete.

The panels are finished on site by pouring concrete (double panel, floors and stairs) and spraying concrete to realise the following different elements of the system:

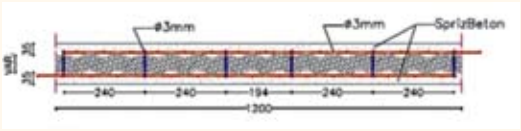
- Vertical Structural Walls
- Horizontal Structural elements
- Cladding elements

PANEL TYPES

The panels are of three types depending upon the application as shown below:

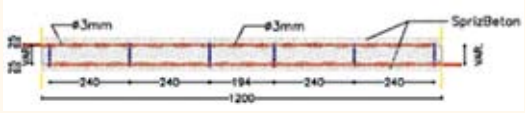
Single load bearing Panel

Longitudinal wires	2.5 /3.0 mm Ø @80 mm c/c
Transverse wires	2.5 /3.0 mm Ø @80 mm c/c
Connectors & cross wires	3.0 mm Ø @ 150 mm c/c
Polystyrene core conforming to IS 4671	Density : ≥ 15 kg/m^3 Thickness: 50 mm to 160 mm Wave Depth: 15 mm
Finished Masonry	Not less than 130mm thick



Single Non Load Bearing Panel

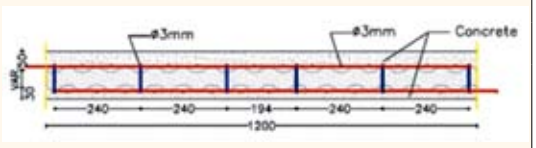
Longitudinal wires	2.5 /3.0 mm Ø @80 mm c/c
Transverse wires	2.5 /3.0 mm Ø @80 mm c/c
Connectors & cross wires	3.0 mm Ø @ 150 mm c/c
Polystyrene core	Density : ≥ 15 kg/m^3 Thickness: 40 mm to 280 mm Wave Depth: 5 mm
Finished Masonry	90 to 370mm thick



Single Floor Panel

Used as floors or roofs span upto 5 m x 5m and supported by the walls in all the sides. The panels are finished on site by 50 mm of casted concrete in upper side and 30 mm of projected plaster in the lower side.

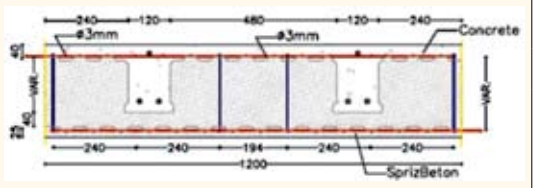
Longitudinal wires	2.5 /3.0 mm Ø @80 mm c/c
Transverse wires	2.5 /3.0 mm Ø @75 mm c/c
Connectors & cross wires	3.0 mm Ø @ 150 mm c/c
Polystyrene core	Density : ≥ 15 kg/m^3 Thickness: 80 mm to 160 mm Wave Depth: 5 mm
Finished Masonry	Not less than 80mm thick



Two Pot Floor Panel

With span up to 9 m, these panels are characterized by the presence of joist. The joists are reinforced on site by the steel bars according to the structural verification and are finished by 40 mm of casted concrete (M25) on the upper side and 25 mm of projected plaster (M15) in the lower side.

Longitudinal wires	2.5 /3.0 mm Ø @80 mm c/c
Transverse wires	2.5 /3.0 mm Ø @75/150 mm c/c
Connectors & cross wires	3.0 mm Ø @ 150 mm c/c
Polystyrene core	Density : ≥ 15 kg/m^3 Thickness: 40 mm to 280 mm Wave Depth: 5 mm
Finished Masonry	Not less than 65mm thick



MATERIAL REQUIREMENTS

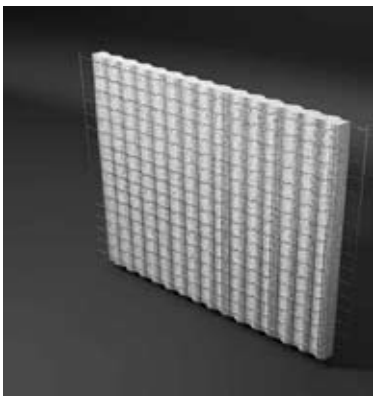
Steel for both wire mesh and connectors.
Zinc Coating – The zinc covering is variable with the diameter of the wire mesh. Standard wire mesh shall be 3.0 mm dia and minimum zinc coating galvanizing shall be of 60 gm/m^2.

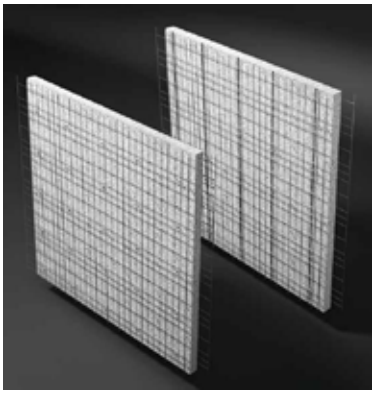
Mechanical characteristics

Tensile strength (2.5 mm Ø)	:	≮ 750 N/mm^2
Tensile strength (3.0 mm Ø)	:	≮ 700 N/mm^2
Yield strength (2.5 mm Ø)	:	≮ 680 N/mm^2
Yield strength (3.0 mm Ø)	:	≮ 600 N/mm^2
Elongation	:	> 8%

Chemical characteristics

% C	:	< 0.24
%P	:	< 0.055
%S	:	Max 0.045
%Ceq	:	<0.52
%Si	:	0.300 – 0.600





APPLICATIONS

The panels are used as:

i. load bearing walling in buildings
ii. non- load bearing wall panels
iii. partition infill wall in multi storey framed buildings
iv. floor / roof slabs

INSTALLATION PROCEDURE

Foundations

Foundations for the EPS Core Panel system whether strip or raft are conventional. If strip foundations are used, they should be levelled and stepped as this makes panel positioning easier.

For EPS Core panels, parallel sided timber or metal template of the width of panel shall be required to mark the position of the wall panels on the foundation and the spacing of the starter bar holes.

Wall start-up

- Line wall positions shall be marked and profiled.
- A timber or metal template of the exact width of panel (from wire to wire) shall be used to mark the position of the panels with chalk or pencil lines.
- On the panel, lines positions shall be marked to drill the starter bar holes. These should be in a zig zag pattern at 600 mm centres on each side of the panels. Starter bars should be at all panel joints and on the opposite side in mid panel plus at all wall corners and joints.
- Starter bars should be either 6 mm or 8 mm dia. 500 mm long with 100 mm drilled into the foundations and 400 mm above.
- Drill bits shall be used to give a tight fit with the starter bars.
- Once starter bars are in position, EPS Core panels shall be placed between the starter bars, starting from a corner. Starter bars shall be wire-tied to the panel mesh and the panels to each other on the overlapping mesh.

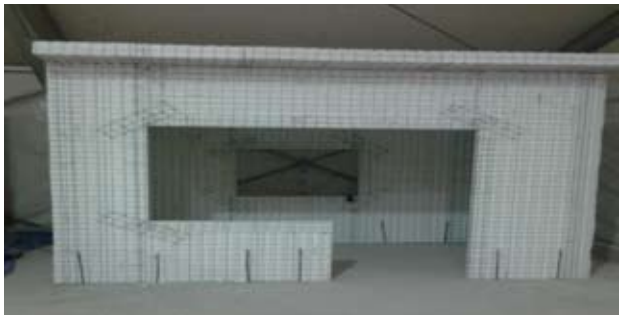
Wall construction

- All corners and wall joints shall be reinforced with right angled wire mesh to the full height of the walls.
- To cut panels to fit for door & window openings, wire should be cut with a wire cutter or angle grinder. Measure and mark the cut lines before starting to cut.
- After the wire mesh has been cut, EPS shall be cut with a hacksaw blade or stiff blade hand saw.
- Added steel mesh reinforcement shall be required around door and window openings to ensure that no plaster cracks form in these areas. Mesh reinforcement strips shall be tied diagonally with wire around openings before plastering.
- Once wall panels are in place and tied together, bracing shall be required to hold them vertical before plastering. This shall be done only on one side of the panels.
- Once the panels are plastered on one side, the wall bracing shall be removed after 24 h. Plastering on other side can be done without bracing.

Door and Window fittings

- Fix a metal angle iron or hollow tube sub frame into the openings before plastering. Fix and plaster these in place and then secure the frames to the sub frame.
- In order to secure heavy door/window frames, the EPS where the bolts are to be fixed to the wall, shall be

burnt or cut and this space shall be filled with mortar or concrete to hold the bolts.



Plastering

- Plastering shall be done by machine or hand. The indicative quantity of each material per m^3 shall be:
  (i) Cement: 350 kg
  (ii) Sand with mixed granulometry: 1600 kg. Sand should be without clay or any organic substance and totally washed.
  (iii) Water – 160 l. The quantity of water may be different according to the natural sand moisture. W/C = 0.52 and l/C = 4.50 shall be maintained.
- Any problem of workability should be solved without adding water. The retraction cracks formation may be avoided by adding polypropylene fibers in the mix (1kg/m^3).
- In order to control the final plaster thickness, some guides should be used. These shall be removed as soon as the plaster 'sets up' and the spaces are filled and are smoother before the plaster gets dry.
- Spray application should be done in two steps with a first layer covering the mesh applied on both the sides of the wall and the finishing layer as soon as the first layer gets dry.

Plumbing and electrical fittings

- Plumbing and electrical conduits shall be behind the panel wire mesh before plastering.
- The space behind the wire mesh shall be opened up by using a blow torch to partially melt the EPS along the lines of the conduits.
- As the EPS used in the panels is fire retardant, it will melt under the flame but not burn.
- The wire mesh shall be cut with wire clippers to make space for DB boards, switches and plug boxes.

Connection

The Reinforced EPS Wall system is composed by panels consisting of a polystyrene sheet assembled together with welded wire mesh.

SPECIAL FEATURES

Structural Stability

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, 2700 mm 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.

Durability

Durability is achieved with the use of proper grade and thickness of concrete as per IS 456. Minimum 45 mm thick plaster is recommended for structural and fire safety point of view.

Behaviour in earthquake

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.

Fire Safety

The quality of 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.

Thermal Performance

The thickness and density of the panel can be customized 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 80 mm core and finished thickness of about 150 mm provides the same thermal insulation as an insulated solid masonry wall of about 400 mm, with obvious advantages in terms of additional space

During finishing

After finishing

Acoustic Performance

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

Behaviour under high winds/Cyclone

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.

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.

Cost Effectiveness

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

Lightness, ease of transport and handling

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

MAJOR WORKS COMPLETED

At Angul, Odisha:

Load Bearing Structures

- Construction of C, D & F type flats of 3 to 4 storey having a total of 70 flats
- Construction of G type flats of 3 storey having a total of 60 flats
- Construction of Police Quarters of 3 storey having a total of 18 flats

Partition Walls for Non-load Bearing Structures

- Construction of C & D type flats of 3 to 4 storey having a total of 38 flats

CERTIFICATION

Performance Appraisal Certificate No. 1020-S/2015 issued to M/s Jindal Steel & Power Ltd., Angul, Odisha by BMTPC.

STANDARDS/REFERENCES

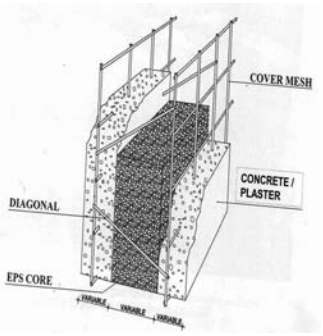
IS 456:2000	Code of practice for plain and reinforced concrete (Reaffirmed 2016)
IS 4671:1984	Specifications for expanded polystyrene for thermal insulation purposes

QuickBuild 3D Panels

(Suitable for Low Rise to Medium Rise Structures)

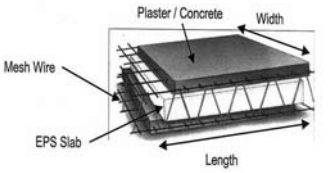
ABOUT THE TECHNOLOGY

In quick build 3 D Panel system, the panels consist of fire resistant grade insulated polystyrene core, two engineered layers of Galvanized Steel Mesh and galvanized steel trusses. The steel trusses are pierced through the polystyrene core and welded to the outer layer sheets of Galvanized steel mesh.



The wall panel is placed in position and a wythe of structural plaster is applied to both sides. The wall panel receives its strength and rigidity from the diagonal cross wires welded to the welded-wire fabric on each side. This combination produces a truss behavior, which provides rigidity and shear terms for a full composite behavior.

The shell of the structure is built by manually erecting the panels directly onto the slab with reinforcement rods. Desired utilities like doors, windows and ventilators may be pre-built while plumbing, electrical conduits may be added onsite.



These panels are used in the construction of exterior and interior load-bearing and non-load bearing walls and floors of buildings of all types of construction.

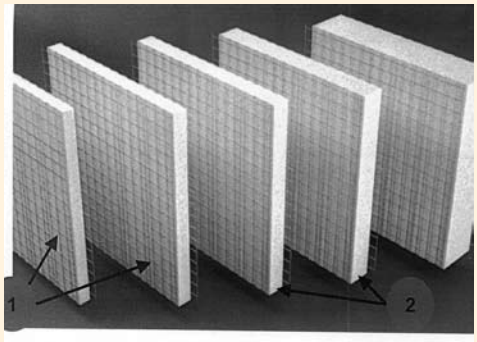
The details of these panels are shown in figures given at the right.

PANEL TYPES

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

Wall Panel

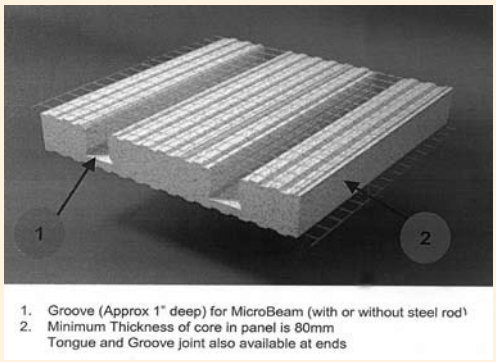
Longitudinal wire	2.5 mm Ø @ 50 mm
Transverse	2.5 mm Ø @ 50 mm
Steel truss wire	3.0 mm Ø pierced through the core at offset angle @ 100 mm spacing
Chemical Composition	C < 0.24%, P < 0.055% S < 0.055%, Ceq< 0.52%
Galvanizing	Zinc coating of 60 gm/ m^2 ± 5 gm/m^2
Mechanical characteristics: Yield stress Breaking load Elongation	 > 600 N/ mm^2, > 680 N/mm^2, > 8%
Polystyrene Core	Density > 15 kg/m^3 thickness 50/80/100 mm
Self-load	120 kg/m^2
Load bearing	350 kN/m
Plaster ratio: In two coats	1st coat of 20 mm of 1:2:3 (1 cement: 2 sand: 3 chips) 2nd coat of 10 mm of 1:5 (1 cement: 5 sand)



1. Various Mesh configurations and Wire diameters available
2. Various Polystyrene core thickness available

Roof Panel

Longitudinal wire	2.5 mm Ø @ 50 mm
Transverse	2.5 mm Ø @ 50 mm
Steel truss wire	3.0 mm Ø pierced through the core at offset angle @ 100 mm spacing
Chemical Composition	C < 0.24%, P < 0.055% S < 0.055%, Ceq< 0.52%
Galvanizing	Zinc coating of 60 gm/ m^2 ± 5 gm/m^2
Mechanical characteristics: Yield stress Breaking load Elongation	 > 600 N/ mm^2, > 680 N/mm^2, > 8%
Polystyrene Core	Density > 15 kg/m^3 thickness 50/80/100 mm
Self-load	280 kg/m^2
Load bearing	10 kN/m^2
Plaster ratio 30mm thick: In two coats	1st coat of 20 mm of 1:2:3 (1 cement: 2 sand: 3 chips) 2nd coat of 10 mm of 1:5 (1 cement: 5 sand)
Concrete 75 mm thick:	1:2:4 (1cement: 2 sand: 4 chips 50% of size < 18mm + 50% of size < 10mm)



1. Groove (Approx 1" deep) for MicroBeam (with or without steel rod)
2. Minimum Thickness of core in panel is 80mm
Tongue and Groove joint also available at ends

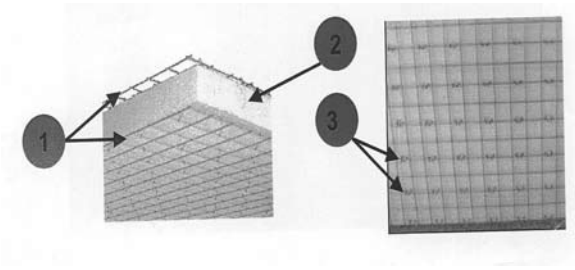
Staircase Panel

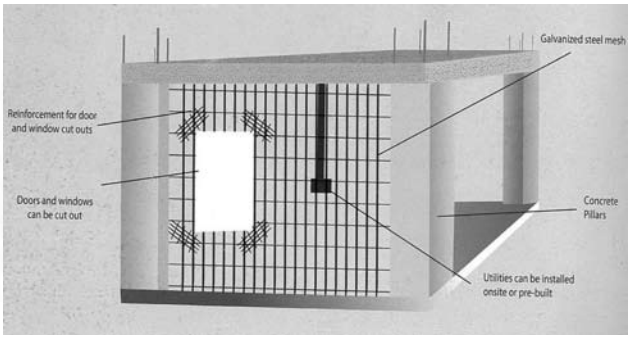
This panel consists of expanded polystyrene block shaped according to designing requirements and reinforced by a steel mesh. The block is joined by steel wire connectors welded in electro-fusion across the polystyrene core. These are used for the construction of flight of stairs up to a max span <6m having a live load of 4kN/m^2. The reinforcement steel bars have to be placed inside the holes before concrete casting.

Longitudinal wire	2.5 mm Ø @ 50 mm
Transverse	2.5 mm Ø @ 50 mm
Steel truss wire	3.0 mm Ø pierced through the core at offset angle @ 100 mm spacing
Chemical Composition	C < 0.24%, P < 0.055% S < 0.055%, Ceq< 0.52%
Galvanizing	Zinc coating of 60 gm/ m^2 ± 5 gm/m^2
Mechanical characteristics: Yield stress Breaking load Elongation	 > 600 N/ mm^2, > 680 N/mm^2, > 8%
Polystyrene Core	Density > 15 kg/m^3 thickness 50/80/100 mm
Self-load	280 kg/m^2
Load bearing	10 kN/m^2
Plaster ratio 30mm thick: In two coats	1st coat of 20 mm of 1:2:3 (1 cement: 2 sand: 3 chips) 2nd coat of 10 mm of 1:5 (1 cement: 5 sand)
Concrete 75 mm thick:	1:2:4 (1cement: 2 sand: 4 chips 50% of size < 18mm + 50% of size < 10mm)

MANUFACTURING PROCESS

QuickBuild 3D panel is manufactured from welded wire space frame integrated with a polystyrene (EPS) insulation core sandwiched between two layers of engineered galvanized steel mesh that are held together with steel trusses. Steel trusses are pierced through the polystyrene core and welded to the outer layer sheets of galvanized steel mesh to form a rigid panel.





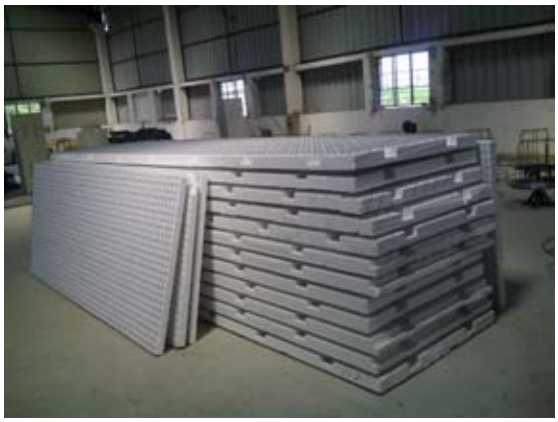
For any structure, foundation is built using conventional methods, starter bars are cast into the slab. The panels are erected vertical in plumb and temporarily supported by way of bracing Rebar which is set between the mesh and the polystyrene (for easy wall alignment). Splice meshes are then fixed using fasterner tool. Door & window openings can be cut both before or after panel erection. Roof panels are then erected and fastened with joining mesh. Concealed plumbing and electrical wiring can be pre-built into the panel using hot air torch. Subsequently, doors and windows are fixed. Structural plaster is finally applied pneumatically on both sides and concreting of exterior side of the roof panel is done. Natural Curing is done for concrete to gain strength.

FIXING OBJECTS TO WALLS

- Light weight object: 2.5 mm screws, pins or similar devices may be used.
- Heavy object (shelves, water tanks etc.): Plastic pins with 45 mm screws or similar devices are recommended.
- Very heavy object: During erection, metal pins may be inserted in plaster pallets. Alternatively, threaded pins fastened with epoxy resin may be used.

SPECIAL FEATURES

The panel receives its outer place strength and rigidity by truss action. Outer shortcrete layers are the chaired members.



Structural Stability

The monolithic structure of the panel in conjunction with concrete enables a structure built with it to withstand earthquakes, hurricanes and high winds.

For load bearing structure of G+3 or higher in seismic prone areas, analysis report from recognized Institute is recommended for its safety against earthquake forces.

Durability

- Concrete of adequate grade and cover as per IS 456:2000 provides required durability to this structure.

- Exterior coating may be applied to provide additional protection to the reinforcement against corrosion in aggressive environment.

Behavior in earthquake

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.

Water Tightness

Externally the walls shall be protected by an approved render applied to minimum 35 mm sprayed 25 MPa concrete. DPC/radar barrier shall be installed at ground level to prevent rising damp. DPC shall also be used around window sills and a sealant shall be applied around window or door frames.

Thermal Performance

QuikBuild panels are an efficient and thermally advantageous solution for all construction needs. These panels are the rigid foam insulation that provides long term thermal resistance that does not need to be adjusted for age.

Acoustic Performance

The panels have superior sound dampening capability compared to masonry walls and this can be further enhanced by increasing the core thickness. Up to 50 dB insulation.

Behavior in moisture/humidity

The panel is excellent for preventing condensation/absorption on interior walls. The external walls/roof can use waterproofing mortar for additional protection.

Optimize Energy Performance

- QuikBuild panels are an efficient and thermally advantageous solution for all construction needs. The panels are manufactured in varying thicknesses to meet the environmental design criteria to deliver a range of R-value specifications.

Recycled Content

- About 10% to 20% of the materials are recycled.

PRECAUTIONS

- Do not overload partition walls on one side only. Instead, spray the concrete on both sides alternatively
- If the panel is cut during erection and its meshwork has no wire-crossing points, panels should be joined with flat meshwork (min. width 225 mm)

APPLICATIONS

- The technology is used in the construction of exterior and interior load-bearing walls upto 3 storeys and non-load bearing walls and floors of buildings of all types of construction.

MAJOR WORKS COMPLETED

- Christ College, Kilacherry (T N) in February 2012
- Meridian Hotel, White Field, Bangalore in May 2013
- Bethany School, Koramangalka, Bangalore in October 2013
- Sure Energy Systems Pvt. Ltd., Hyderabad (AP) in November 2013
- VTRC Ponmeni, Madurai (TN) in December, 2013
- Vineetha Industries, Adugodi, Bangalore in January 2014
- SERC Taramani, Chennai (TN) in February 2014
- VME Reality, Chembarabakkam (TN) in May 2014
- KPCL Wood House, Kovalam (TN), August 2014
- Champs Empowering Education, Hyderabad (AP) in August 2014

CERTIFICATION

Performance Appraisal Certificate No. 1019-S/2015 issued to Beardsell Ltd, Chennai by BMTPC.

STANDARDS/REFERENCES

• Axial Compression Test and Static Flexural Test on Panels as Wall elements and Roof or Slab elements respectively by IIT Madras	
• Pull off test on plastered surface of structural concrete insulated panels at Bangalore by Civil-Aid Technoclinic Pvt. Ltd. Bangalore	
• Report on Shaking Table Test of a 1:2.35 Scale 4-Story Building Constructed with 3D Panel System University of Technology, Iran.	
IS 456:2000	Code of practice for plain and reinforced concrete (Reaffirmed 2016)
IS 875 (Part 1):1987	Code of Practice for Design Loads (Other than Earthquake) for buildings & structures: Part 1 Dead Loads (Reaffirmed 2013)

Concrewall Panel System

(Suitable for Low Rise to Medium Rise Structures)

ABOUT THE TECHNOLOGY

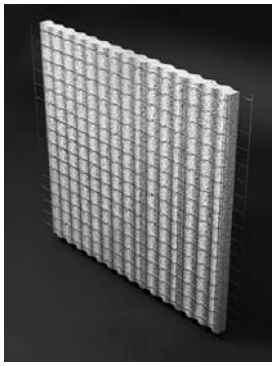


Fig.1: Single (core)

The Concrewall System is an industrial system for the construction of structural walls of reinforced concrete for building in single panel up to G+3.

The system is composed of a factory produced panel of undulated (wave shape) polystyrene covered on both sides by an electro-welded zinc coated square mesh of galvanized steel and linked by 40 connectors per sq m made of high-elastic-limit, 3 mm dia wires realizing a 3 dimensional hyper-static reinforced steel. (Figs 1 & 2)

The panels are assembled on site and in-situ concrete (double panels, floors, stairs) and shotcreted concrete sprayed (single panel) to realize the following different elements of the system:

- Vertical structural walls
- Horizontal structural elements
- Cladding element
- Internal walls.

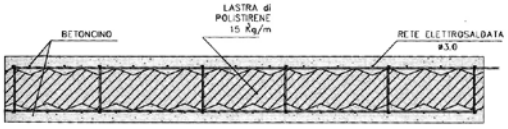


Fig.2: Cros-section

PANEL TYPES

Single Bearing Panel – Used as Load Bearing Wall

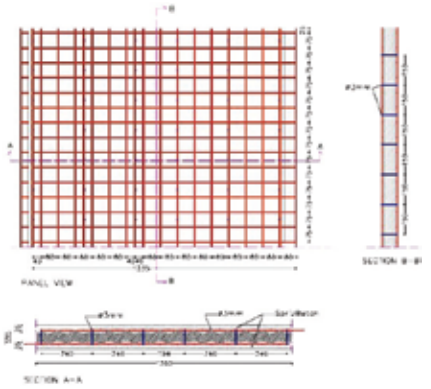


Fig. 3 Single Bearing Panel

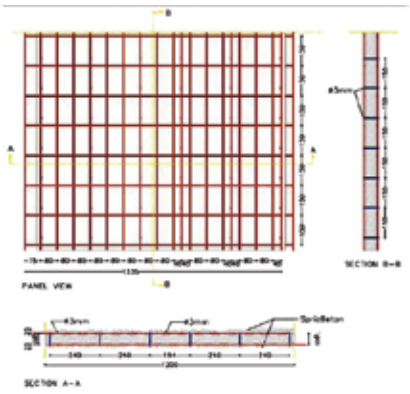


Fig. 4 Single Non-load Bearing Panel

Mesh

Width	: 1235 mm
Longitudinal wires	: 2.5/3.0 mm ø @ 80 mm c/c (max)
Transverse wires	: 2.5/3.0 mm ø @ 75 mm c/c (max)
Connectors & cross wire	: 3.0 mm ø @ 150 mm c/c

EPS

Density	: ≥ 15 kg/m^3
Thickness	: 40 mm to 240 mm
Wave Depth	: 15 mm

Single Non Load Bearing Panel

Mesh

Width	: 1235 mm
Longitudinal wires	: 2.5/3.0 mm ø @ 80 mm c/c (max)
Transverse wires	: 2.5/3.0 mm ø @ 75 /150 mm c/c (max)
Connectors & cross wire	: 3.0 mm ø @150 mm c/c

EPS

Density	: ≥15 kg/m^3
Thickness	: 40 mm to 280 mm
Wave Depth	: 5 /15 mm

Single Floor Panel

Used as floors or roofs span upto 5 m x 5m and supported by the walls in all the sides. The panels are finished on site by 50 mm of casted concrete in upper side and 30 mm of projected plaster in the lower side.

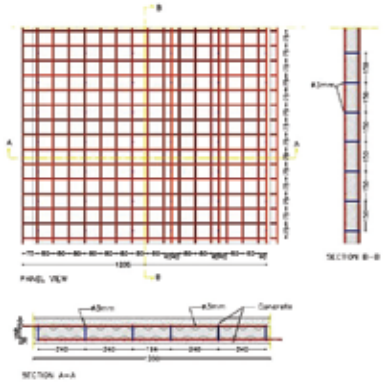


Fig. 5 Single Floor Panel

Mesh

Width	: 1235 mm
Longitudinal wires	: 2.5 / 3.0 mm ø @ 80 mm c/c
Transverse wires	: 2.5 / 3.0 mm ø @ 75 mm c/c
Connectors & cross wire	: 3.0 mm ø @ 150 mm c/c

EPS

Width	: 1200 mm
Thickness	: 80 mm to 200 mm
Density	: ≥15Kg/m^3

Floor Panel with Joists

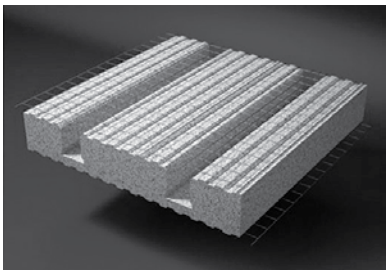


Fig. 6 Floor Panel with Joists

Galvanized steel wire mesh

Longitudinal wires	: 2.5 mm ø every 70 mm
Transversal wires:	: 2.5 mm ø every 70 mm
Cross steel wire:	: 3.0 mm ø (approx. 68 per m^2)
Polystyrene slab density	: ≥15 kg/m^3

This panel is used for the floor and the roof system and it is 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.

These are suitable for slabs having spans up to 8 m and with live loads up to 4 kN/m^2.

MATERIAL REQUIREMENTS

Raw Materials

- Steel for both wire mesh and connectors
  Zinc Coating – The zinc covering is variable with the diameter of the wire mesh. Standard wire mesh shall be of 2.5/3.0 mm ø and zinc coating galvanizing shall be of 60/90 gm/m^2 with a tolerance of ± 5 gm/m^2.

Mechanical characteristics

Tensile strength (2.5mm ø)	: 750 N/mm^2
Yield strength (2.5mm ø)	: 680 N/mm^2
Tensile strength (3.0mm ø)	: 700 N/mm^2
Yield strength (3.0mm ø)	: 600 N/mm^2
Elongation	: > 8%

Chemical characteristics

% C	: < 0.24
% P	: < 0.055
% S	: < 0.055
% Ceq	: < 0.52

- ***Expanded Polystyrene*** – Self-extinguishing type EPS in accordance with IS 4671:1984 (UNI EN 13163:2013) having density not less than 15 kg/m^3.

PRODUCTION PROCESS

Concrewall Panels of different dimensions are produced with two raw materials namely steel wire in coils and polystyrene blocks.

1. *Galvanized wire:* It includes the following phases:
   - Perfect straightening and cutting of the required wires
   - Assembly by electrical welding of the wires of different dia to make mesh of pre-established lengths

2. *Polystyrene blocks EPS:* The most complete hypothesis shall include the following:
   Shape the dried blocks and cut sheets of a specific form and dimension according to the final type of product. The possible scraps are grounded and recycled, within certain limits, in the production of EPS blocks on the condition that these are first cleaned and are without any foreign substance, with particular attention to the presence of dust.

3. *Assembly:*
   Assembly of the Concrewall panel shall be made by electro-welding no.6 wires (in transversal and perpendicular position with respect to the panel surface) with two meshes, forming a sandwich including the EPS sheet between these, which has been previously inserted.

4. Operations 'out of line':
   The production line is complete after cutting and bending of the external overlapping meshes.

INSTALLATION PROCEDURE

1. Foundations

Where Foundations for the Concrewall System are used, they should be levelled and stepped as this makes panel positioning easier.

For concrewall panels, parallel sided timber or metal template of the width of panel shall be required to mark the position of the wall panels on the foundation and the spacing of the starter bar holes.

2. Wall start up

- Line wall positions shall be marked and profiled.
- A timber or metal template of the exact width of panel (from wire to wire) shall be used to mark the position of the panels with chalk or pencil lines.
- On the panel lines, positions shall be marked to drill the starter bar holes. These should be in a zig zag pattern at 600 mm centres on each side of the panels. Starter bars should be at all panel joints and on the opposite side in mid panel plus at all wall corner joints.

- Starter bars should be either 6mm or 8 mm dia, 500 mm long with 100 mm drilled into the foundations and 400 mm above.
- Drill bits shall be used to give a tight fit with the starter bars.
- Once starter bars are in position, place the Concrewall panels between the starter bars starting from a corner. Starter bars shall be wire-tied to the panel mesh and the panels to each other on the overlapping mesh.

3. Wall construction

- All corners and wall joints should be reinforced with right angled wire mesh to the full height of the walls.
- To cut panels to fit for door & window openings, wire should be cut with a wire cutter or angle grinder. Measure and mark the cut lines before starting to cut.
- After the wire mesh has been cut, EPS shall be cut with a hacksaw blade or stiff blade hand saw.
- Added steel mesh reinforcement shall be required around door and window openings to ensure that no plaster cracks form in these areas. Mesh reinforcement strips shall be tied diagonally at every corner of openings before plastering.
- Once wall panels are in place and tied together, bracing shall be required to hold them vertical before plastering. This shall be done only on one side of the panels.
- Once the panels are plastered on one side, the wall bracing shall be removed after 24 hours. The panels are now sufficiently stiff so that plastering on other side can be done without bracing.

4. Door and Window fittings

- Before plastering metal 'cliscoe' type window and door frames (which should be sized to the width of the panels) may be fitted into the pre-cut panels.
- Metal 'cliscoe' type window frame fitted into future house panel before plastering.
- Metal lugs from the back of metal frames shall be wire tied to the panel mesh to keep the frames in position.

For any other kind of frames, suitable method in accordance with the manufacturer's specifications may be used.

5. Plastering

- Plastering shall be done by machine or hand. The indicative quantity of each material per cum. should be as follows:
- Cement: 350 kg
- Sand with mixed granulometry: 1600kg. Sand should be without clay or any organic substance and totally washed.
- Water – 160 litres. The quantity of water may be different according to the natural sand humidity. The parameters that should be constant are: W/C = 0.52 and I/C = 4.50.
- Any problem of workability should be solved without adding water. The retraction cracks formation may be avoided by adding Polypropylene fibers in the mix (1kg/m^3).
- In order to control the final plaster thickness, some guides should be used. These shall be removed as soon as the plaster 'sets up' and the spaces are filled and are smoother before the plaster gets dry.
- Spray application should be done in two steps with a first layer covering the mesh applied on both the sides of the wall and the finishing layer as soon as the first layer gets dry.

6. Roof/floor panel

- After the vertical panels are assembled, verticality of the walls should be checked and the bending meshes positioned on all the corners. Thereafter, horizontal bending meshes shall be placed to connect the floor/roof to the vertical panels. The bending meshes should be fixed throughout the perimeter of the floor/roof, at the level of intrados.
- When the horizontal bending meshes are fixed and checked floor/roof panel shall be placed on these.

The lower mesh of the panel shall be fixed by steel wire to the bending meshes.

- Between the edges of floor/roof panel and vertical panel, gap of 35 mm should be left to ensure structural continuity. The plaster applied on the walls shall be continued from one level to another level.

Placing of the Concrewall elements for the floor and/or roof should be done before the application of the external layer of plaster on the walls. Casting of concrete on the floor/roof panels (after placing the additional reinforcing bars, if required) should be done after the walls are plastered and a number of props shall be put to limit the deformation of the panel.

7. Plumbing and electrical fittings

- Plumbing and electrical conduits shall be behind the panel wire mesh before plastering.
- The space behind the wire mesh shall be opened up by using a blow torch to partially melt the EPS along the lines of the conduits.
- As the EPS used in the panels is fire retardant, it will melt under the flame but not burn.
- The wire mesh shall be cut with wire clippers to make space for DB boards, switches and plug boxes.

ADVANTAGES

Fast Construction
The speedy construction represent additional savings.

Design Flexibility
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.

Ease of Use
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.

LIMITATION OF THE TECHNOLOGY

Economical for mass housing only.

SPECIAL FEATURES

Structural Stability
The System receives its outer plane strength and rigidity by truss action where the shotcrete layers are the chord members.

Durability
Durability shall be in accordance with IS 456:2000 which specifies exposure conditions, concrete strength and cover requirements

Behavior in earthquake
Being light in weight, earthquake forces are less in the structure. With proper design and detailing, the structure can be made safe.

Fire Safety
During the fire ignited inside the building (temp. raised up to 163°C), no distress/distortion of panels was observed in any part of the unit except breaking of a window glazing.

Water Proofing

No dripping or leakage of water through slab during 24 h of ponding was observed except for minor damp patches on the ceiling at few places.

The inner face of the wall was observed to be free from which was found to be within the permissible limits dampness or sweating during 10 h of jetting at regular intervals of 30 min.

Thermal Performance

The reduction in outside and inside temperature was recorded up to 5.8°C indicating a good thermal comfort.

Acoustic Performance

Sound intensity was measured outside and inside the unit to know the difference in sound levels using sound level meter. The results showed reduction of sound level by 35dB indicating a good acoustic comfort.

Behavior under high winds

The design of roof to wall connections shall be to a specific design to ensure that the roof structure is properly restrained against uplift.

WORKS COMPLETED

Following 3 plants in India have been set up using Schnell Machineries

- West: Maad Constructions Co Ltd, Pune, Maharashtra
- East: Jindal Steel & Power Ltd, Angul, Odisha
- North: Synergy Thryslington, Mohali, Punjab

Buildings Constructed

- Industrial Township at Angul, Odisha
- Mass Housing, G+3 Buildings, at Vasai, Maharashtra
- Hostel & Hospital Buildgins in Punjab & Himachal Pradesh
- Anganwadi Buildings across India by Vedanta Group
- In-fill Wall used in different regions

Use with Other Systems

- In-fill Walls for Steel-frame & Floor Buildings
- Use with Al/Plastic Monolithic Formwork

CERTIFICATION

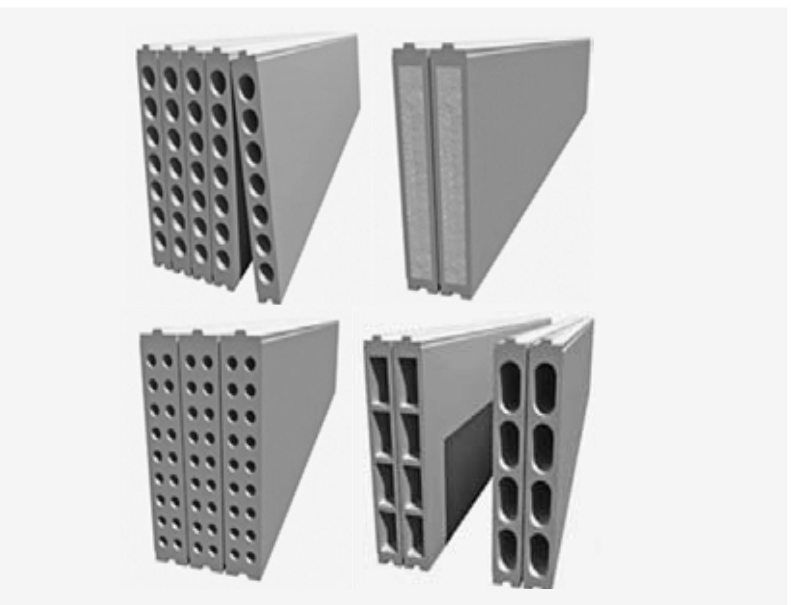
Performance Appraisal Certificate No. 1031-S/2017 issued to M/s Schnell Home, Italy by BMTPC.

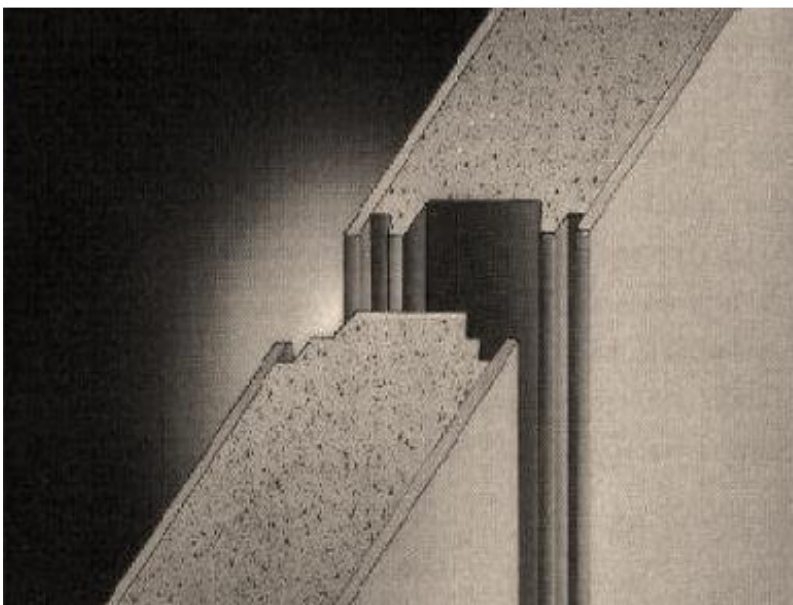
STANDARDS/REFERENCES

IS 456:2000	Code of practice for plain and reinforced concrete (Reaffirmed 2016)
IS 4671:1984	Specifications for expanded polystyrene for thermal insulation purposes
BS 476(Part 22):1987	Fire resistance

Precast Sandwich Panel Systems

Other Systems





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°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.

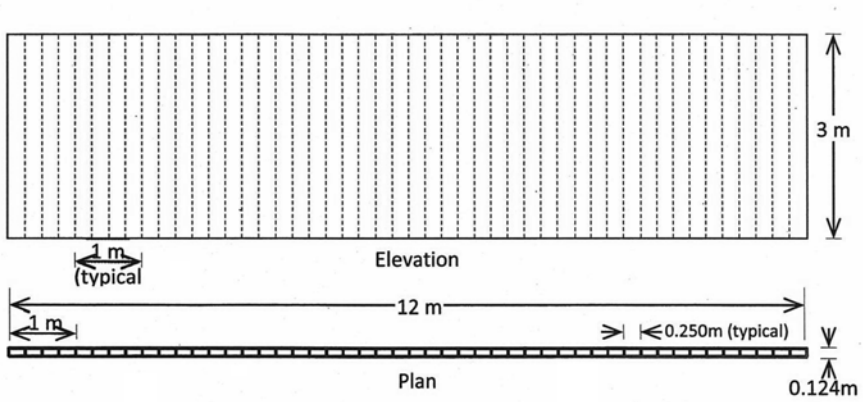
ii) As partition walls in multi storeyed frame buildings. Panels can also be filled suitably. Such walls can also be used as cladding for industrial buildings or sport facilities etc.

iii) As compound walls / security walls.

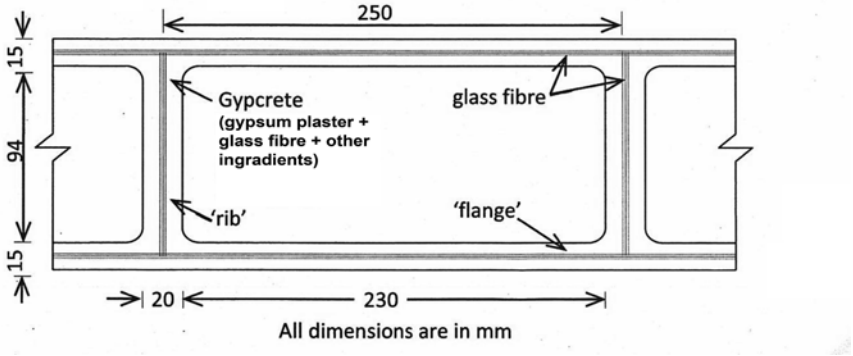
iv) As horizontal floor slabs / roof slabs with reinforced concrete micro beams and screed (T-beam action). This system can also be used in inclined configuration, such as staircase waist slab and pitched roofing.

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, $\mathbf{E_G}$	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

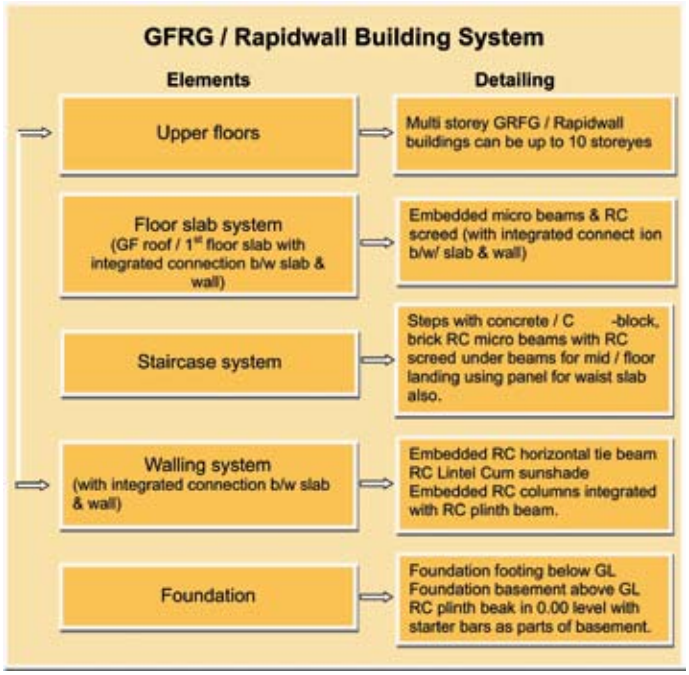
DESIGN

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/UNDER CONSTRUCTION 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.
- Demonstration houses (36 DUs) at Nellore, Andhra Pradesh.
- Construction of IIT Tirupati Building at Tirupati.

CERTIFICATION

- 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.

REFERENCES

• 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.	
IS 3809:1979	Fire Resistance Test of Structures

Prefabricated Fibre Reinforced Sandwich Panels (Aerocon)

(Suitable for Load Bearing Panels in Single Storey and as Non-Load Bearing Panels for Low to High Rise Structures)

ABOUT THE TECHNOLOGY

Aerocon panels are Prefabricated Fibre Reinforced Sandwich Panels, made of two fibre reinforced cement facing sheets, on either sides of a lightweight concrete core. The core is made from a mix of Portland cement, binders and silicaceous & micaceous material aggregate. These panels have a unique tongue and groove jointing system that facilitates rapid construction and are fully cured at the factory itself. These panels are of manufactured by using Flexo Board (FOB)/ Fibre Cement Board (FCB). Details of these panels are shown in Figs. 1 to 3:

Fig.1

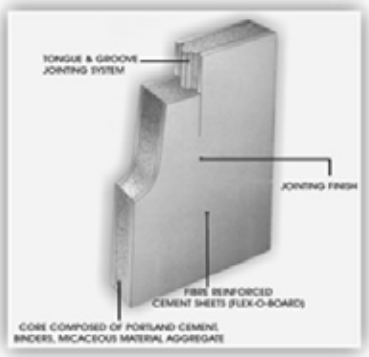


Fig.2

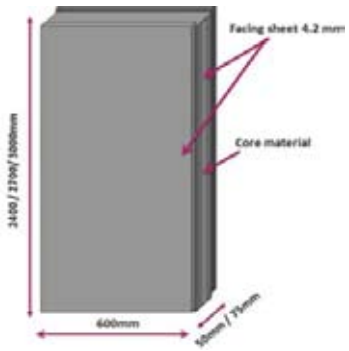


Fig.3

The product range of these panels shall be as under:

S. No	Sizes	Thickness	Edges
1.	2400 mm height x 600 mm width	50 mm & 75 mm	Square edge (Fig. 4) Recess edge (Fig. 5)
2.	2700 mm height x 600 mm width		
3.	3000 mm height x 600 mm width		

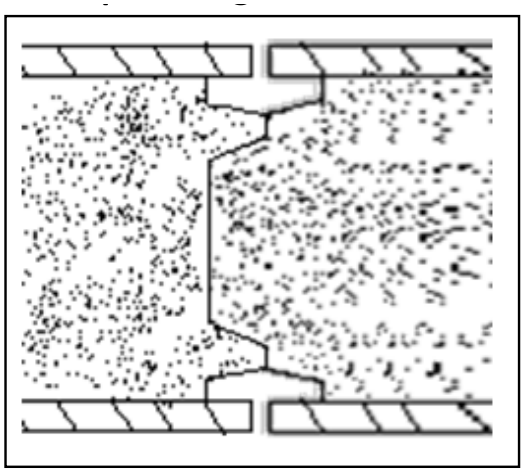


Fig.4 Square edge Panel

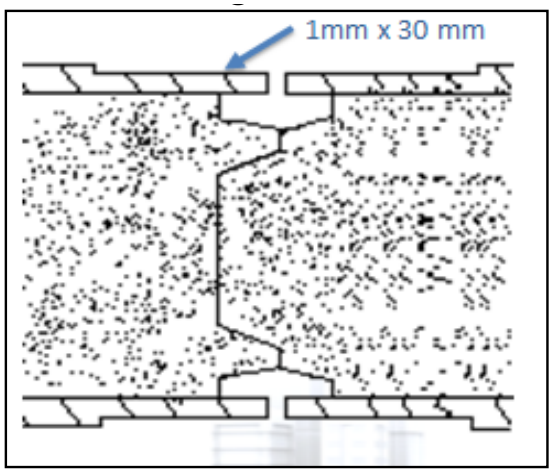


Fig.5 Recess edge Panel

USES OF AEROCON PANELS

These panels may be used for following applications:

- Partitions - In Offices, malls, educational institutions, hotels/restaurants, Residential, commercial, educational and industrial buildings
- Prefab Structures (Single story- as load bearing & Non-load bearing applications)- Accommodation units, site offices, security & store rooms, warehouse/go-downs, schools, army barracks, low-cost housing
- Mezzanine Flooring - Industrial/SEZ, warehouse/go-downs, storerooms, shopping malls, etc.
- Cladding - Shopping malls, school/college/university, duct covering, site offices & administration offices
- Boundary/Fencing - Residential, commercial, defence, etc.
- Fire Separation walls - Shopping malls, hotels, stair case enclosures etc.

MANUFACTURING PROCESS

Prefabricated Fibre Reinforced Sandwich Panels are made up of two fibre reinforced cement sheets with a core separating sheets. The core of the panels is of binders like portland cement and reinforcing bars such as cellulose and synthetic binders. The core contains materials such as pulverized fly ash, light weight aggregates as fillers and foaming agents. These materials are mixed thoroughly with water in conventional manner and sandwiched between a pair of fibre cement facing sheets which is separated and supported by using conventional jigs and fixtures.

The adhesion between the core material and fibre cement sheets is achieved by inorganic bonding by aeration while manufacturing the panel in-situ. The panels are allowed to harden for a predetermined period and thereafter jigs/ fixtures are separated. The panels are cured by retaining the humidity of the composite by wrapping the composite with polymeric films. No water is used for curing.

TECHNICAL SPECIFICATION

S. No.	Properties	Test Method	Requirements *			
			50 mm thick		75 mm thick	
			FOB	FCB	FOB	FCB
1.	Weight (dry) (kg/m^2)	Nominal weight	39	38	54	51
2.	Axial load (kN/m)	Factor of safety = 2.5	53	50	83	65
3.	Bending (kg/m^2) (a) 1.5m span (b) 2.9m span	Factor of safety = 2.5	 66 198	 -- 300	 95 265	 -- 400
4.	Flexural strength (kg/cm^2)	IS 2380 (Part 4):1977	67	42	58	48
5.	Compressive strength (kg/cm^2)	Typical test results	30	--	40	--
6.	Thermal conductivity (W/m°.K)	IS 3346:1980/ BS 4370 (Part 2): 1993	0.22	0.16	0.21	0.17
7.	Sound transmission class (dB)	IS 9901 (Part 3): 1981/ IS 11050 (Part 1):1984	34	37	37	39
8.	Fire resistance (minutes)	IS 3809:1979/ BS 476 (Part 20-22):1987	60	120	120	120
9.	Surface spread of flame	BS 476 (Part 7): 1997	Class I		Class I	
10.	Fire propagation index (I)	BS 476 (Part 6): 1989	3.7	4.7	3.7	4.7
11.	Ignitability	BS 476 (Part 5): 1979	Class P (not easily ignitable)		Class P (not easily ignitable)	

** The above requirements are the minimum values for the panels.*

INSTALLATION OF PANELS APPLICATIONS & JOINTING PROCEDURE

Partition Walls

Full height partition

- Recess or square edge panels shall be used for full height partitions.
- Floor plan shall be marked as per approved drawings. The floor channels (F.C.) & ceiling Channels shall be used for fixing of panels with self-expansion screws of size N 6x50 mm at every 600 mm center to center on 50 mm face of channel.
- The height needs shall be checked for each individual panel before inserting, the same method shall be followed for all panels.
- The 600 mm side of panel shall be lifted & kept parallel to floor. The groove side of panel shall be kept towards wall or column end.
- The panel shall be inserted by tilting it into ceiling channel first and then position the same from 14 mm side of the floor channel as shown in Fig. 6.
- The panel shall be slowly pushed into the floor channel with two heavy duty screw drivers without damaging the corners as shown in Fig. 7.
- The panel shall be positioned & pushed towards wall and right angle of panel shall be checked as shown in Fig. 8.
- Plugs/packings shall be inserted, if required in floor channel to ensure right angle.
- The jointing material shall be applied along entire length of tongue and groove for jointing and inserting the next panel. The panel shall be pushed to secure a rattle free joint.
- The partition shall be completed by jointing panel by panel as per the above procedure.

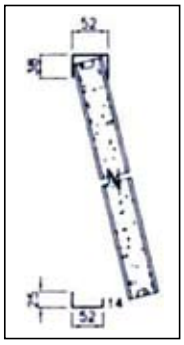


Fig.6

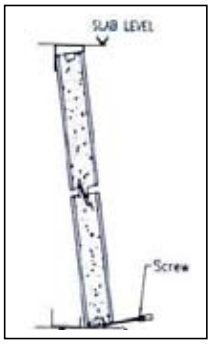


Fig.7

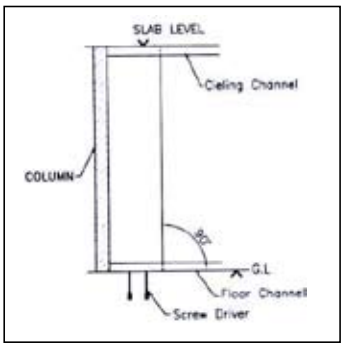


Fig.8

Half height partition

- The partitions shall always end in 'L' or 'T' shape of 300 to 600 mm panel width as shown in Fig 9.
- The floor channel shall be fixed with self -expansion screws at every 600 mm center to center.
- The first panel starting from the existing brick wall should be fixed as per the following two options:
  Option – 1 Starting with existing brick wall, a drill shall be made to brick wall and panel at the distance of 300 mm as shown in Fig. 10 from top and bottom side of the panel and insert the steel rod.

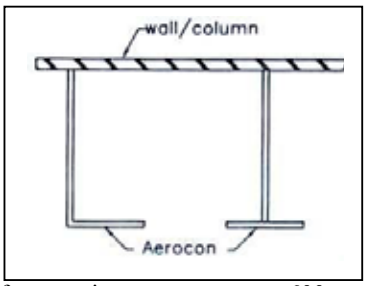


Fig.9

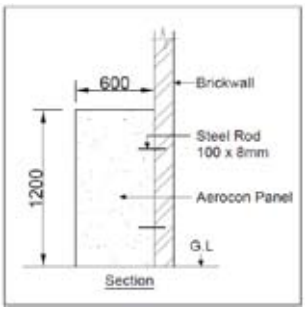


Fig.10

Option – 2 The L angle cleat shall be fixed at corner with nuts and bolts as shown in Fig. 11.

- The top end & free end walls must be covered using beading as shown in Fig. 12.
- Different materials like timber, medium density fibre boards, PVC, Aluminium etc. as per required design shall be used as shown in Fig. 13.
- Fevicol shall be applied on the inner surface of the beading before fixing to the panels.
- All screws should be dipped in Fevicol before fixing to the beading. In factories and workshops Aluminium/ galvanized iron channels (ceiling channel) shall be used as beading.
- Jointing material shall be applied on entire length of tongue & groove portion before fixing panels to improve stability & prevent the lateral movement.
- With this half height partition will be ready for finishing.

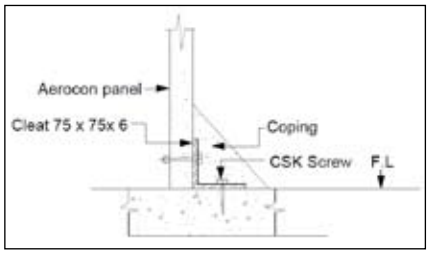


Fig.11

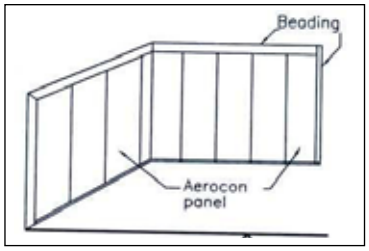


Fig.12

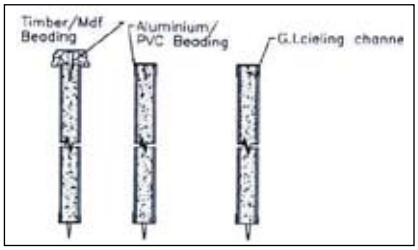


Fig.13

Jumbo height partitions (above 3.0m)

- Panel partition work can be done without steel frame up to 4.50 m height & 4.80 m width.
- Frame work shall not be required for these type of partitions up to 4.5 m.
- Panels shall be staggered for strength & rigidity as shown in Fig. 14. Height of the panels shall be decided accordingly.
- Partition shall be supplied with top support, such as steel, concrete etc.
- The floor & ceiling channel shall be fixed as per laid procedure.
- For horizontal joining, the full length panel shall be fixed first and jointing material shall be applied in the groove portion.
- Hexagonal PVC/wooden beading shall be placed on top groove of the 3 m panel before placing the 1.5 m panel and the same pushed into the ceiling channel as shown in Fig. 15.
- The 1.5 m panel should come next in lower side and 3 meter panel in upper side & proceed in the similar way. The partition shall be completed by fixing panels one by one as per the above procedure. For joint finishing of panels, Clause 2.3.2.7 may be referred.
- If the partition exceeds 4.50 m length and 4.80 m width, then steel support shall be provided as shown in Fig.16.

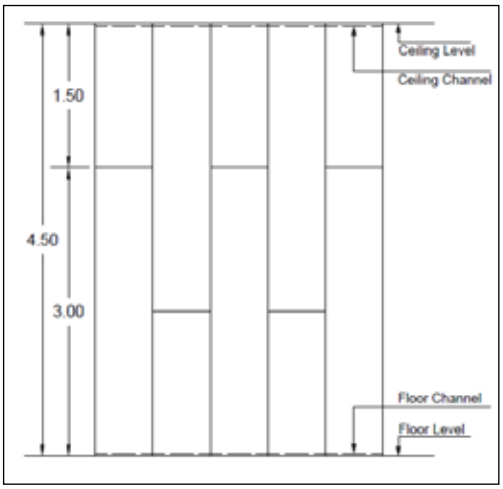


Fig.14

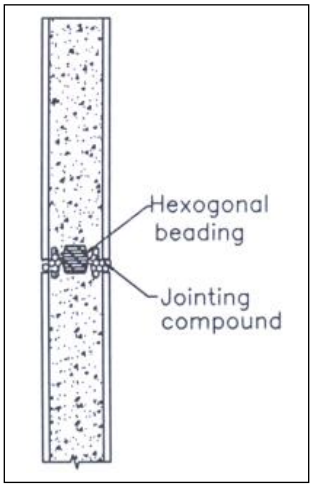


Fig.15

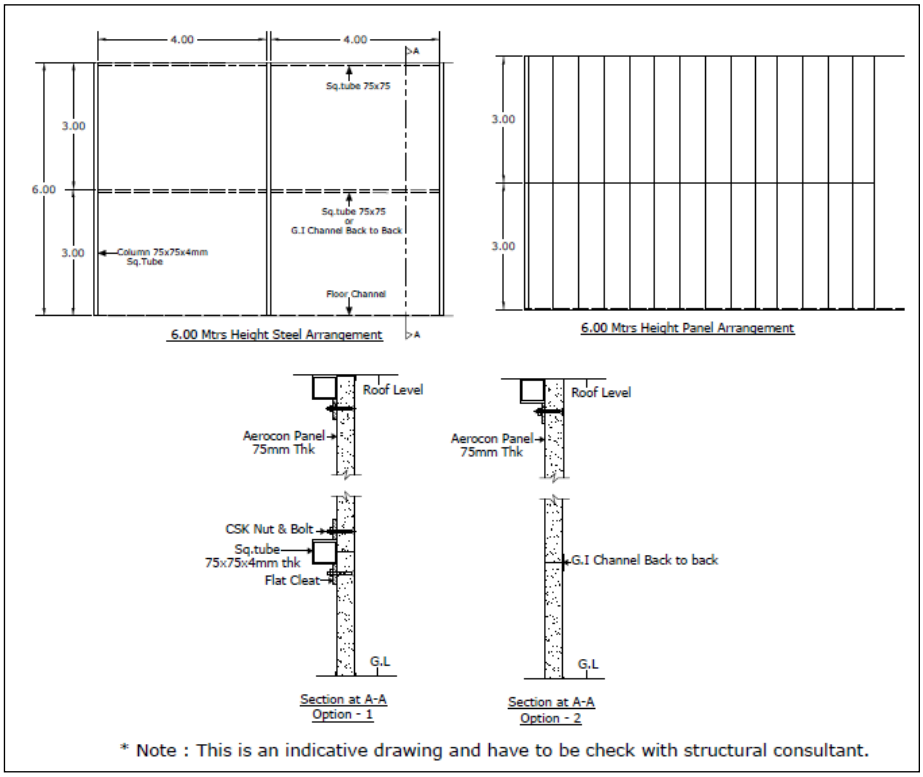


Fig.16

Load-bearing structures (Single storey)

These structures shall be made based on size, location and functional requirements. These load-bearing structures can be designed to a maximum span of 5.2 m as these are suitable with roofing option of the panels as shown below Fig. 17. The length of each room can be up to 6 m i. e. each room with a carpet area of 5.2 x 6 meter. These rooms can be constructed in a row, with multiples of 5.2 m x 6 m.

Typical layout for possible load bearing structures is shown in Figs. 18 to 20.

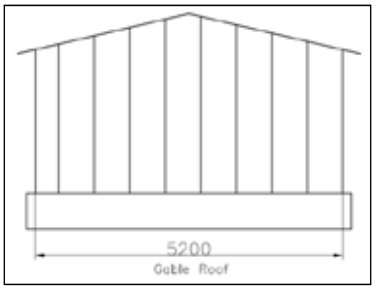


Fig.17

Row Houses

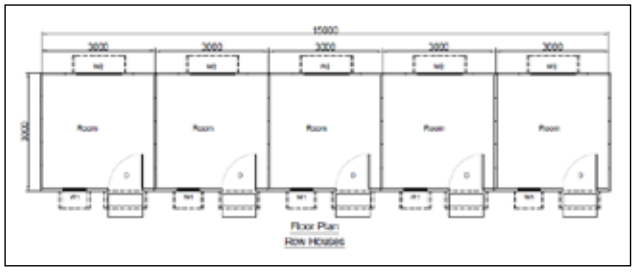


Fig.18

Individual House.

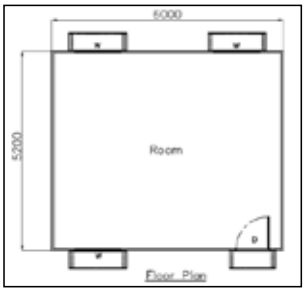
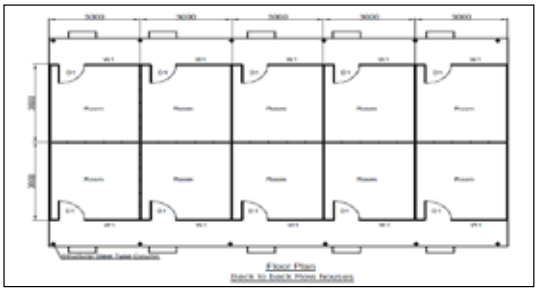


Fig.19



Back to Back Row Houses.

Fig.20

Details of typical foundation for walls and columns are shown below Figs. 21 & 22

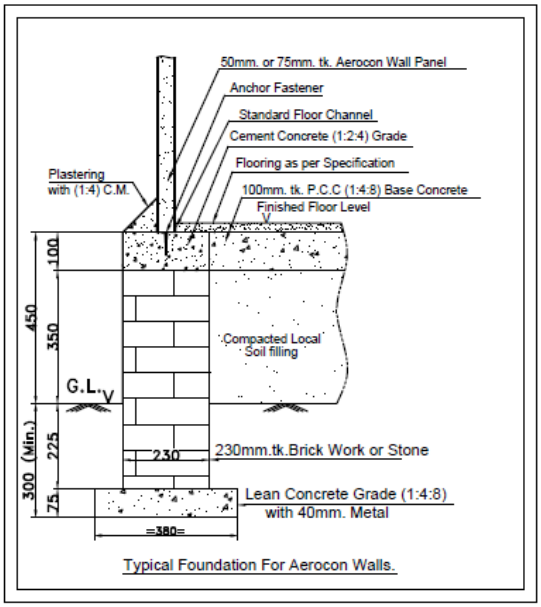


Fig.21

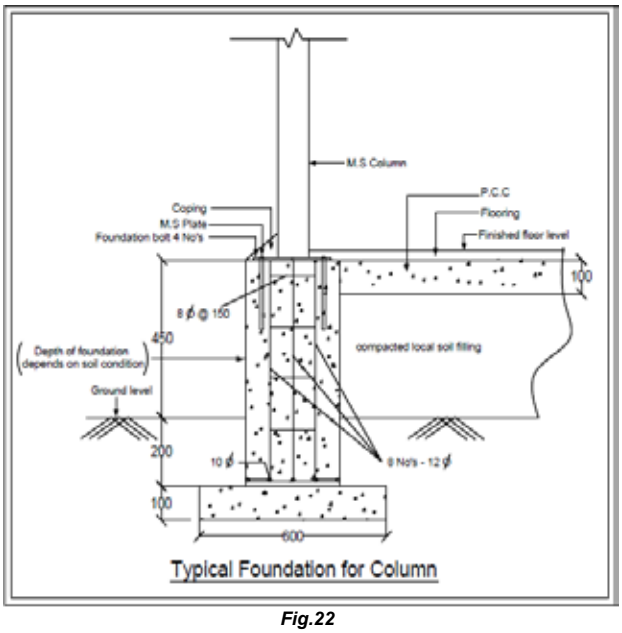


Fig.22

Panels with Recess/Square edge shall be used for construction of walls.

- The four corners shall be marked and position the 'L' Base plate component and diagonals checked as per the drawing as shown in Fig. 23.

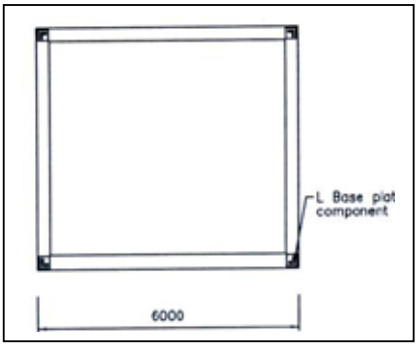


Fig.23

- The base plate shall be fixed by drilling 12mm dia holes with hammer drill and fasten self - expansion anchor fasteners of size M 8 x 65 mm (Hilti/Fischer) as shown in Fig. 24.

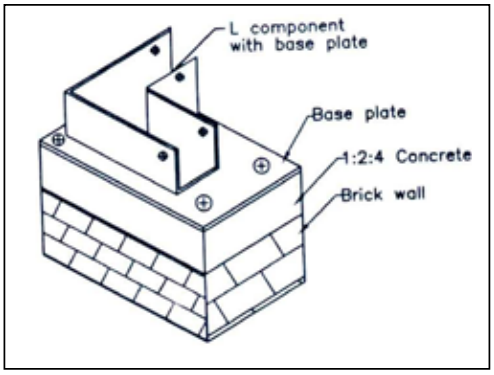


Fig.24

- The floor channel shall be fastened with N 6 x 60 mm self-expansion screws at 600 mm center to center.
- The panels shall be erected from a corner. It shall be ensured with plumb that the first panel is perfectly vertical. After fixing at least two panels on one side start fixing the panels at right angle as per the drawing to ensure stability to the structure.
- The corner cover plate shall be fixed from outside to make the corner rigid as shown in Fig. 25.
- Jointing material shall be applied on tongue & groove portion of the panels to make the joints firm.
- The second panel shall be positioned 550 mm away from the first panel and slowly drop slide towards first panel. This technique enables fast & proper joining of panels. It must be started from the gable side and all sides complete one by one.
- During installation suitable temporary support shall be provided using 75 mm dia. timber log or M.S. pipes of 50mm dia firmly grouted into the ground on either side of panels in 450 angle.
- Every 3rd panel on either side should be tied with temporary support.
- Fixing of purlin shall be completely resting on panels and duly connected with base plates by fixing with M 10 bolts & nuts.
- The day's work shall be stopped only after completing the four walls and tying each other by truss and purlins.
- All panels shall be fastened to the plinth with anchor bracket of size 75 x 75 x 75 x 6 mm thick as shown in Fig. 26.
- After completion of erection of pre-fab structure, the exposed anchor brackets shall be covered using M20 concrete with baby chips from outside.

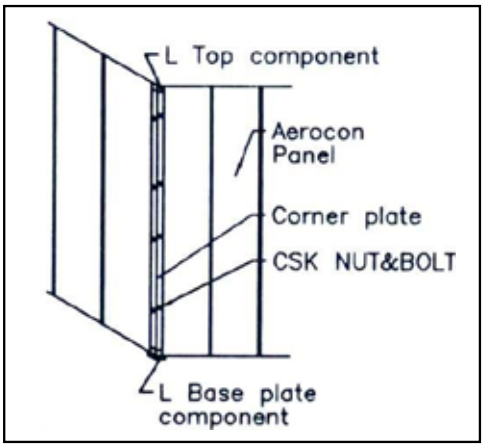


Fig.25

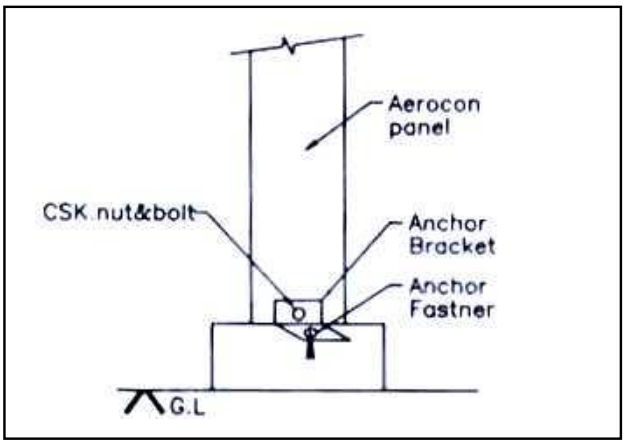


Fig.26

Corner Joints

The 'L' and 'T' joints shall be made by fastening straight ends of the panels with self-expansion screws or 10 dia. x 100 mm long pin as shown in Figs.27 & 28.

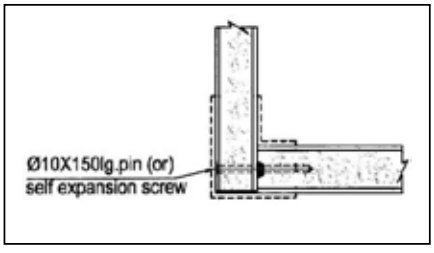


Fig.27

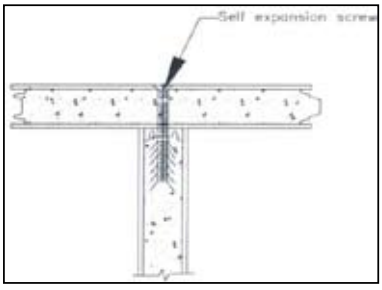


Fig.28

- The core of one panel shall be removed upto 15 mm depth in which the pin will be fastened only in the core, for filling grout cement.
- The panels shall be positioned in right angle and fastened with 150 mm long self-expansion screws at every 900 mm lengthwise using Hilti make or standard bolts 150 mm long galvanized/zinc coated threaded rod dipped in sodium silicate. The bore shall be filled with sodium silicate & fly-ash.

- 8mm dia. holes shall be drilled at 600 mm centres height wise and 15 mm prepared groove shall be filled with grout cement using cocking gun.
- The facing of core (exposed part) shall be finished using silicon acrylic paste. In case of external application, the joints shall be covered with steel cover plate to protect the corner from knocks and other mechanical impacts.
- Lintel panels shall be firmly fixed with fastening the same to lateral panels with 12 mm dia. rods and cement grout. Minimum bearing of 150 mm shall be maintained on either side.

Non-load bearing structures

For non-load bearing structures, steel columns, trusses and Purlins shall be designed as per soil condition and wind velocity. The floor channel shall be fixed between two columns using self- expansion screws at every 600 mm centers, leaving gaps at door positions.

Typical layout plan for a non-load bearing structure is shown below in Fig.29.

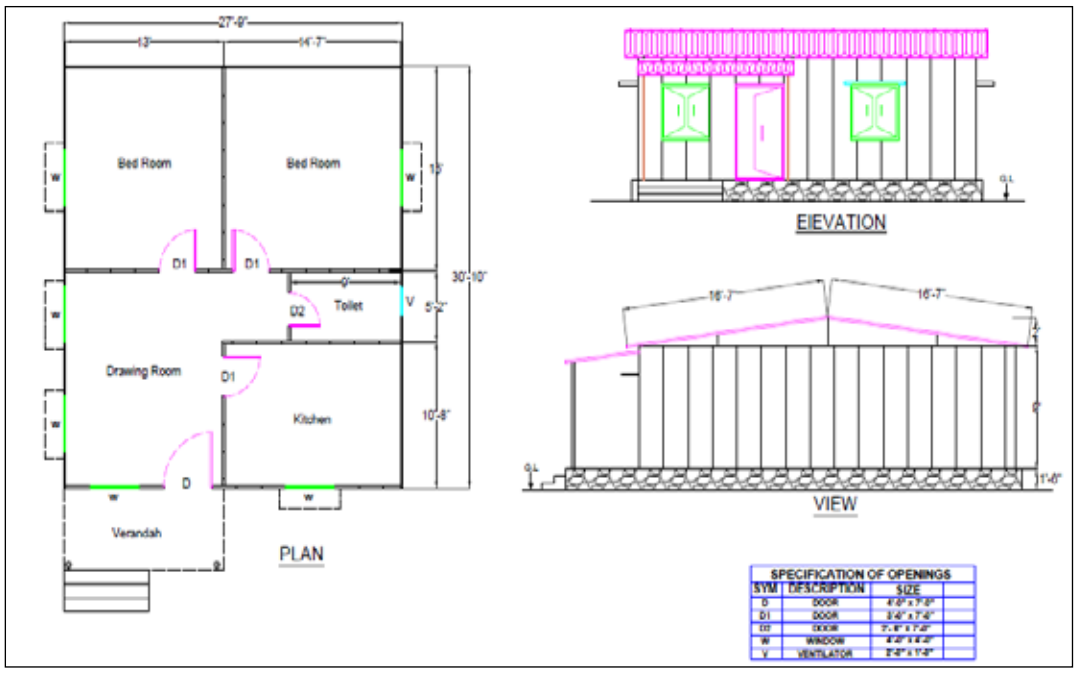


Fig.29 Typical layout plan for a non-load bearing structure

Doors and Windows

Mild Steel, Wooden and Aluminium doors and windows can be fixed with Prefabricated Fibre Reinforced Sandwich Panels.

Electrical Wiring

External wiring : External wiring shall be done on the panels by using PVC caps/pipes duly fixed to the surface.

Concealed wiring

- Surface routing shall be done by cutting the facing sheet and removing core.
- Face chasing should be avoided for panels used in prefab structure external and load bearing especially the panels on which the trusses & purlins are fixed.
- Maximum depth of route shall be 50 percent of the thickness of material
- Switch box upto 40 mm depth shall be fixed in 50 mm panels and upto 60 mm depth in 75 mm panels.
- Load bearing walls should not be routed horizontally.

Plumbing Installation

- In Prefab structures, the toilets can be constructed with these panels. The required pipelines shall be fixed on the panel externally.
- If pipe lines need to be concealed, a false wall should be created with 50/75 mm panel to the required height on the internal side only.
- Water Closet (WC) shall be fixed with bolts & nuts. However, detailing needs to be worked out based on site conditions. The WC shall preferably be fixed on floor and bolted to the panel wall.
- The surface of the panel shall be treated with marble/ granite/ceramic/glazed tiles using appropriate tile adhesive chemicals as per the procedure recommended by the tile adhesive manufacturer. It is recommended to use smaller tiles.

SUPPLY OF THE PANELS

The manufacturer has supplied the panels as per the details given below:

S. No.	Name & location of the Client	Quantity supplied (sqm) approx.	Period of supply
1.	Classic Mall, Mumbai for construction of Phoenix Mall	20000	2012
2.	D B Reality Pvt. Ltd., Mumbai for construction of Millan Mall	13000	2014
3.	Runwall Builders, Mumbai for construction of apartments	20000	2014
4.	Piramal Group, Mumbai for construction of housing complex	8000	2015
5.	Royal Palm, Mumbai for construction of a hotel	15000	2015
6.	ITC Ltd., Hyderabad for construction of a chocolate factory	6000	2015
7.	Gannon Dunkerley, Tanda, UP for construction of industrial complex	5000	2015
8.	Patel Engineering, Jammu (J&K) for construction of a hydro project	1000	2015
9.	DRDO, Panagarh (WB) for construction of staff accommodation	8000	2015
10.	Future Group, Mumbai for construction of City Centre Mall	4000	2015
11.	DLF, Noida for construction of Mall of India	3500	2015
12.	Larsen & Toubro, Hyderabad for construction of TOD Mall	4000	2015-16
13.	NTPC (Simplex), Noida for construction of industrial complex	5000	2015-16
14.	Shapoorji & Pallonji, Hyderabad for construction of warehouse	6000	2016
15.	Jaya Shree Textiles, Kolkata for construction of textile factory	6500	2016
16.	BGR Energy, Vijayawada for construction of housing complex	15000	2016
17.	MES, Leh (J&K) for construction of army accommodation	20000	2016
18.	Bihar Construction Deptt., Bihar for construction of District counselling centers	10000	2016
19.	Prime Hospitals, Hyderabad construction of a hospital	4500	2016
20.	GMR Infra, New Delhi for construction of Cargo at IGI Airport	4000	2016

CERTIFICATION

Under Performance Appraisal Certification Scheme, Prefabricated Fibre Reinforced Sandwich Panels has been evaluated and certified by BMTPC PAC No.: 1030-S/2017 has been issued to M/s HIL Ltd., Hyderabad.

STANDARDS AND REFERENCES

Indian Standards

IS 712:1984	Specification for building limes (Reaffirmed 2014)
IS 2380 (Part 4):1977	Methods of test for wood particle boards and boards from other lignocellulosic materials – Determination of flexural strength (Reaffirmed 2013)
IS 2380 (Part 2):1977	Methods of test for wood particle boards and boards from other lignocellulosic materials – Determination of dimensional stability (Reaffirmed 2013)
IS 2547 (Part 1): 1976	Specification for gypsum building plaster: Part 1 excluding premixed lightweight plaster (Reaffirmed 2017)
IS 3346:1980	Method of determination of thermal conductivity of thermal insulation materials
IS 3809:1979	Fire resistance test for structures
IS 3812 (Part 2):2013	Specifications for pulverized fuel ash - Part 2 : for use as admixture in cement mortar and concrete (Reaffirmed 2017)
IS 11050 (Part 1):1984	Rating of sound insulation in buildings and of building elements - Part 1 : airborne sound insulation in buildings and of interior building elements (Reaffirmed 2017)
IS 12089:1987	Specifications for granulated slag for manufacture of portland slag cement (Reaffirmed 2013)
IS 12269:2013	Specifications for 53 grade Ordinary Portland Cement
IS 13000:1990	Specifications for Silica-Asbestos-Cement Flat Sheets (Reaffirmed 2015)
IS 14862:2000	Specifications for fibre cement flat sheets (Reaffirmed 2015)
BS 476 (Part 4):1970	Test method for non-combustibility of building and structures
BS 476 (Part 5):1979	Method of tests for ignitability
BS 476 (Part 6):1989	Method of tests for fire on building materials and structures
BS 476 (Part 4):1997	Method for fire classification of surface spread of flame
BS 476 (Part 20-22):1987	Fire resistance test to building materials and structures
BS 4370 (Part 2):1993	Method of tests for rigid cellular materials
ASTM E 72:2015	Standard test method for conducting strength test of panels for building construction

References

Fire propagation, fire resistance, Ignitibility evaluation & Surface spread of flame by Fire Research Laboratory, CBRI, Roorkee (IS 3614:1979)
Thermal Conductivity & Thermal Resistivity study of Panels by Indian Institute of Technology Bombay, Mumbai
Dimensions, Transverse strength, Deflection & Compressive strength study of Panels by JNTUH College of Engineering, Hyderabad

Rising EPS (Beads) Cement Panels

(Suitable for Non Load Bearing Structures)

ABOUT THE TECHNOLOGY

These are lightweight composite wall, floor and roof sandwich panels made of thin fiber cement/calcium silicate board as face covered boards and the core material is EPS granule balls, adhesive, cement, sand, fly ash and other bonding materials in mortar form.

The core material in slurry state is pushed under pressure into preset molds. Once set, it shall be moved for curing and ready for use with RCC or steel support structure beams and columns. These panels are primarily used as walling material but can also be used as floor and roof panels. These are non-load bearing panels to be used with structural support frame only.

SIZE AND TYPE OF PANELS

Size	:	Panels are normally produced in sizes and dimensions as given below:
Length	:	2440 mm (may be increased up to 3000 mm)
Width	:	610 mm (may be altered as per requirement but should not be too wide since handling of the panels become difficult)
Thickness	:	50-250 mm. Dimensions are shown in Fig. 1.

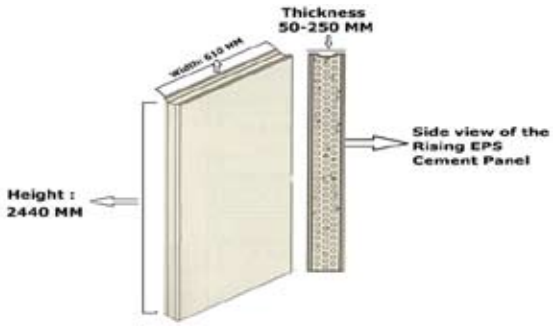
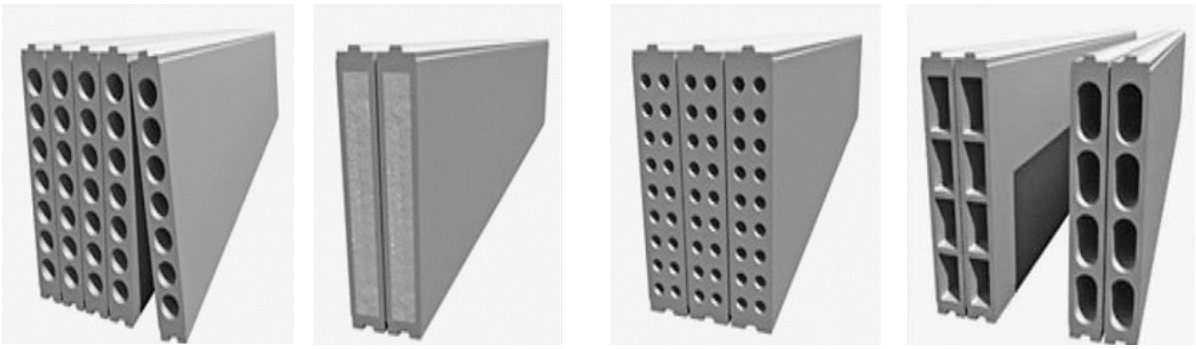


Fig.1

Type: Panels are produced in 4 types as shown in Fig. 2 below:



Pole holes *Solid heart* *Rod holes* *Block hole*

Fig.2

The above four types of panels have different applications depending on the requirements e.g. Solid heart should be used as walling material in any type of construction and pole, rod and block hole may be used where different types of inserts are used like iron rods or wires for security etc.

RAW MATERIALS

(i) OPC 43/53 grade cement shall conform to IS 8112:2013/12269:2013.
(ii) Fly ash shall conform to IS 3812 (Part 2):2003.
(iii) EPS beads shall conform to IS 4671:1984 and shall have density not less than 15 kg/m^3.
(iv) Fibre cement board shall conform to IS 14862:2000.

(v) Calcium silicate board shall conform to EN 14306:2009
(v) Fine (sand) & coarse aggregate shall conform to IS 383:2016.
(vi) Water shall conform to IS 456:2000.
(vii) Addage RD Powder, AKULPOL-9192, Akulcel 48000 (Additives & Bonding agents) shall conform to the manufacturer Ms. Sakshi Chem Science Pvt. Ltd. Mumbai specifications.

PERFORMANCE CRITERIA

Rising EPS panels shall meet the following performance criteria when tested in accordance with the relevant Standards:

Sl.No.	Performance Characteristics	Criteria	Test Method
1.	Flammability of EPS	≥ 600kgs/M³	IS ASTM D 7309:2013
2.	Axial compression	≥ 3.5MPa	IS 2095 (Part1):2011
3.	Resistance to continuous heating	≥ 70ºC	ASTM F 1939:2015
4.	Flexural Strength	≥ 1N/mm²	IS 516:1959
5.	Acoustic Performance	≥ 35dB	IS 9901:1981
6.	Thermal conductivity	≥ 0.1W/M² k	IS 3346:1980
7.	Thermal Resistance	≥ 0.40M² k/W	IS 3346:1980
8.	Water penetration	There should be no damage or leakage	EN1609:2013
9.	Fire rating of the panels	Should be Grade 1/3 Hrs	BS 476 (Part 20 & 22)
10.	Resistance to structural damage from a large light body	There should be no collapse or dislocation	BS 5234 (Part 2):1992, Annex E
11.	Anti-bending damage load	≥ 1.5 times of its weight	BS 5234(Part 2):1992
12.	Non-combustibility	Should be 'A' level	GB 8624:2012
13.	Water tightness behind panels after 24 Hrs at 250mm water head	No droplets should be observed	ASTM C1185:2016
14.	Drying Shrinkage value	≤ 0.1%	IS 2185 (Part 1):2005
15.	Single point hanging strength	≥ 1000N	BS 5234 (Part 2):1992

INSTALLATION OF EPS CEMENT PANEL, APPLICATIONS & JOINTING PROCEDURE

Procedure

With RCC frame structure: If RCC frame structure is used in the construction, then the panels should be directly fixed on the walls, pillars, beams and floor with the help of cement glue and later iron locking rods should be inserted into the panels and the pillars, beams and floors at 45° so that they are firmly locked with each other and become one single unit.

The manufacturer shall inform the specialized chemical "cement glue", if available in India/manufactured by reputed chemical/ water proofing companies to the customers.

With Steel frame structure: If steel structure frame is used in the construction, then U type channels should be used to hold the panels with the structure. In this case additional clips should be welded with the frame pillars and beams to hold the U cannel firmly with the pillars/beans and floor. Then only the panels should be inserted into the U channels. There after PU glue should be applied to hold the panels firmly. The thickness of the panels shall determine the size of U channel.

After installation of the panels in both the above systems, all gaps should be checked and filled with additives, PU and cement mixers and later thin putty should be applied to give uniform smooth surface ready for paint.

Installation of Panels

Receipt and inspection of Panels

Once the panels are received, it should be checked if the edges are safe and also there are no cracks or damages on the surface of the panels which can happen during transportation and handing.

Laying of panels as per drawings

Once panels received are as per the drawings, then it should be separated and laid down as per the drawings for easy installation and to avoid extra handling.

Marking and sizing the panels

Once panels are placed at the proper place, marking should be down as per drawing and proper sizing should be cut of the required panels as per the drawings. (See Figs. 3 & 4)

Fig.3 Marking of the panels as per drawings

Fig.4 Cutting of panels as per drawings

Actual installation as wall

The panels are lifted and placed as per the drawings. Fo installation of the panels, following points should be considered:

1.1 Joining of panels with each other

- The panels shall be placed at the marked space and adjusted together. Dust should be cleaned on the tongue and groove of the panel to be installed. Cement mortar shall be applied and glue filled in the gaps on the panel joining parts and force them together to form one panel. Levels of both panels shall be checked. (See Figs. 5 & 6)
- The panels shall be fixed with steel bar between each other or between the panels and the floor to lock them together. (See Fig. 7)

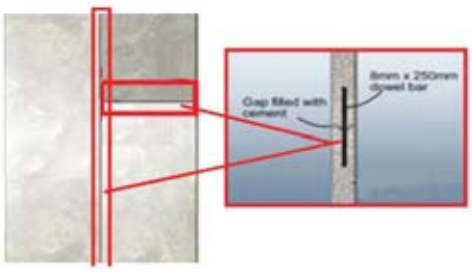


Fig.5 Placing panels together

Fig.6 Applying cement and glue

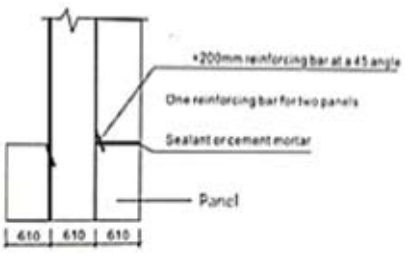


Fig.7 Part elevation of wall panels

1.2 Typical Joint between two panels side by side:

- The panels shall be fixed with dowel bars and the bars inserted in one panel at 45° and hammer it down to lock both the panels. (See Figs. 8, 9 & 10)

1.3 Typical joint with floor:

- The panels shall be placed on floor, cement and glue applied between panels and floor and L type steel bars inserted through the panels edge at 45° in the floor. The panel will then be locked to the floor. (See Figs. 11 & 12)

Fig.8 Steel bars

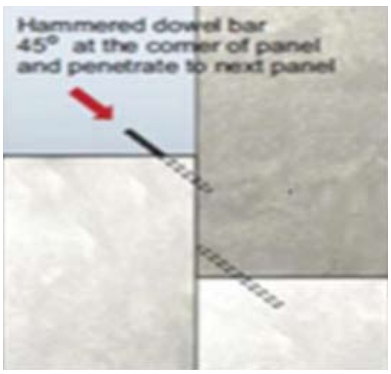


Fig.9

Fig.10

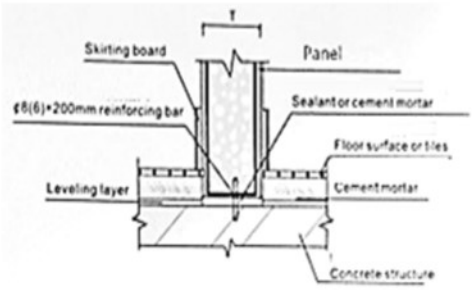


Fig.11

Fig.12

1.4 Typical L and T joint with panels:

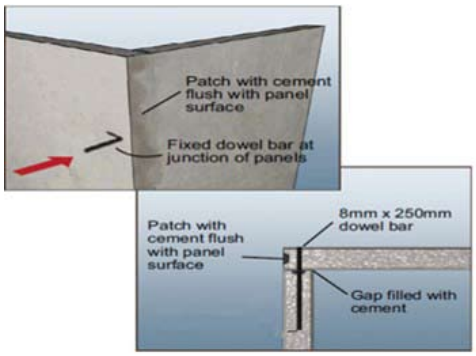


Fig.13

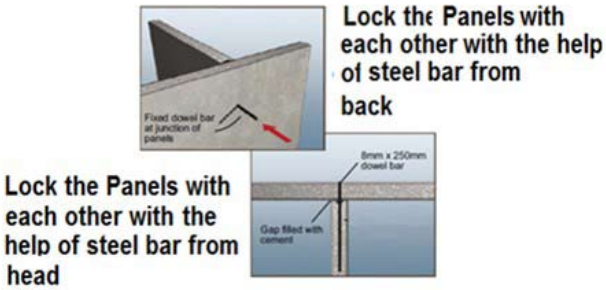


Fig.14

1.5 Joining of upper and lower panels together:

- The panels shall be placed one over the other vertical/ horizontal after applying cement and glue. The steel rod shall be inserted from the sides of the panels into each other to join them together and locked. (See Figs. 15 & 16)

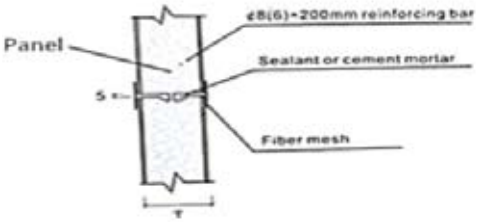


Fig.15

Fig.16

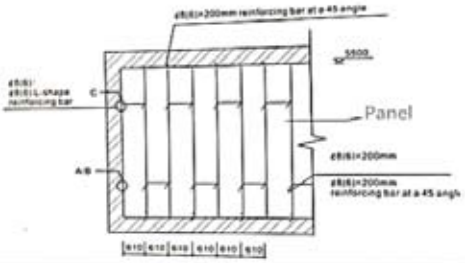


Fig.17

- A wall of these panels shall be inter-connected with steel bars inserted at 45° and fixed with cement and glue in between panels. (See Fig. 17)

2.1 Connecting panels with RCC pillar/RCC Walls/RCC beams:

- For connecting these panels with RCC pillars, the panels shall be placed with the pillar after applying cement and glue on the side of the panels and pushed to make the perfect position.

  Following are three types of connections depending on the situation:

  Steel rods/screw or bolt shall be inserted in the pillar and the panels locked with the help of the above. Thus the panel will be fixed and becomes part of wall connected with pillars. (See Figs. 18, 19 & 20)

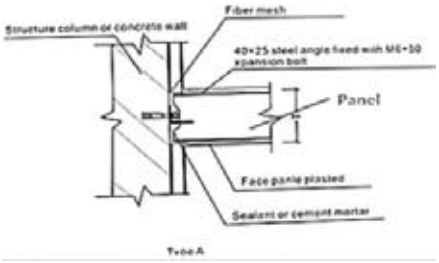


Fig.18

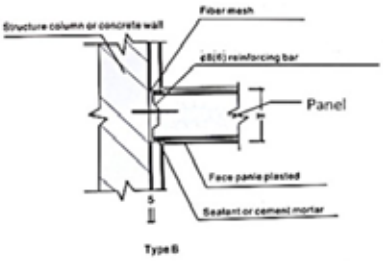


Fig.19

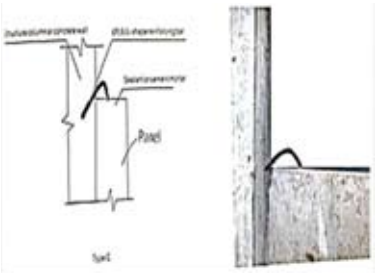


Fig.20

2.2 Wall head fixing:

- Dowel bar of 250mm length and 8mm dia shall be fixed into pre-drilled hole of the panels and lock the panel to the overhead beams or RCC roof slab. (See Figs. 21, & 22)

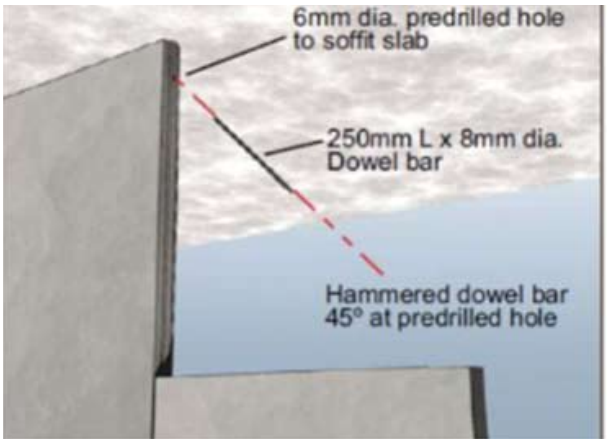


Fig.21

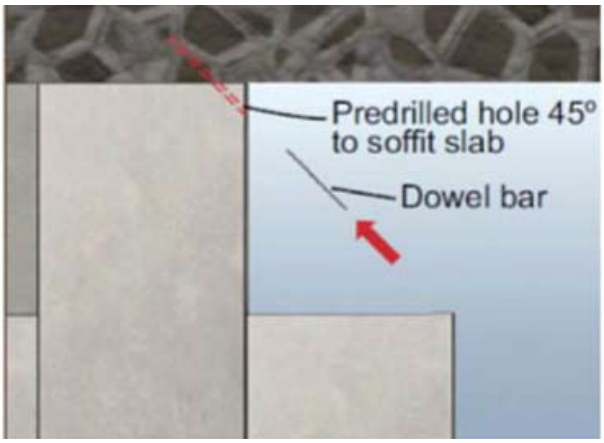


Fig.22

2.3 Fixing panels to the Steel frame (Pillars & Beams)

- *Connection of wall panel to RHS column*
  Steel L-angle/C Channel/Z channel shall be welded to the side of RHS column and the panel inserted inside the angle/channel and locked. The thickness of the panels shall determine the size of angle/channel. (See Figs. 23, 24 & 25)

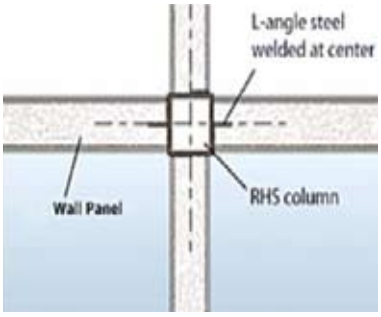


Fig.23

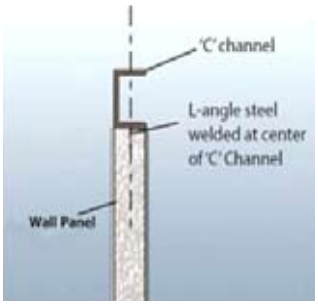


Fig.24

Fig.25

3.1 Cutting of space for doors and windows

- The space on the drawing where doors and windows are required to be placed shall be marked and then while making walls keep that space. There is another way also where the space is cut later on once the walls are set fully.

3.2 Door Opening

- The panels shall be placed horizontally to keep space for doors. (See Figs. 26 & 27)

3.3 Window Opening

- The panels shall be placed horizontally to keep space for windows. (See Figs. 28 & 29)

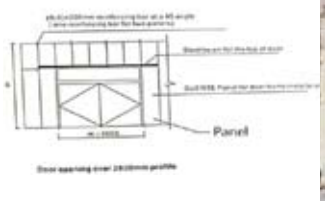


Fig.26

Fig.27

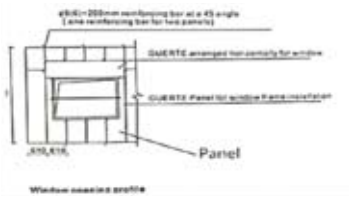


Fig.28

Fig.29

3.4 Cutting space for doors and windows after the panels are fixed.

- The position of steel inserts shall be marked to protect the wall from any movement while cutting of panels. All the steel bars shall be inserted at 45° angle to lock the panels with each other to stop further movement. (See Fig. 30)

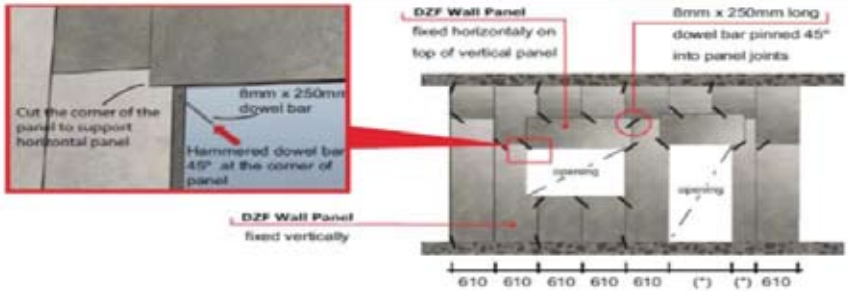


Fig.30

3.5 Frame Fixing (See Figs. 31, 32, & 33)

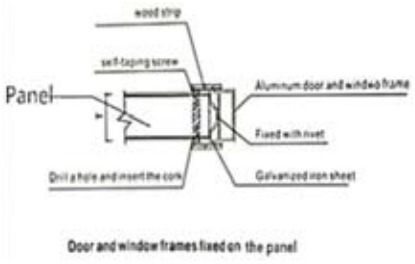


Fig.31

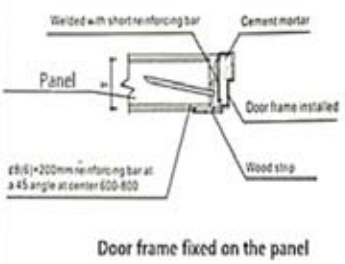


Fig.32

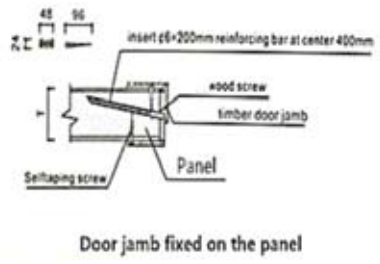


Fig.33

4. Laying of electrical conduits

- The wire shall be embedded from the ceiling into the trench. (See Figs. 34 & 35)

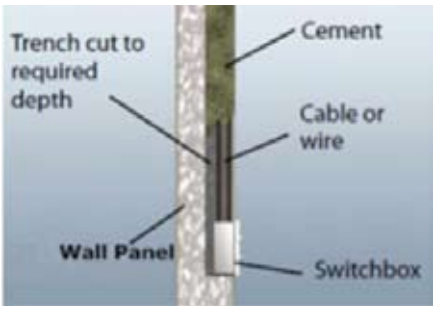


Fig.34

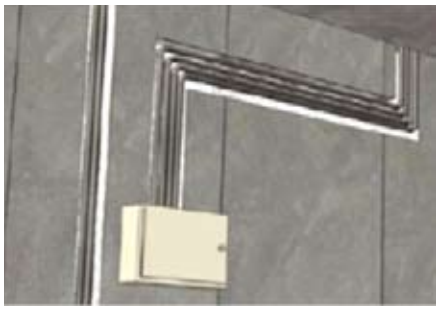


Fig.35

5. Hanging Force (See Fig. 36)

- Expandable metal bolt shall be used and hooked on the wall panel.
- Tile adhesive shall be used for fixing heavy granite tiles.

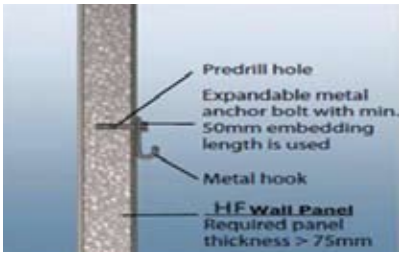


Fig.36

6. Fixing the Panels as floor (See Fig. 37)

- Steel frame shall be fixed if this is to be a raised platform otherwise the panels can be used directly as floor after making the ground level properly.
- Floor tiles can be fixed on these panel, if required.

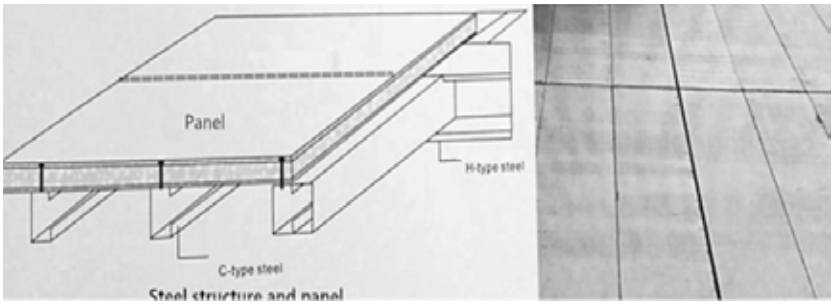


Fig.37 (Screeding concrete not shown in these drawing)

7. Fixing the Panels as roof (See Figs. 38 & 39)

- These panels can be used in the roofing as long as it is non-load bearing application.
- Steel frame shall be fixed as base for fixing the panels as roof.

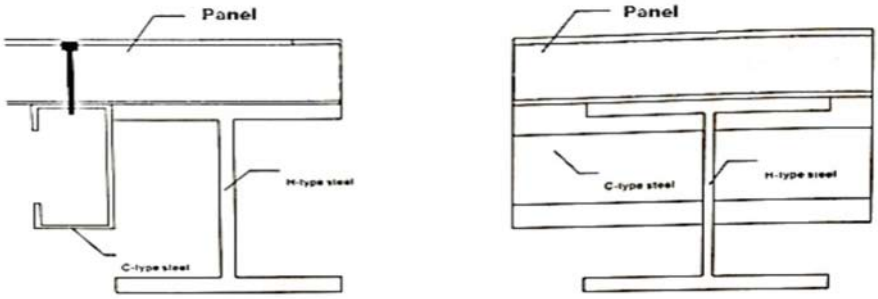


Fig.38 (Screeding concrete not shown in these drawing)

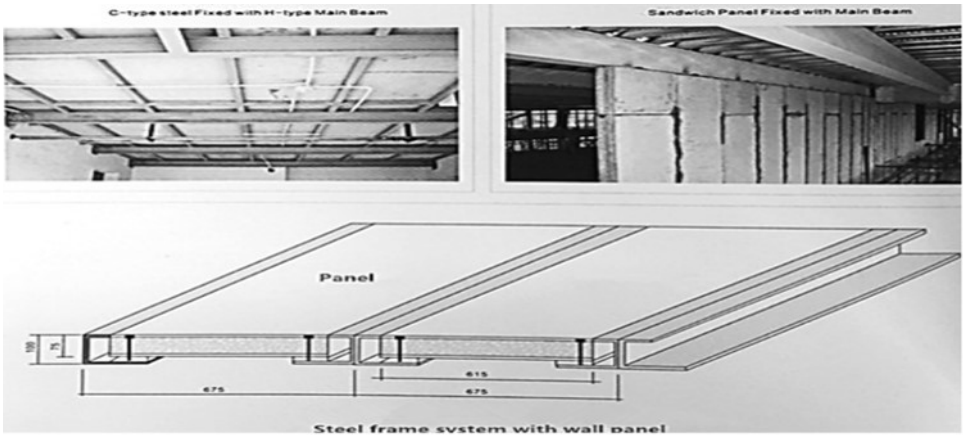


Fig.39 (Screeding concrete not shown in these drawing)

CERTIFICATION

Under Performance Appraisal Certification Scheme, the present formwork system has been evaluated and certified by BMTPC PAC No. 1032-S/2017 has been issued to M/s Rising Japan Infra Pvt. Ltd., New Delhi.

EXECUTED PROJECT

- These panels are presently manufactured by the firm in China. The firm has constructed, as reported, a 4 storey prototype residential complex at Nagpur using the panels from China. The firm proposes to install the plant in India shortly for manufacture of the panels.
- The Panels, manufactured in China by the said firm, have been installed at the third floor of G+6 residential Complex being constructed by NBCC at Kidwai Nagar, New Delhi

USES, LIMITATIONS AND CRITICAL DETAILS OF PANELS

Uses:

These panels may be used for the applications in Housing, Commercial complexes, Schools, offices, Electric sub-stations, Hotels and resorts, High rise buildings, Boundary walls, Highway railings, Bridges side support, river lining etc.

Limitations on the basis of performance, safety, geo-climatic conditions:

These are non– load bearing panels and should be used as walling, floor and roofing with additional structural support, steel or RCC depending on the design. However, these may be used as single floor construction or stairs case slabs, kitchen/bathroom slabs etc. without support structure.

These panels are non- load bearing only if they are used without any pillar and beam support. However, they may be used as walling material with RCC or steel frame structure.

The panels, if used for floors/roofs, shall require screeding concrete of 35mm thick with nominal reinforcement/ GI wire mesh for shrinkage monolithic action to avoid leakage through the panel joints.

STANDARDS AND REFERENCES

IS 383:2016	Coarse and fine aggregate for concrete - specification (Third Revision)
IS 456:2000	Plain and reinforced concrete - code of practice (Reaffirmed 2016)
IS 2185 (Part 1):2005	Specification for Concrete Masonry Units - Part 1 Hollow And Solid Concrete Blocks (Reaffirmed 2015)
IS 3346:1980	Method of determination of thermal conductivity of thermal insulation materials
IS 3809:1979	Fire resistance test for structures
IS 3812 (Part 2):2003	Specifications for pulverized fuel ash - Part 2 : for use as admixture in cement mortar and concrete (Reaffirmed 2017)
IS 8112:2013	Specifications for 43 grade Oordinary Portland Cement
IS 9901:1981	Measurement of sound insulation in buildings and building elements
IS 12269:2013	Specifications for 53 grade Ordinary Portland Cement
IS 14862:2000	Specifications for fibre cement flat sheets (Reaffirmed 2015)
IS 516:1959	Method of test for strength of concrete (Reaffirmed 2013)
IS 4671:1984	Specifications for expanded polystyrene for thermal insulation purpose.
IS 2095 (Part 1):2011	Specifications for gypsum plaster boards - part 1 plain gypsum plaster boards (Reaffirmed 2011)
ASTM C 1185(08):2016	Standard test method for sampling and testing non-asbestos fibre cement flat sheets
ASTM F 1939:2015	Standard test method for radiant heat resistance of combination of materials
BS 476 (Part 20-22): 1987	Method of determination of fire resistance of building materials and structures
BS 5234 (Part 2):1992	Specifications for performance requirements for strength and robustness of partitions including method of tests
EN 1609:2013	Specifications for thermal insulating products for buildings
GB 8624:2012	Classification of burning behavior of building materials

Light Gauge Steel Structural Systems

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.

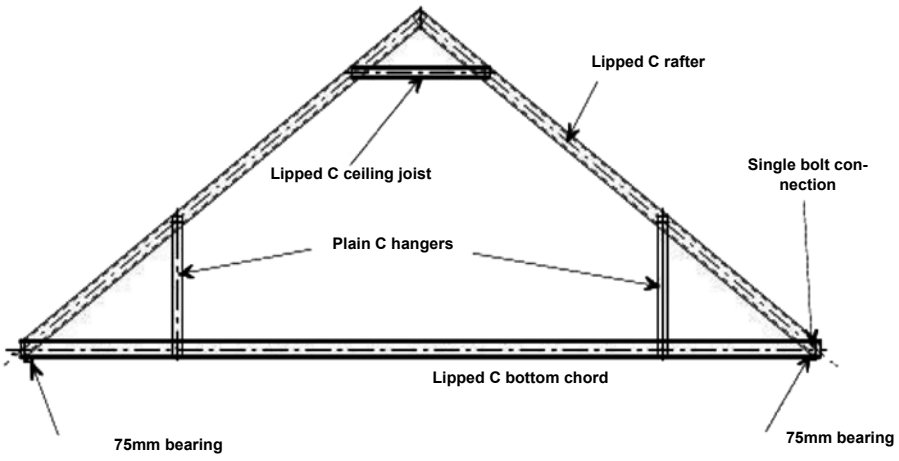
Roof frame

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.

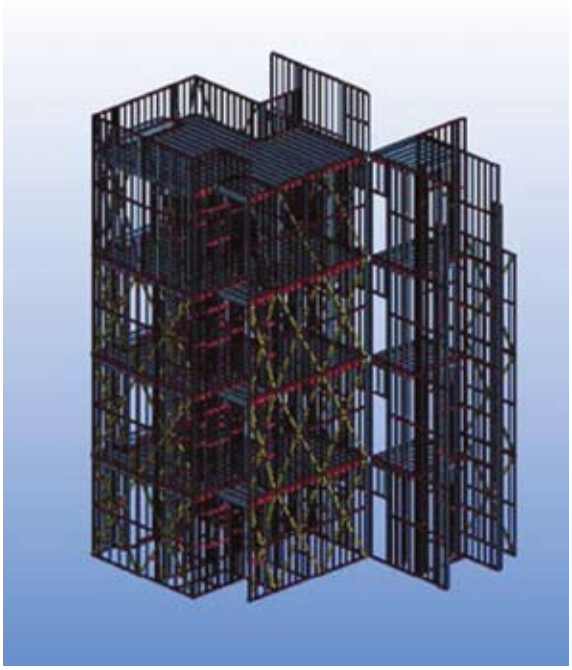
The trusses are placed at 600 mm maximum spacing and are battened and tiled in a conventional manner.



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 - 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 certified 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

Under Performance Appraisal Certification Scheme, the Light Gauge Steel Framed Structures (LGSF) has been evaluated and certified by BMTPC PAC No. 1014-S/2014 has been issued to M/s JB Fabinfra Pvt. Ltd., New Delhi.

STANDARDS

IS 801: 1975	Code of practice for use of cold formed light gauge steel structural members in general building construction (Reaffirmed 2016)
IS 2095 (Part 1) : 2011	Specification for Gypsum Plaster Boards - Part 1 Plain Gypsum Plaster Boards (Reaffirmed 2016)
IS 14862 : 2000	Specification for Fibre Cement Flat Sheets (Reaffirmed 2015)
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.

Light Gauge Stell Framed Structure with Infill Concrete Panel (LGSFS-ICP) Technology

(Suitable for Low Rise to Medium Rise Structures)

ABOUT THE TECHNOLOGY

Light Gauge Steel Framed Structure with Infill Concrete Panels (LGSFS-ICP) Technology is an innovative emerging building and construction technology using factory made Light Gauge Steel Framed Structure (LGSFS), light weight concrete and precast panels. The LGS frame is a "C" cross-section with built in notch, dimpling, slots, service holes etc. produced by computerized roll forming machine. These frames are assembled using metal screws to form into LGSF wall and roof structures of a building. Provisions for doors, windows, ventilators and other cutouts as required are incorporated in the LGSFS.

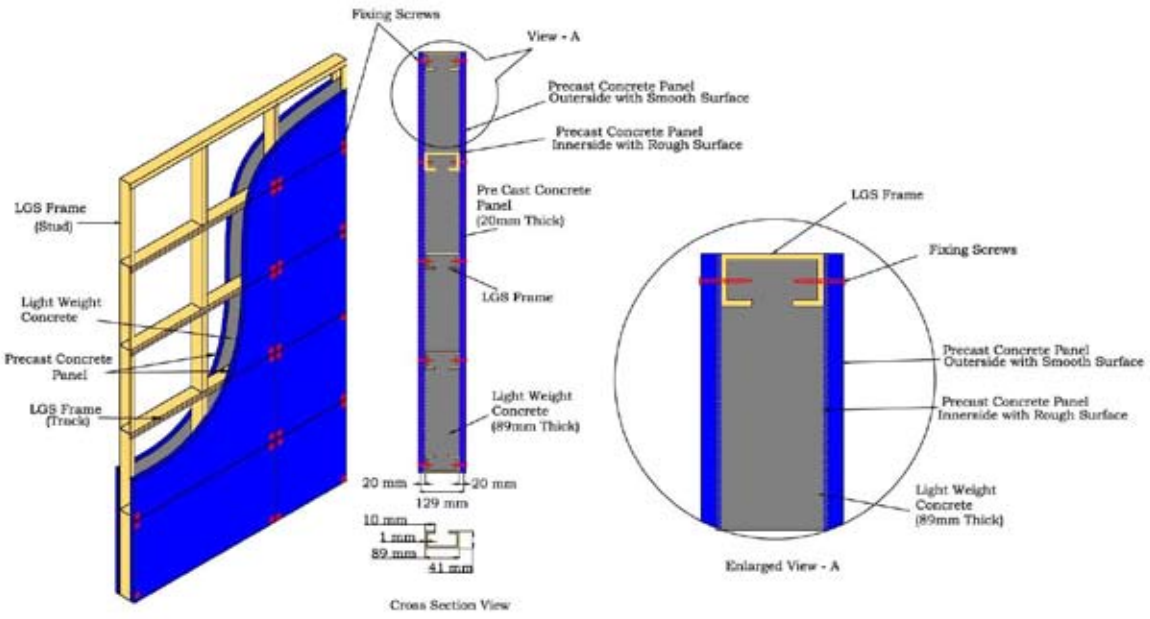


Fig.1 Structural Details of LGSFS-Infill Concrete Wall

The LGS frames are manufactured in a factory and assembled in to LGSF wall structures and then transported to the construction site and erected wall by wall on a pre-built concrete floor as per the floor plan of the building. Steel reinforced concrete panels of size 610 mm x 305 mm x 20 mm thick are manufactured at factory and transported to site. These panels are fixed on either side of the LGSFS wall using self-drilling/tapping screws to act as outer and inner faces of the wall leaving a gap between them. This gap is then filled with light weight concrete using a special mixing and pumping machine. Electrical and plumbing pipes/conduits are provided in the service holes of the LGSFS before concreting is done. Self-compacting concrete is mixed and pumped into the gaps between two panels. The concrete flows and fills the gap and provides adequate cover to the LGS frames and joints. The concrete shall also adhere to the concrete panels. After curing, LGSFS with in-fill concrete and panels (LGSFS-ICP) forms a monolithic sandwich composite wall structure with thermal and sound insulation properties.

The roof structure of LGSFS-ICP building is constructed using metal/plastic formwork system with steel reinforced concrete as per structural design. Standard procedures are employed to concrete the roof slab. After curing for 96 h, the formwork is de-moulded and the wall and roof are putty finished. Door and window frames are fixed to the

LGS frames and shutters fixed with necessary accessories. Finishing work such as laying floor tiles, fixing electrical and sanitary fixtures and painting is carried out using standard conventional methods.

After completion of ground floor, first, second and third floors of the building is constructed using the same procedure that of the ground floor. The staircase, chajja and parapet walls of the building are also constructed using LGSFS-ICP Technology.

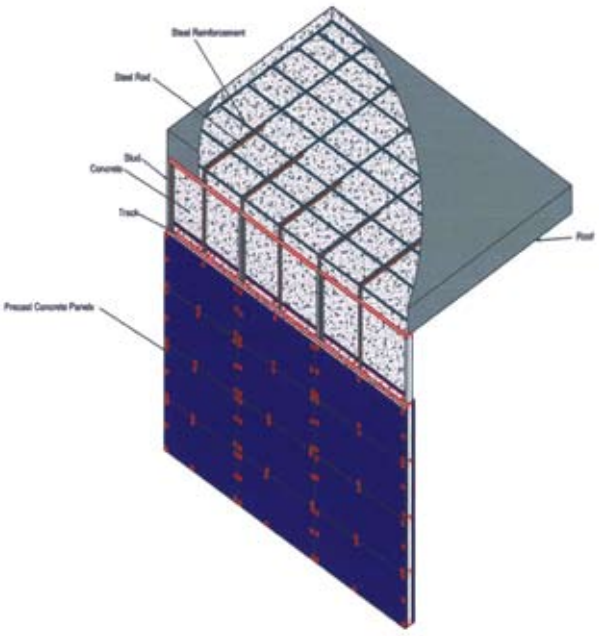
MATERIAL REQUIREMENTS

1. Raw Materials

i. LSG Coil of galvanized steel shall conform to IS 277:1992.
ii. Fasteners and Connectors
   (a) Frame assembly screws: Shall be galvanized steel screws self-drilling type of size 10 x 25 mm having Truss-head and shall be as per ASTM C 1513-10.).
   (b) Wall Erection Screws: Shall be galvanized steel screws self-drilling type of size 8 x 25 mm having Hex Washer head and shall be as per ASTM C 1513-10
   (c) Precast Concrete Panels Fixing Screws: Shall be of galvanized steel screws self-drilling type of size 8 x 50 mm having CS head and shall be as per ASTM C 1513-10.
   (d) Wall and Foundation Anchor Bolt: Shall be of high tensile galvanized steel of size 10 x 100 mm/ 10 x 150 mm and 12 x 100 mm/ 12 x 150 mm and shall be as per ASTM C 1513-10.
iii. Foaming Chemicals: Shall be made from protein foam concentrate and FC-lite foaming agent
iv. Gypsum plaster board: Shall be of size 1830 mm x 1220 mm and 12.5mm to 20 mm thick and shall conform to IS 2095 (Part 1):2011
v. Water Proofing Treatment: Shall be using integral waterproofing compound as per IS 2645:2003
vi. Putty: Shall be as per IS 63:2006
vii. Ordinary Portland cement (OPC) shall be of 43/53 grade as per IS 269:2015
viii. Sand and Aggregates shall be as per IS 383:2016
ix. Reinforced Steel: Shall be as per IS 1786:2008
x. Structural steel: Shall be as per IS 800:2007
xi. Steel fiber: Shall have length of 60 mm &dia. 0.75 mm and shall be as per EN 14889-1:2006
xii. Glass fiber: Shall be made from Fiber mesh 303 E3 and shall be as per EN 14889-2:2006

2. Light gauge steel frame/ structure

The Light gauge steel frame structure (LGSFS) comprises of “C “cross section studs (vertical members) and tracks (horizontal members) frames assembled together by means of mechanical screws. The joints between wall & roof junctions/wall to wall junctions are designed as rigid joints

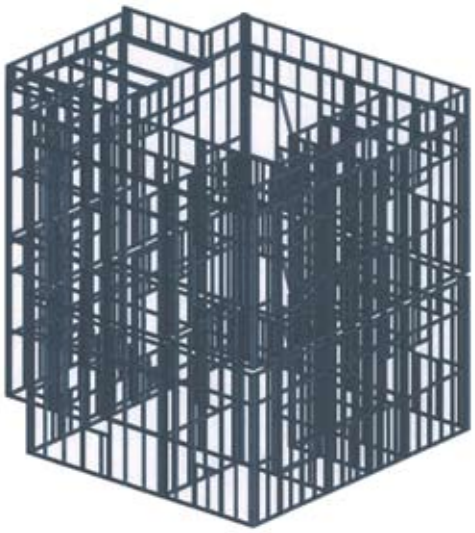


3. Precast concrete panels

Precast Concrete Panels are used as facing sheets for construction of walls. Self-compacting concrete of M20 grade is used. Metal modes, concrete mixing machine and vibration tables are used for manufacturing the panels. The panels are designed to withstand the concrete weight pumped in between the gap of the panels without failure and buckling.

The steel reinforced precast concrete panels (PCP), has one side rough surface and the other side smooth surface. The PCP’s are fixed on either side of Light Gauge Steel Frame Structures (LGSFS)–studs and tracks using

mechanical fasteners. While fixing, the rough side of the panels are facing inside and smooth side is facing outside. Each PCP is fixed with 6 screws. Light weight concrete is pumped in to the gap between two PCPs. The concrete bonds with the rough surface of the panels. Thus, the LGSFS and PCPs are firmly joined to make a monolithic steel–concrete structure.



4. Concrete/light weight concrete

The concrete used for infill wall is light weight and free flow. The density shall be 1500-1800 Kg/m^3 after adding/mixing foam or EPS beads as per the design mix developed by the agency. The light weight concrete shall be of grade M5 to M10, as required. The light weight concrete shall be mixed and used at site.

MANUFACTURING PROCESS

The manufacturing process of the constituents of LGSFS-ICP system is as follows:

1. Light Gauge Steel Frame Structure

Cold formed Light gauge steel frame super structure is manufactured out of min. 0.95 mm pre-treated factory finished hot dipped GI high tensile steel sheet (AZ 150 GSM Aluminium zinc alloy coated steel and having yield strength of 550MPA) which shall be as per IS 800:2007 and conforms to AISI specification and IBC 2009. The wind loads shall be as per IS 875 (Part 3):2015. The framing section is cold form “C’ type of 0.55 mm to 1.55 mm thickness in required length as per structural design requirements, duly punched with dimple slots at required locations as per approved drawings. The slots shall be along center line of the web and shall be placed at 250 mm min. away from both edges of the member. The frame is supplied in specified dimensions and fastened with metal strip of 25 mm x 25 mm x 0.50 mm to both adjoining walls.

2. Precast Concrete Panels

Precast concrete panels are manufactured using cement, sand, aggregates, glass &steel fibers, water and admixtures using a design mix and curing cycle developed by the agency. It is steel fibre reinforced precast concrete panel. It gets strength as steel reinforced concrete.

The overall dimensions of the panel are 1220 mm x 610 mm x 20 mm thick and the weight shall be around 36 kg. The panels are designed to have smooth or textured outside surface and rough inside surface. The panels are also designed to withstand green concrete load of 200 kg without failure and deflection shall be less than 1.0 mm.

The concrete used for the panels shall be of grade M20 having water absorption less than 8%.
Mix ratio of light weight aggregate for 1.0 cu.m is as follows:
Cement = 300 kg
Sand = 400 kg
Flyash = 300 kg
6mm-8mm Aggregate = 1350 kg
PPfibre + steel fibre = 4.14 kg
Water = 150 kg
Admixtures = 150 ml

3. Concrete/Light Weight Concrete

The wall or the roof is constructed using M20 grade concrete and M5 –M10 grade light weight concrete. The concrete used is light weight and free flow. The light weight concrete is mixed and used at site. The concrete/light weight concrete is pumped into the gap between the panels.

4. Assembly/Connecting Screws and Anchoring Bolts

LGS frames are assembled together to fabricate LGSF structures using self-taping screws. The LGSF structures such as wall, roof, truss and staircase are connected by using special screws which shall conform to ASTM C 1513. The anchoring boards used for connecting LGSF wall structure to the foundation shall conform to relevant Indian/ American Standards.

APPLICATIONS

The technology is used for construction of Low rise residential buildings up to G+3 storey – EWS, LIG & MIG houses, Schools, Health centers, Community centers, independent houses and rehabilitation buildings.

INSTALLATION/ CONSTRUCTION OF LGSF STRUCTURES

1. Construction of Foundation and Plinth

The foundation and plinth is constructed confirming the floor plan of the building. The foundation depth, width, steel reinforcement, grade of concrete etc. is determined by structural analysis report prepared on the basis of soil condition, height of building, number of storeys, special live load requirement, if any.

2. Assembly of LGS Frames and Construction of Wall

The LSG frames manufactured using numerically controlled roll forming machine using CAD design shall be transported to the construction site. The frames shall be assembled into wall structure. All the wall structures shall be connected together one by one as per the building plan by connecting screws. The wall position shall be marked on the floor and the wall structure placed on the marking. After completing the same, straightness, square and the levels shall be checked by magnetic spirit level. The bottom track shall then be connected with the floor using anchor bolts at every 600 mm bolts.

3. Fixing of Pre-cast Panels

The precast concrete panels shall be fixed on the LGSF wall structure on studs and tracks by using metal screws. The panels shall be fixed first on the outer side of the LGSFS wall. Electrical/plumbing pipes/conduits shall be fixed as per the electrical and plumbing layout. After completion, the panels shall be fixed inside the LGSFS walls and allocations for electrical and plumbing cutouts shall be marked on the panel.

4. Concrete Mixing and Pumping

Self-compacting concrete of required grade/light weight concrete shall be mixed using concrete mixing machine and then pumped into the gap between two panels using a special pumping unit. Care shall be taken to pump the concrete gradually and uniformly on all the walls. Concreting shall be done till the gap is completely filled up to the top of the LGSFS wall.

5. Construction of Roof Slab

The roof slab of the building shall be constructed by using metal/plastic shuttering and conventional concreting. Necessary steel reinforcement as per design shall be provided over the formwork and concreting shall be done to required thickness. Balcony and chhajja etc., wherever required shall also be constructed using formwork. After curing the slab, shuttering shall be removed and bottom of the roof slab putty finished.

6. Reinforcement

Deformed steel bars of 8mm/10mm dia. as per design shall be used.

7. Staircase and Railing

Staircase and balcony railing shall be fixed using conventional methods.

8. Fixing Electrical and Plumbing Fixtures

The panels shall be cut at the marked locations for fixing electrical and plumbing fixtures.

9. Fixing of Doors, Windows & Ventilator Frames and Shutters

The doors, windows & ventilator frames shall be fixed on the cutouts provided in the LGSFS. The frames shall be

made of WPC, uPVC and other materials, as required. Thereafter, the doors and windows shutters shall be fixed to the frames. The shutters shall be made of glass fibre/ HDF sandwich composite materials.

10. Fixing Floor Tiles

Floor tiles of desired quality and make shall be fixed to the floor, as required. Similarly, wall tiles of desired quality and make shall be fixed in the kitchen, bath and toilet using conventional methods, as required.

11. Surface Finishing and Painting

Cement based putty shall be applied on the outside and inside walls and then painted with desired colour.

SPECIAL FEATURES

Structural Stability

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.

Durability

Buildings shall be designed as per codal provisions of IS 456.

Behavior in earthquake

The buildings shall be designed for loads in accordance with IS 875 (Part 1 to 5) and IS 1893 (Part 1).

Behavior in wind

The wind loads shall be as per IS 875 (Part 3).

Fire Safety

During fire performance oriented test, it was observed that there was some minor cracks on the surface of all the walls.

Rain

During the ponding on roof slab for 24 hours, no dripping or leakage of water through roof slab or drop patches were observed on underside of the roof slab.
During rain simulation of external face of the wall by jetting for 12 hours, no leakage of water, dampness or sweating were observed on inner face of the wall.

Thermal Performance

There was a reduction in temperature upto 4ºC inside the unit indicating that it has got a good thermal comfort.

Acoustic Performance

The unit has got a good acoustic comfort.

Light weight

Weight of the LGSFS-ICP building is about 20-30% lighter when compared to conventional building thereby resulting in material and energy savings.

Limitation of Use

- LGSFS-IPC Technology may be used for construction upto G+3 storey Buildings only.
- For more than G+3 storey buildings, hybrid construction methods shall be used.

Critical Details

- 10 mm thick plaster on external walls shall be provided to take care of water proofing.
- Guard bars and wooden/steel windows shall be provided. Aluminium sliding windows shall be avoided.
- Sun shades shall be provided for all windows/external doors as per design.

WORKS COMPLETED

1. Police Constable Quarters (G+1) building for Karnataka State Police Housing Corporation Ltd., Bangalore in 2012.

CERTIFICATION

Performance Appraisal Certificate No. 1028-S/2016 has been issued to M/s Society for Development of Composites, Bangalore by BMTPC.

STANDARDS/REFERENCES

• Design and Construction of "2 Police Constables Quarters (G+1) building for Karnataka State Police Housing Corporation Ltd., Bangalore" by the manufacturer	
• Technical Report on "Light Gauge Steel Frame Structure with Infill Concrete Panels for Fast Tack and Disaster proof Housing"	
• Structural Analysis Report for "G+2 storey building constructed using LGSFS-ICP Technology" by M/s Nagesh Consultants, Bangalore	
IS 277:2003	Specifications for Galvanized Steel Sheets (Plain & corrugated)
IS 383:2016	Specifications for fine and coarse aggregates for concrete
IS 456:2000	Code of practice for Plain & Reinforced concrete (Reaffirmed 2016)
IS 800:2007	Code of practice for general construction in steel (Reaffirmed 2012)
IS 801:1975	Code of practice for use of Cold Formed Light gauge Steel structural members in General building construction (First Revision) (Reaffirmed 2016)
IS 875 (Parts 1,2,4&5):1987	Code of Practice for Design Loads (other than earthquake) for buildings & structures (Reaffirmed 2013)
IS 875 (Part 3):2015	Code of Practice for Design Loads (other than earthquake) for buildings & structures - Part 3 Wind Loads
IS 1786:2008	Specifications for high strength deformed steel bars and wires for concrete reinforcement (Reaffirmed 2013)
IS 1893:2016	Criteria for Earthquake Resistant Design of Structures (Part 1) - General Provisions and Buildings
IS 1904:1986	Code of Practice for design and construction of foundations in soils: General requirements (Reaffirmed 2015)
IS 2062:2011	Specifications for hot rolled medium & high tensile structural steel
IS 2095 (Part 1):2011	Specifications for gypsum plaster boards - Part 1 plain gypsum plaster boards (Reaffirmed 2016)
IS 9012:1978	Recommended practice for shotcreting (Reaffirmed 2016)
ASTM C1513-10	Standard specification for steel taping screws - cold formed steel framing connections
EN 14889-1-2006	Fibre for concrete, steel fibres - definitions, specifications and conformity
EN 14889-2-2006	Fibre for concrete, polymer fibres - definitions, specifications and conformity

Steel Structural Systems

Factory Made Fast Track Modular Building System

(Suitable for Low Rise to High Rise Structures)

ABOUT THE TECHNOLOGY

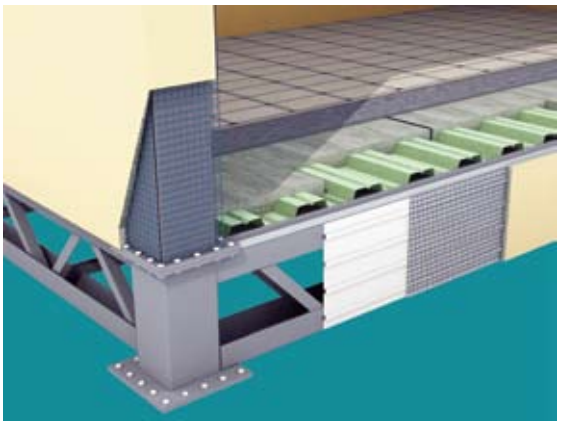
Factory Made Fast Track Modular Building System comprises of prefabricated steel structure with different walling components. About 70 percent of the work is done in the factory with minimal usage of concrete, which enables system to deliver the building within a few days of work at site. The steel moduled 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) & IS 875 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 and IS 801.

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.

STANDARDS/REFERENCES

• Report of Seismic Evaluation of Model of G+7 CRC framed structure for a ground motion compatible to zone V spectrum by SERC, Chennai.	
• Inspection Report of the visit for Performance Appraisal Certification.	
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 7:2016	National Building Code of India 2016.

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), AS/NZS 4600 and the Australian Composite Standard AS 2327 (Part-I). The design load shall be taken as prevalent in IS 875 (Part 1 & 3). Earthquake forces shall be taken in accordance with IS 1893 (Part-1).

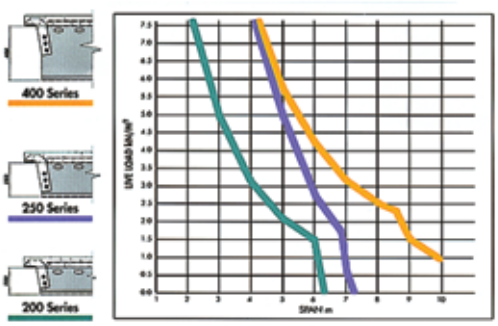
The section properties and design parameters are calculated from the section geometry, supplementary full scale tests and finite elements analysis.

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:

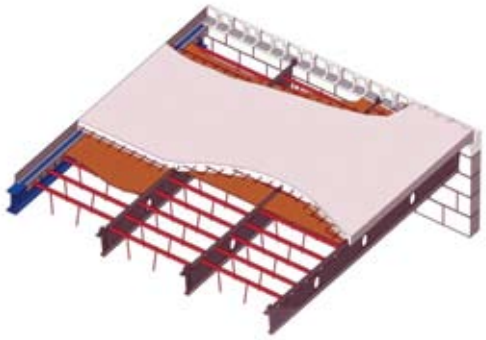
Depth (mm)	*Weight (kg/ In m)*
200	9.41
250	10.59
300	11.76
350	12.94
400	14.12



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.

STANDARDS/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

Precast Concrete Construction Systems

SRPL Building System (Waffle Crete)

(Suitable for Low Rise to Medium Rise Structures)

ABOUT THE TECHNOLOGY

Waffle-Crete Building System consists of large, structural, ribbed panels of reinforced precast concrete, bolted together and the joints between the panels are caulked to form the walls, floor and pitched or flat roofs of buildings.

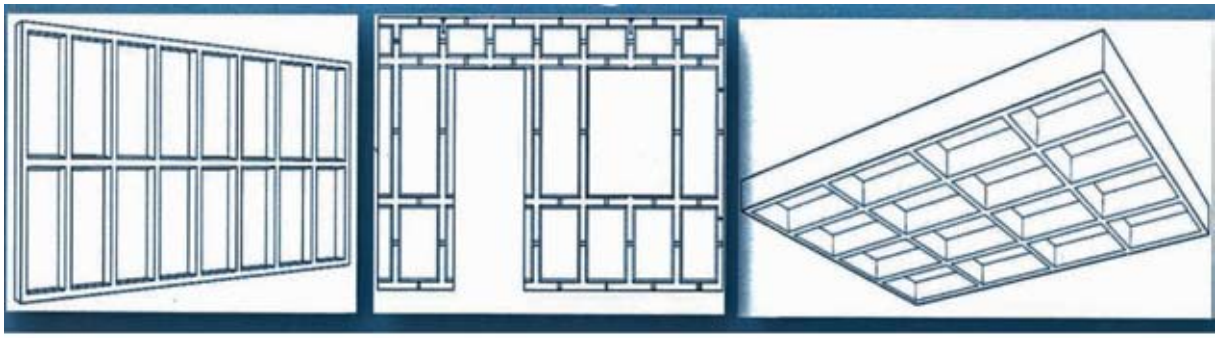
The surface of each panel consists of 51 mm thick slab or skin, stiffened with the ribs around the perimeter and across the panel, giving an overall panel thickness of 152 mm or 203 mm.

In single storey buildings, floors are constructed using precast reinforced concrete floor panels supported on precast concrete grade beams on well- compacted earth. The walls are constructed of 152 mm thick wall panels of precast reinforced dense concrete.

For buildings of more than one storey, the walls are supported on foundations designed as per the soil condition. A concrete apron are laid around the perimeter of buildings where there is a danger of water or wind erosion of the ground adjacent to the building. Metal or timber window and door frames are incorporated into the wall panels during casting or fitted after erection into openings that are formed in the panels during casting.

Internal walls consist of either reinforced precast concrete ribbed panels, conventional masonry walls or concrete walls. Where precast concrete panel or masonry internal walls are used in single storey buildings, these are normally be erected on a concrete surface bed or on concrete strip footings and not on *suspended floor*.

Services like water supply and electricity shall be normally accommodated in preformed slots in the ribs of panels, before the walls are lined. The casting can be done in casting yard while foundation is done, which reduces the construction time. Curing time is reduced by trapping the moisture generated from the concrete. The building after construction can be shifted from one place to another as the structure is joined using bolt connections.



Standard wall panel | Harmonized wall panel | Ceiling/floor panel

The Waffle-Crete system consists of the following core elements:

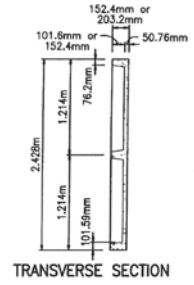
- Lightweight insulated precast insulated molds
- Insulated curing covers that are used in conjunction with Waffle-Crete molds
- Specialized equipment are designed for use with Waffle-Crete molds and covers
- A construction methodology for casting and erecting concrete panels with molds and equipment.

Concrete panels cast in molds and then covered with a curing cover are removed from the mold and erected. Modular panels and bolted connections speed up the erection process. The system can be utilized for a variety of structural applications.

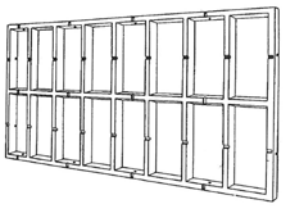
TYPE OF PRECAST CONCRETE PANELS & WALLS

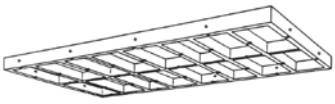
1. Standard reinforced precast concrete wall, floor and roof panels are 2.43 m wide and are manufactured in lengths of 3.65 m, 4.26 m, 4.87 m, 5.48 m, 6.09 m & 7.31 m. The surface of each panel shall consist of a 51mm thick slab, stiffened with tapered ribs around the perimeter and across the panel. The ribs shall be at approx. 1214 mm centres in one direction and 610 mm in the other and give an overall panel thickness of 152 mm or 203 mm, as required.

2. Harmonized reinforced precast concrete wall panels are 2.58 m high and are manufactured in lengths of 3.65 m, 4.26 m, 4.87 m, 5.48 m, 6.09 m & 7.31 m. All harmonized panels shall be 152 mm or 203 mm thickness. The surface of these panels shall consist of a 51 mm thick slab, stiffened with ribs around the perimeter and across the panel. The ribs shall be at approx. 610 mm centers,with two horizontal ribs along its length, one approx. 836 mm from the bottom and the other 418 mm from the top. These panels are used for window/door and window cut-outs.

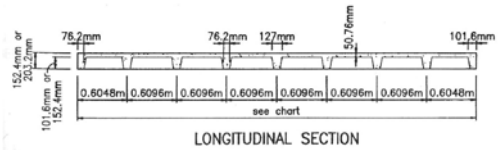


TRANSVERSE SECTION


WALL PANEL – 2.438m height


FLOOR SLAB – 2.438m span

Standard Panel Sizes	
W-12	3.6481m
W-14	4.2576m
W-16	4.8673m
W-18	5.4769m
W-20	6.0865m
W-24	7.3057m
special sizes available	



LONGITUDINAL SECTION

3 Accessory Panels

a) Eave panels are used as decorative building trim and also cover waffle voids that may be exposed on the edges of cut roof panels.

b) Grade beams are used to cast a first floor foundation. Grade beam panel are keyed to fit floor panel ribs.

c) Stair panels are included an adjustable blockout to cast concrete stairs of variable width up to 2.44 m. Stair molds are available in 3.66 m & 6.10 m lengths with 164 mm risers.

4 Waffle-crete Floor Slabs

Thickness of concrete of topping may vary for different requirement of fire ratings. Floor slabs with a 60 minute fire-resistance rating shall require a minimum of 38 mm concrete topping and floor slabs with a 120 minute fire-resistance rating shall require a minimum concrete topping of 75 mm or cladding to the underside.

The joints between the plasterboard shall be sealed according to the manufacturer's recommendations. Floor slabs with a 30 minute fire-resistance rating shall not require a concrete topping. Thickness of concrete topping may vary for different requirement of fire-ratings.

5 Type of Walls

5.1 There are six types of internal and external walls which are used in conjunction with brick or concrete masonry walls etc. The wall panels are 152 mm or 203 mm thick overall.

i. **Type 1** 152 mm or 203 mm panels, unlined.
ii. **Type 2** Wall panels lined on one side with 12.5 mm thick gypsum plasterboard on 38 mm x 38 mm timber studs at 600 mm centers fixed to the panel ribs with screws into nailer blocks cast into concrete at 600 mm centers.
iii. **Type 3** Wall panels lined on one side with 12.5 mm thick gypsum plasterboard of 63.5 mm x 35 mm x 0.71 mm thick on galvanized steel studs spaced at maximum 450 mm centres fixed to the ribs of the panels with 18 gauze steel galvanized wire wound around threaded 6 mm dia. galvanized steel fasteners hand-driven into a previously drilled hole in the rib of the floor panel.
iv. **Type 4** Wall panels lined on one side with two layers of 12.5 mm thick gypsum plasterboard on galvanized steel studs with staggered joints similar to those used in Type 3 wall fixed to the panel ribs in the same manner as wall Type 3.
v. **Type 5** Wall panels lined on one side with 12.5 mm thick gypsum plasterboard on top hat section galvanized steel channels fixed to the panel ribs as for wall Type 3 and insulated with 150 mm thick glass fibre.
vi. **Type 6** Wall panels lined on one side with 12.5 mm thick gypsum plasterboard on timber studs fixed to the panel in the same manner as for wall Type 2 and insulated with 50 mm thick glass fibre.

MATERIAL REQUIREMENTS

Rebar Fe 415/485 are in accordance with IS1786:2008 and of dia. 12 mm, 16 mm & 20 mm.

Wire mesh is made of 6 mm dia. bar as per IS1786:2008 @ 300 mm c/c.

Connection bolts M 16 x160 mm, M 16 x 380 mm & M 16x310 mm conforming to ASTM A 307 Gr A/IS 1363 (Part1-3):2002.

Anchor bolts HIT V M16 & HY 200R chemical conforming to ASTM A 307 Gr A/ IS 1363 (Part 1- 3):2002.
Concreting to be of M 30 grade concrete in accordance with IS 456:2000, without fly ash and coarse aggregate shall be not more than of 20mm size. Water-cement ratio to be 0.40. Mix design with admixtures conforming to IS 9103:1994 shall have compressive strength of 19 N/mm^2 in 18-24 h.

Swift lift Anchor have two anchors in each wall panel and four anchors in each floor panel. Spacing of anchors to be according to cut-outs provision in respective panel.

Gypsum board conforming to IS 2095 (Part 1):2011.

MANUFACTURING PROCESS

Process of manufacturing of the panels is as follows:

i) Waffle-Crete components shall either be cast on site or in casting yard. An inverted panel or a concrete surface bed shall be used as a base on which the components shall be casted.
ii) The heavy quality insulated plastics and aluminium molds shall be blocked off at any point if a particular non-standard sized panel is required.
iii) Holes for bolted connections between components shall be usually formed during the casting of the components.
iv) Metal, RCC or timber window and door frames shall be fitted in the block-outs left for the purpose.
v) Steel rod and mesh reinforcement shall be placed in the mold as specified by the professional engineer responsible for design of the building. Spacer blocks shall be used to correctly locate the reinforcement to ensure that the specified concrete cover is achieved.
vi) Concrete of minimum grade of M 35 MPa shall be poured into the molds from ready mix trucks / dumpers or other suitable means.
vii) Specially designed vibrator shall be used to strike off and compact the concrete in one operation.

viii) The insulated plastics and aluminium cover to the molds keep the heat and moisture during curing of the panels.

ix) The concrete components shall be lifted using specially designed lifting beam, or with cable slings and embedded lifting anchors at appropriate positions.

x) The panels shall be stacked horizontally on top of each other, supported on timber spacers and stored in the casting yard until required at site.

xi) Panels shall be de-molded after checking the results by rebound hammer

xii) Molds shall be stacked in the casting yard and curing of panels shall be done

xiii) The panels shall be transported to the erection location by trailer

xiv) The panels shall be lifted using crane and fixed on the location by connection bolts

xv) After connection bolts are fixed, panels shall be covered with high strength chemicals

xvi) Thereafter, finishing items like flooring, door & window fixing and painting etc. shall be done.

ERECTION PROCEDURE

(i) The properties of the soil on site shall be established by a professional engineer and the foundations and floors designed accordingly.

(ii) The conventional cast-in-situ concrete foundations and surface beds with thickened edge beams or footings, shall be constructed on site in accordance with IS 1904:1986. The surface beds shall be laid on well compacted earth.

(iii) When suspended floor panels and foundations are used, the grade beams shall be located under the longitudinal external walls of the building. They shall be placed in position on the surface of the ground on well compacted and levelled earth, laid end-to-end with butt joints.

(iv) Where the span between the grade beams on either side of the building is such that it is necessary to use two or more floor panels across the width of the building, the ends of the panels at the joints where they meet shall be supported by additional grade beams, laid parallel to the external grade beams.

(v) A continuous damp-proof membrane of a suitable plastic material, at least 0.25 mm thick, shall be provided under conventional concrete foundations and surface beds.

(vi) The wall panels shall be hoisted and set in a vertical position, onto hardwood shims on the panel floor, concrete footing or surface bed, to create a space of uniform thickness under the bottom ribs of the wall panels, for the grouted joint.

(vii) After levelling and aligning the wall panels on the shims, these shall be bolted to the floor panels and grade beams, or to the cast-in-situ concrete surface bed or foundations.

(viii) Where threaded galvanized steel or stainless steel rods are used instead of anchor bolts, the ends of the rods

shall be embedded in epoxy grout in holes drilled into the concrete, in strict accordance with the manufacturer's instructions.

(ix) Sand-cement grout having a compressive strength of 35MPa at 28 days shall be used in all horizontal joints between precast concrete components, unless otherwise specified by the engineer. A vibrator rod shall be used to ensure that the grout completely fills the joints.

(x) Intermediate floors shall always consist of panels which are bolted together. There are three types of floor to wall connections. In the first case the floor panel shall be supported on top of an external wall, in the second case two floor panels shall be supported on an internal wall and in the third case a floor panel shall be supported on a ledger beam.

(xi) Staircases which are of precast concrete shall be deigned in the normal manner and bolted to the supporting structure. At the beginning of a rise, the staircase shall be bolted with a 19 mm dia. vertical expansion anchor through a 76 mm x 76 mm 38 mm recess in the first step to the supporting structure. At the upper end of the rise, the staircase shall be fixed with a minimum of three 19 mm dia. x 254 mm long expansion anchors through the floor.

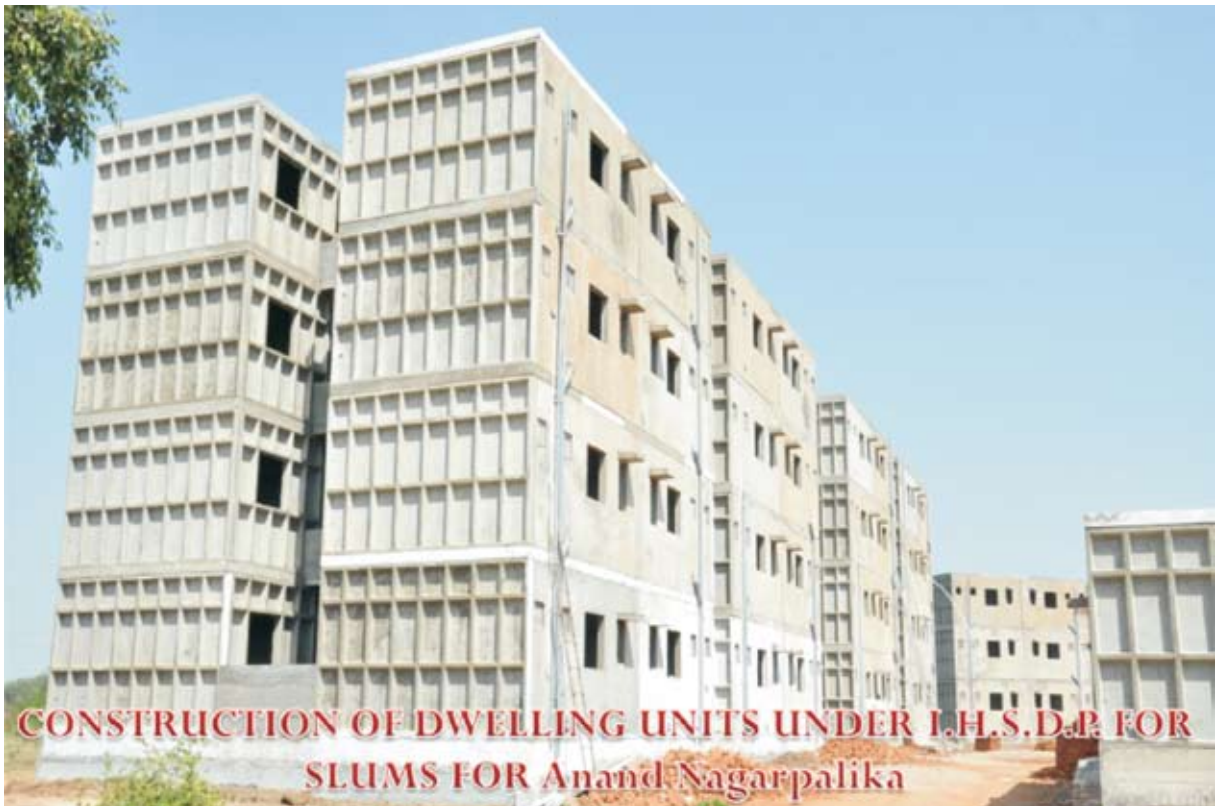
(xii) On the outside of the building, the grout shall be partially raked out of the horizontal joint all round between the bottom of the external walls and the floor, concrete surface bed or footing to allow for the insertion of butyl rubber rope, followed by a bitumen impregnated foam plastics backer rod or bond breaker and caulked with one component polyurethane sealant.

(xiii) The adjoining vertical ribs of the external panels shall be bolted together with 12.7 mm dia. galvanized steel or stainless steel bolts at 1.2 m centres through preformed or drilled holes for 152 mm thick panels or 20 mm dia. bolts at 1.2 m centres for 203 mm thick panels.

(xiv) The vertical joints between external wall panels shall be caulked on the outside of the building with one component polyurethane sealant a bitumen impregnated foam plastics backer rod or bond breaker.

Roof Construction and Gable Wall

(i) Triangular wall in-fill panels shall be hoisted into position on hardwood shims on top of the end walls of the building and bolted together through the adjoining outer horizontal ribs with 12.7 mm dia. galvanized steel or stainless steel bolts at 1.2 m centres.



(ii) Precast concrete roof panels which span between the gable ends shall be hoisted into position on the sloping tops of the gable wall panels and bedded in 6 mm thick 4:1 sand: cement mortar, to form a pitched roof. The pitch shall generally be 30º.

(iii) Galvanized steel plates, 60 mm long x 100 mm wide x 10 mm thick, at 2.4 m centres and cast into the ribs on the underside of the roof panels on either side of the ridge, shall be connected at the apex by welding a steel rod at the joint between each pair of plates.

(iv) Depending on the structural design of the building and span of roof, the roof shall be supported at its apex by a ridge beam spanning between the gable wall infill panels at each end.

(v) The adjoining roof panels shall be bolted together with 12.7 mm dia. galvanized steel or stainless steel bolts at 1.2 m centres, through preformed or drilled holes in the ribs of the panels. Before fully tightening the bolts, butyl rubber rope shall be inserted into the joint between the panels, followed by a bitumen impregnated foam plastics backer rod or bond breaker and the joint shall be caulked externally with one compound polyurethane sealant or equivalent.

(vi) Flat roof shall consist of 152 mm or 203 mm thick precast reinforced ribbed wall panels bolted together and covered with a conventional waterproofing system on screed. Precast roof copings shall be bolted to the roof panels with 12 mm dia. bolts at 1219 mm centers.

(vii) Internal walls on suspended floors shall usually be constructed of timber with 12.5 mm thick gypsum plasterboard cladding on both sides. Conventional burnt clay or concrete masonry internal walls shall usually be erected on conventional concrete surface beds and foundations.

(viii) Internal walls shall also be plugged and screwed by means of steel brackets and bolts to the adjacent vertical ribs of the external walls at T-junctions and bolted or plugged and screwed to concrete surface beds or precast floors.

Windows, Doors, Services and Attachment of Fittings

Timber or steel window and door frames shall be fitted into preformed openings in the wall panels and sealed all round with silicone sealant, unless they have been cast in during manufacture of the panels.

Electrical and plumbing services shall be installed in the preformed notches on inside of the wall panels, or through sleeves cast into the ribs.

Sanitary fittings, cupboards, shelving, and other heavy fittings shall be attached to the walls with galvanized steel bolts taken through holes drilled in the backing skin of the wall panels, or with expansion bolts fixed to the panel ribs.

Protection against corrosion and finishes

Steel bolts, anchor bolts, nuts, washers, threaded rods, brackets and cleats used at connections and joints in external walls, roofs, floors and foundations are hot-dip galvanized in accordance with IS 4759:1996 and coated with a metal primer, a good quality bituminous paint or epoxy painting or they are of stainless steel.

The exterior surface of roofs and external walls shall be painted with two coats of suitable exterior grade acrylic emulsion paint. Painting of reminder of the building shall be carried out in accordance with the manufacturer's requirements.

APPLICATIONS

The system is used for low rise to mediurm rise mass housing projects, commercial buildings, manufacturing facilities, retaining walls etc.

SPECIAL FEATURES

Structural Stability

The strength of connections between components and with recessed bolts shall be determined by test before use. In addition to conventional structural design aspects, the design of the building shall address the following:

- Stability of gable walls
- Bracing of façade walls against wind loads
- Structural integrity and resistance to progressive collapse due to accidental damage to local elements.

Durability

The structural design shall comply with all the relevant Indian Standards, including IS 456:2000, IS 875 (Part 1, 2 & 3):1987, IS 4326:2013, IS 1893 (Part 1):2016, IS 13920:2016 & National Building Code of India 2016. Reference shall also be made to the design recommendations given in Waffle-Crete's design manual and specifications.

Behavior in earthquake and wind

All precast concrete floor, wall and roof panels and grade beams shall also be designed for loading conditions during de-molding, transportation and erection.

Fire Safety

Floor slabs with a 60 minute fire-resistance rating shall require a minimum of 38 mm concrete topping and floor slabs with a 120 minute fire-resistance rating shall require a minimum concrete topping of 75 mm or cladding to the underside

MAJOR COMPLETED PROJECTS

- 464 Dwelling units under IHSDP for slums of Anand Nagarpalika (Gujarat)
- 480 Dwelling units of Dahod Nagarpalika (Gujarat)
- 512 Dwelling units Housing (G+3) at Bharuch Nagarpalika, Bharuch (Gujarat)

CERTIFICATION

Performance Appraisal Certificate No. 1021-S/2015 issued to M/s Shaival Reality Pvt. Ltd., Ahmedabad.

STANDARDS/REFERENCES

No. 97/260	South Africa Agreement Certificate No. 97/260 for Waffle-Crete Agreement System of Waffle-Crete International Inc
IS 158:1981	Ready mixed paint, brushing, bituminous, black, lead free, acid, alkali and heat resisting
IS 456:2000	Code of Practice for Plain and Reinforced Concrete (Reaffirmed 2016)
IS 875 (Parts 1&2):1987 IS 875 (Parts 3):2015	Code of Practice for Design Load of Buildings and Structures (Reaffirmed 2013)
IS 1363:2002	Hexagon Head Bolts, Nuts and Screws of Product
IS 1367:2002	Technical Supply Conditions for Threaded Steel Fasteners
IS 1786:2008	High strength deformed steel bars and wires for concrete reinforcement - specification (Reaffirmed 2013)
IS 1893 (Part 1):2016	Criteria for Earthquake Resistant Design of Structures (Part 1). General Provisions and Buildings.
IS 1904:1986	Code of practice for design and construction of foundations in soils – general requirements (Reaffirmed 2015)
IS 2095 (Part 1):2011	Specifications for gypsum plasterboards –Plain gypsum plaster boards (Reaffirmed 2016)
IS 4326:2013	Code of Practice for Earthquake Resistant Design and Construction of Buildings
IS 4759:1996	Hot Dip Zinc Coating on Structural Steel Products
IS 7215:1974	Tolerances for Fabrication of Steel Structures (Reaffirmed 2016)
IS 9103:1999	Concrete admixtures - Specification (Reaffirmed 2013)
IS 10505:1983	Code of practice for construction of floors and roofs using precast concrete waffle units (Reaffirmed 2013)
IS 13920: 2016	Code of practice for ductile detailing of Reinforced Concrete Structures subjected to seismic forces.

Precast Large Concrete Panel System

(Suitable for Low Rise to High Rise Structures)

ABOUT THE TECHNOLOGY

Precast Large Construction Panel (PLCP) system consists of various precast elements such as walls, beams, slabs, columns, staircase, landing and some customized elements that are standardized and designed for stability, durability and structural integrity of the building. Precast residential building construction involves design, strategic yard planning, lifting, handling and transportation of precast elements. This technology is suitable for construction of high rise buildings resisting seismic and wind induced lateral loads along with gravity loads. The building framing is planned in such a way that maximum number of repetitions of moulds is obtained. These elements are cast in a controlled factory condition. The factory is developed at or near the site which provides an economical solution in terms of storage and transportation.

TYPES OF PRECAST ELEMENTS AND MOULDS

Two main types of precast concrete elements, namely precast reinforced concrete elements and precast pre-stressed concrete elements are used as per the details given below:

i. Precast reinforced concrete elements

These shall consist of reinforcement bars and/or welded wire meshes within the elements to provide the tensile strength and resistance against cracks such as façade walls, beams, columns, slabs, refuse chutes, staircases and parapet walls.

ii. Precast pre-stressed concrete elements

These shall consist of pre-stressing tendons within the elements to provide a predetermined force needed to resist external loadings and cracks such as hollow core slabs, beams and planks.

Typical size of precast elements is given below:

Sr. No.	Precast Components	Typical Sizes*
1	Wall Panels	5m x 2.85m
2	Slabs	3m x 5m
3	PODS	1.52m x 1.36m x 2.83m
4	Beam	0.20m x 0.40m x L
5	Staircase	As per design
6	Columns	0.90m x 0.35m x 2.85m

** Sizes of panel slabs may vary as per the architectural and construction requirement.*

iii. Moulds

Moulds for precast elements shall be of steel and concrete. For design of the moulds for various elements, special importance should be given to easy de-moulding and assembly of the various parts. At the same time rigidity and strength and water tightness of the mould are also important taking into consideration forces due to pouring of green concrete and vibration. The type of moulds used for pre-casting various elements with various methods is given below:

Sr. No.	Mould Type	Uses
1	Conventional moulds	Ribbed slab, beams, window panels, box type units and special elements
2	Battery moulds	Interior wall panels, shell elements, roof and floor slabs
3	Tilting moulds	Exterior wall panels where special finishes are required on one face or for sandwich panels
4	Long line prestressing beds	Double tees, ribbed slabs, piles and beams
5	Extrusion machine	Roof slabs and hollow core slabs

Battery Mould

Tilting Mould

POD Mould

MATERIAL REQUIREMENTS

Ordinary Portland Cement: Shall be of 43 grade as per IS 269:2015.

Fine aggregate (M Sand): Shall be as per IS 383:2016 & IS 1542:1992 and 4.7 mm.

Coarse Aggregates: Shall be as per IS 383:1970 and of 20 mm, 40 mm size

Steel reinforcement: Shall be as per IS 1786:2008

Concrete: The grade of concrete shall be M 30 and slump for walls, floors and roofs shall be as per IS 456:2000.

Brick masonry: Shall be designed as per IS 1905:1987

Solid Block work: Shall be as per IS 2185 (Part 1):1979

Aluminium: Shall be as per IS 733:1983

Glass: Shall be as per IS 2835:1987

Non-shrunk non-metallic grout: Cement based flowable grout shall have compressive strength of 65 N/mm^2, flexural strength of 9 N/mm^2 at 28 days and E-modulus of 37000 N/mm^2.

Water proofing membrane: Fibre reinforced repair mortar shall have compressive strength of 45 N/mm^2 at 28 days and density 2250 kg/m^3

Baker Rod: Closed cell polymer based product shall have compressive strength of 0.45 kg/cm^2 min. at 25% deflection, density 22 kg/m^3 min. and water absorption 0.14 gm/cm^3 max.

Corrugated sleeve: Hot dipped galvanized prime steel sheet shall be as per IS 277:2003.

APPLICATIONS

The system is used economically for mass housing projects and commercial buildings, etc.

INSTALLATION

1. Precast Installation

Proper planning and preparatory works shall be required before the actual installation of precast concrete elements in order to ensure quality installation. The following items shall be planned in advance:

i. Method of sequence of assembly and installation: Precast elements should be identified based on their location number and the tagged.
Ii. Method of providing temporary support: Elements should be supported temporarily before these get stabilized. Generally structural members with adjustable ends shall be used for securing the panels. Shims should be used to adjust the panels to ensure dimensional correctness.
iii. Installation tolerances: Installation tolerances should be based on codal provisions and design considerations should be clearly indicated.
iv. Handling and rigging requirements: Elements should be checked for handling stresses before lifting and the cranes should have sufficient capacity to handle the precast panels. At least 10% impact should be considered while calculating the lifting capacity of the crane.

At site locations, panels shall be first unloaded and stacked or directly lifted by the crane. The element shall then be installed on the site and supported by temporary jacks. The cranes shall be released for next lifting once the temporary supports are in place. Shims shall be used to carefully align the element before grouting. The panels shall be grouted after the final adjustments are done.

2. Waterproofing

External joints shall be sealed with baker rods and sealants after filling the joints with grout to avoid the leakage. Additional waterproofing treatment shall be provided at external joints and wet areas to ensure water tightness.

3. Mechanical, Electrical & Plumbing Fittings

- Mechanical, electrical & plumbing fittings shall be kept open or concealed as per the requirements. For concealed fittings, provision for grooves, blockouts shall be made in casting moulds.
- The conduits and electrical boxes shall be embedded and fixed in moulds before casting. For open fittings, these shall be fixed after erection at site.
- For firefighting systems, provision of National Building Code (NBC) and local Building Byelaws shall be adhered to.

4. Fire Rating

- Precast concrete shall be designed for fire rating of 1 to 2 h based on codal requirements.
- Minimum precast concrete wall thickness of 120 mm shall be provided for 1 h fire rating as per IS 456:2000.

5. Finishes

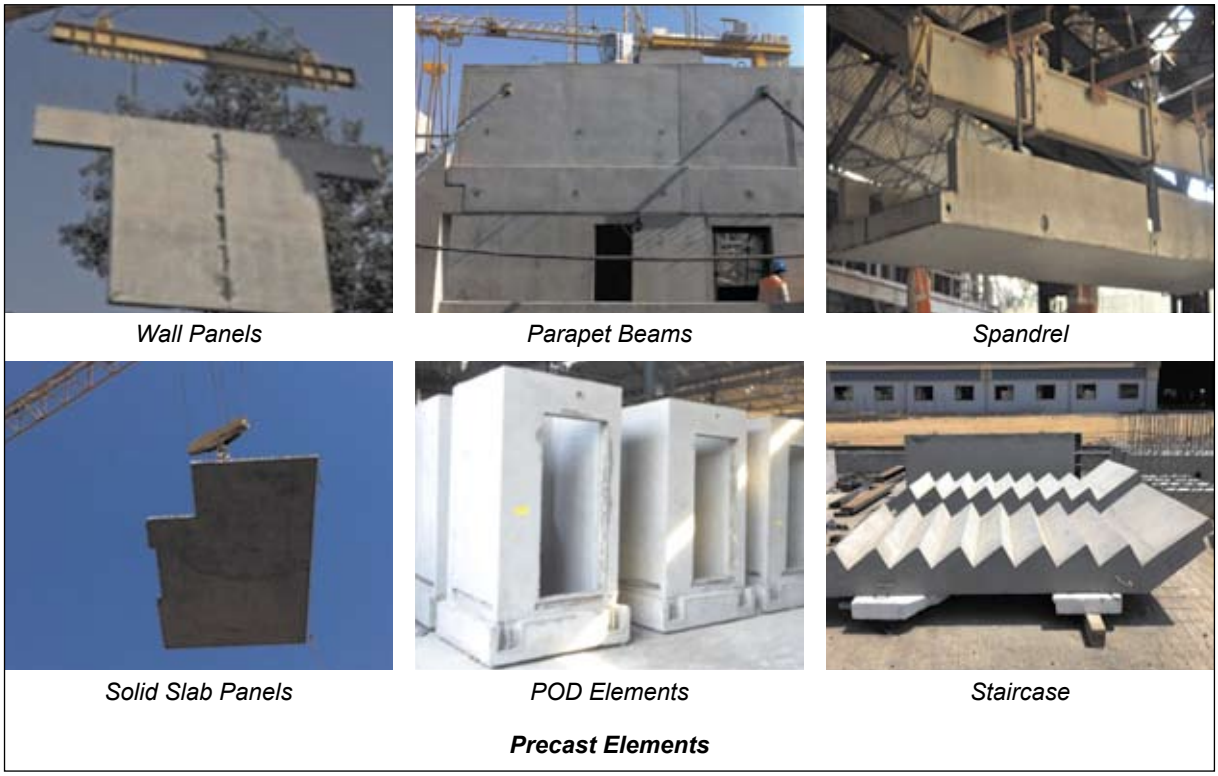
- Variety of shapes, colours, textures and finishes may be obtained with precast concrete.
- The surface treatments shall be done by rebating, grooving, surface coatings, cement based renders, oxide coloring etc.
- Precast concrete facades of various shapes, colours and textures may be moulded and installed.

IMPLEMENTATION OF PRECAST ELEMENTS

1. Casting Concrete

The procedure for casting concrete shall be as follows:

i. Precast concrete elements shall be produced on horizontal/vertical, flat steel surfaced tilting tables.
ii. Prior to casting, electrical conduits and other required shall be fixed in position and the mould treated with mould release agent.
iii. Steel reinforcement shall be kept in position using adequate spacers to ensure correct position and concrete cover.
iv. After that side shutter shall be fixed. The high quality concrete shall be transported from batching plant to the precast yard through transit mixer.
v. Thereafter, concrete shall be carried to mould by gantry crane with concrete bucket.
vi. During casting, table vibrators (as & when required) shall be used to achieve the best compaction. Top surface shall be finished with hand operated trowel which gives smooth finish.



Precast Elements

vii. Care should be taken on embedded items while concreting.

viii. After casting, all exposed surfaces shall be covered with a tarpaulin (as and when required) to avoid vaporization. Casted elements shall be de-moulded once the strength meets the design requirements and the units are then shifted to the stockyard. Thereafter, curing shall be carried out for 5 days.

2. Curing

The curing of the prefabricated elements may be done by the normal methods of curing by sprinkling water and keeping the elements moist. This can also be done in the case of smaller elements by immersing them in specially made water tanks.

3. Screed Concrete for Flooring

The surface for screed concrete shall be clean, free from dust, loose materials, lumps and foreign material.

The screed shall generally be provided over the entire slab. In this case the entire slab shall act as a continuous structural diaphragm providing optimum load transfer mechanism for lateral loads. The screed shall be treated as a part of the compression zone for gravity loads on the slab. The design shall consider composite action between the slab & screed and compressive strength of screed in slab. Further, the interface shear between the slab & screed shall be checked for verifying adequate shear transfer capacity at the interface.

i. Screed on haunches may be provided, only if the conduits are exposed, with the mutual agreement between the project authority and the technology provider. In such cases, additional water proofing treatment of a reputed company shall be provided at the precast slab and site concrete stitch.

ii. Electrical conduits or any other embedment shall be laid as per approved drawings before screed concrete flooring.

iii. The reference level from main survey pillars shall be transferred and marked on side channels.

iv. While marking level, sloping direction in flooring shall be taken care as per approved drawing.

v. Before laying the concrete, cement slurry shall be spread on the slab surface for better bonding and filling of gaps between wall and slab soffit junction.

vi. The concrete should be placed from one end and shall be compacted immediately after placing and levelled uniformly.

vii. The vibrator should be applied smoothly and concrete compacted well.

viii. The concrete shall be allowed to set so as to be in dry condition.
ix. The trowelling shall start after concrete is set and reach dry condition.
x. Curing shall be done by using bunds over the screed surface/wet hessian cloth.

4. De-moulding and Stacking

4.1 Lifting of elements from mould

i. It must be ensured that all the elements should have identification mark.
ii. It must be ensured that all side shutters are loosened so that the elements may be lifted without any damages.
iii. Before demoulding, it must be ensured that compressive strength of the cubes should meet the specified requirements.
iv. The lifting clamps/clutches shall be fixed to lifting beam at proper positions.
v. Then the elements shall be lifted carefully to the stocking area.

4.2 Stacking of elements

i. The surface of stacking area should be horizontal.
ii. The wooden runner shall be placed perpendicular to lifting points and the elements placed over runner.
iii. Number of the elements per lot should not exceed man height.
iv. In case of vertical stacking, the gap between the elements should be 150mm to 200 mm.
v. Stacking shall be done in such a way that slabs of longer span should be placed below that of shorter span.

5. Transportation of Elements

5.1 Loading of slab over trailer

i. It must be ensured that the identification mark on the slab should be the same as per dispatch list.
ii. Any damage occurred during loading should be informed to the concerned authority.
iii. The lifting clamps/clutches shall be fixed to the lifting beam at proper position.
iv. The lifting beam shall be placed over the precast elements and ensured that the clutches are locked properly before lifting.
v. Instruction regarding loading height, positioning of precast elements over the trailer should be followed as per capacity of trailer.
vi. The wooden rubber shall be placed in between the slabs at 500 mm from each end.
vii. Some of precast elements should be placed vertically and transported through “A” frame fixed vehicle.
viii. The slab shall not be overhanging from trailer.
ix. The slab shall be tied firmly to the trailer by means of belt/rope as moving the load without proper tie will cause damage.
x. While transporting elements vertically, the vehicle should be loaded equally on both sides.

5.2 Unloading of slab from trailer and placing in site yard

i. Every slab shall be inspected for dimensions/identification mark and damages etc. prior to unloading at site.
ii. The stacking area should be levelled and hard enough for stacking the elements.
iii. There should be proper access for trailer movement.

6. Erection

The process of erection and installation of panels during the construction cycle by using tower cranes shall be as follows:

i. Before starting erection a survey of the area to receive precast elements shall be done to monitor any difference in dimensions or levels exceeding the tolerances. In case of unacceptable tolerances, necessary action shall be taken for rectification.
ii. Installation shall be done by tower crane with sufficient capacity. Panels shall be shifted from the stack rack/truck from yard to the nearest point of construction site and shall be kept above the truck during the construc-

tion or inside the storage racks as per the site situation.

iii. The necessary access for the truck to reach the nearest point of the tower shall be prepared before starting erection of the panels.

iv. Once the truck reaches the tower, chain and lifting clutch with required capacity and guide rope shall be attached to the precast panels to allow the workers to control the load to its final place.

v. As the elements are lifted to its final position above the cast-in-situ slab/precast panel, vertical and horizontal alignment of the panel shall be adjusted. The gap between the element and adjusted elements shall be maintained as per the drawings within the allowable tolerances. Shims and spacers shall be used for levelling and adjustment.

vi. Temporary propping jacks shall be provided for restraining the walls laterally until grouting.

vii. After completion of fixing, alignment of the panels shall be checked again.

viii. Minor damages, if any to the precast panels shall be repaired by approved materials.

ix. After completion of installation and alignment, elements shall be handed over for inspection.

x. The joints between the precast wall panels shall be filled with joint filler material.

xi. Precast slab shall be erected above the wall panels without any scaffolding system. The electrical conduit/ fitting shall be done. After electrical works are completed, screed concrete shall be laid over the precast slab.

xii. Installation of the next floor shall start only after completion of screed concrete of the previous floor.

xiii. The sequence of erection shall be as follows:
- Installation of precast wall panels above cast-in-situ slab
- Provide temporary props/jacks for restraining of the walls laterally.
- Grout the connection between the wall panels & ground floor slab and the joint between each wall panel.
- Installation of precast slab panels above the erected precast wall panels.
- Screed concrete above the slab after placing of electrical conduits / fittings
- Installation of the wall panels over the floor slab.
- Installation of the roof panels such as parapets etc.

SPECIAL FEATURES

Structural Stability

The overall behavior of a precast structure is dependent on the behavior of the connections which must provide:

- Resistance to all design forces
- Ductility in case of excessive deformation
- Resistance to volume changes and related forces
  - Adequate durability
  - Required fire resistance
  - Feasible production considerations
  - Feasible construction considerations

The overall design of the structure shall be done in accordance with IS 875 (Part 1 to 5), IS 456:2000, IS 1893(Part 1): 2016, IS 13920:2016 and IS 15916:2010, as applicable.

Large panels shall be in accordance with the provisions of IS 11447:1985.

Durability

Structural load bearing walls shall be designed as per codal provisions of IS 456:2000 and IS 13920:2016 as applicable.

Behavior in earthquake and wind

The components of the structure shall be designed for loads in accordance with IS 875 (Parts 1-5):1987 and IS 1893 (Part 1):2016. In addition members shall be designed for handling, erection and impact loads that might be expected during handling and erection.

Fire Safety

Period of fire resistance of RCC buildings is based on NBC requirements. To meet the fire rating requirement, provision specifications.

WORKS COMPLETED

1. Construction of (G+23) Pragati Towers at Mumbai in 1972 (2024 units).
2. Construction of (G+12/G+14) Provident Sunworth Project at Bangaluru in 2015 (5952 units).

CERTIFICATION

Performance Appraisal Certificate No. 1027-S/2016 issued to M/s Larsen & Toubro Ltd., Mumbai by BMTPC.

STANDARDS/REFERENCES

• Suitability of Precast Concrete Large Panel system for Mass Housing Projects by IIT Madras	
• Design & Construction Methodology Review for Rehab Bhiwada Precast Project, Mumbai by IIT Madras	
• Verification of Thermal Performance Reports – Evaluating RCC Wall apartments in Ahmedabad & Chennai by Indian Institute of Science, Bangalore.	
IS 456:2000	Code of Practice for Plain and Reinforced Concrete (Reaffired 2016)
IS 875 (Parts 1,2,4&5):1987 IS 875 (Part 3):2015	Code of Practice for Design loads (other than earthquake) of buildings and structures
IS 1786: 2008	High strength deformed bars and wires for concrete reinforcement (Reaffirmed 2013)
IS 1893 (Part 1):2016	Criteria for Earthquake Resistant Design of Structures (Part 1) - General Provisions and Buildings
IS 1904:1986	Code of practice for design and construction of foundations in soils – general requirements (Reaffirmed 2015)
IS 2062:1992	Hot Rolled Medium and High Tensile Structural Steel
IS 7215:1974	Tolerances for Fabrication of Steel Structures (Reaffirmed 2016)
IS 9103:1999	Specifications for Concrete admixtures (Reaffirmed 2013)
IS 11447:1985	Code of practice for construction of large panel prefabricates (Reaffirmed 2013)
IS 13920:2016	Code of practice for ductile detailing of Reinforced Concrete structures subjected to seismic forces.
IS 15916:2010	Code of practice for building design and erection using prefabricated concrete (Reaffirmed 2013)

Industrialized 3-S system using RCC precast with or without shear walls, columns, beams, Cellular Light Weight Concrete Slabs/Semi-Precast Solid Slab

(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

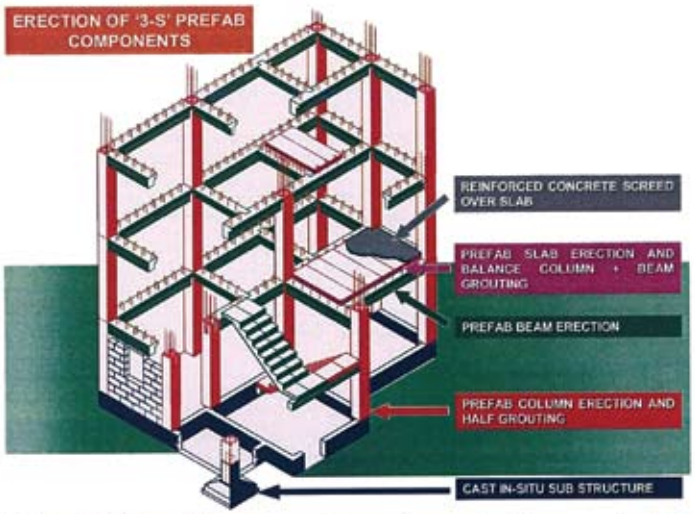
For 100 mm ACC Wall, Sound absorption is 38 – 40 db*

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 Projects 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 (Reaffirmed 2016)
IS 875 (Pt.3):2015	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 - Specification (Reaffirmed 2013)
IS 1893 (Pt.1):2016	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 (Reaffirmed 2015)
IS 2185 (Pt.3):1984	Specification for Concrete Masonry Unit - Part 3: Autoclaved Cellular (Aerated) Concrete Blocks (Reaffirmed 2015)
IS 3792:1978	Guide for heat insulation of non-industrial buildings (Reaffirmed 2013)
IS 6073:2006	Autoclave Reinforced Cellular Concrete Floor and Roof Slabs - Specification (Reaffirmed 2017)
IS 13920:2016	Ductile detailing of reinforced concrete structures subjected to seismic forces - Code of practice
NBC 2016	National Building Code, 2016

Walltec Hollowcore Concrete Wall

(Suitable for Non Load Bearing Structures)

ABOUT THE TECHNOLOGY

These are extruded non-load bearing concrete hollowcore wall panels manufactured in fully automated machines. Walltec wall panels are factory produced using light weight concrete made of river sand, crushed stone aggregate, light weight aggregate and Ordinary Portland cement. The concrete are extruded and cut while still wet to the requisite length. Curing and sealing are followed for 24 to 48 hours by stacking and palletizing after which the walls are watered and cured for a further period of 7 to 8 days. After 15 days the panels are ready for transportation to site.

Walls have cylindrical hollow cores incorporated with 7 No. 53 mm dia voids in the 92mm thickness and 6 No. 74 mm dia. voids for the 120 mm thickness panels. The corresponding nominal weight shall be 140 kg/m^2 and 170 kg/m^2 for 92 mm and 120 mm thick panels respectively. Hollows are incorporated in Walltec walls to reduce weight, facilitate mechanical, electrical and plumbing services through hollows, thereby increasing sound and thermal insulative properties. The sides of all panels are tongued and grooved to facilitate positive jointing.

Walltec walls do not require stone or wood sills/frames to level surfaces for windows and openings. Lintels need not be cast as panels may be placed horizontally as lintels wherever required. Wash basins, cup-boards, mirrors, paintings etc. may be hanged with regular plug screws. Details of the wall panels showing hollow cores is given in Fig.1

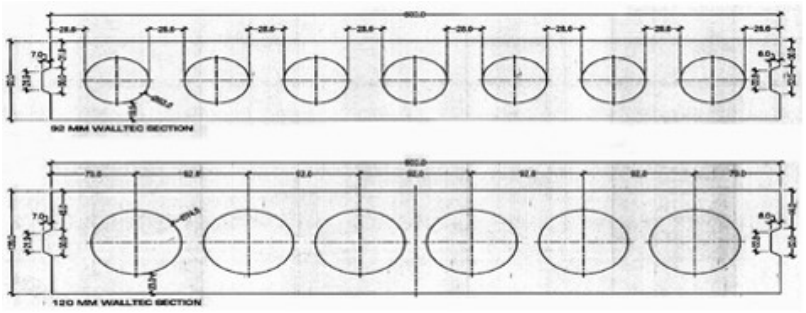


Fig.1

TYPE AND SIZE

Walltec walls are produced in standard widths & thicknesses and in lengths to suit room height as per the details given below and shown in Figs. 2 & 3:

Wall width	: 600 mm
Wall thickness	: 92 mm & 120 mm
Wall Height	: 2.40 m, 2.60 m, 2.85 m, 3.00 m, and 3.30 m
Weight	: 92 mm : 140 kg/m^2, 120 mm :170 kg/m^2

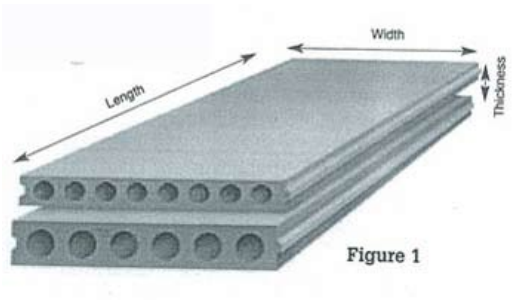


Fig.2

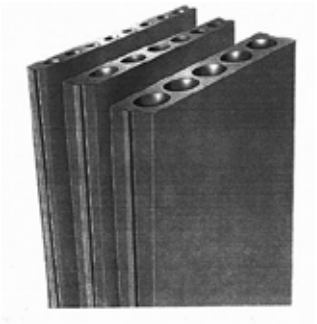


Fig.3

Walltec walls use regular concrete of density 2350 kg/m^3 and Walltec Lite uses light weight concrete of density 1550 kg/m^3.

TOLERANCES

The panels shall be produced in accordance with the following tolerances:

Length	: ±10 mm,
Width	: ±3 mm,
Thickness	: ±3 mm,
Squareness of end	: ±6 mm
Differential bowing between adjacent panels of the same Length	: =15 mm

RAW MATERIALS

i) OPC 53 grade cement shall conform to IS 12269:2013
ii) River sand and coarse aggregate 2-6 mm shall conform to IS 383:2016
iii) Flyash shall conform to IS 3812 (Part 1):2013
iv) Crushed Autoclaved Aerated Concrete (AAC) Waste

MANUFACTURING PROCESS

The manufacturing process of Walltec wall panels is as follows:

Raw Material
Sieved River Sand, 6mm Stone Aggregate, AAC Waste shall be supplied to the plant by supplier where it shall be weighed and sieve analysis & silt content checked as per the quality assurance norms. Cement shall be supplied in closed bulkers directly from the manufacturers' plant and fed into cement silo directly using blower. AAC Waste shall be crushed and sieved in using crusher & sieve combo machine which also has a dust collector shall collect superfine particles and the crushed AAC aggregate (8mm and lower fineness) shall be fed directly into the LWA (light weight aggregate) aggregate bin which shall be equipped with a moisture probe.

Concrete Mixing
Concrete required shall be batched and mixed at an automatic batching and mixing plant with Planetary Pan Mixer and Moisture probes. The relatively dry aggregates shall be automatically weighed & batched into the mixer from Aggregate Bins. Two of the Aggregate bins shall be equipped with moisture probes to ascertain accurate weighing and water content calculation later in the final concrete mix. Afterwards cement and water shall be added into the mixture. A low water-cement ratio of about 0.3 ensures that concrete is zero-slump and gains about 70% of its design strength within 12-24 hours of casting. Moisture content of the mixed concrete shall also be automatically controlled and adjusted by the software thus ensuring consistent concrete mix at all times. The software auto adjusts for water content based on readings of the moisture probes. After mixing, the concrete batch shall be fed to the conveying system, which brings fresh concrete to the hopper of the Acotec Wall – line where Walltec-Walls shall be cast, cut, trimmed, stacked, pre-cured, restacked and strapped into bundles.

Extrusion
The Walltec-Wall elements shall be formed in a continuously operating extruder. The concrete shall be compacted onto thin base moulds, which support the products during the pre-curing time. Base moulds shall be automatically fed to the extruder as a continuous ribbon. The base mould length shall determine standard length of the products. There can simultaneously be maximum five plate lengths in the system. The extruder shall compact the concrete with extrusion screws against the packing bar and side walls. Top surface of the product shall be vibrated by a vibrating plate.

Cutting
After extruding, the products shall be cut according to the base mould length. A circular saw shall cut the fresh concrete on each base mould seam. Then the cut product together with the supporting plate shall be pulled to the stacker.

Trimming

When necessary, the fresh product shall be stopped at a specified point, where the manually adjusted circular saw cuts off the wanted trimming piece. Trimming length shall be max. 20 cm. The trimmed off concrete shall be recycled back to the extruder.

Stacking

Cut, fresh products shall be stacked into pre-curing stacks. Depending on the product thickness and weight each stack shall contain 4 to 10 products and base moulds. Stacks shall be supported by steel pallets, which are automatically fed underneath each stack.

Pre-curing

The stacks shall stay 12 to 24 hours in the pre-curing indoor storage area where natural pre-curing occurs for each stack which is covered with tarpaulin to stop any evaporation and moisture loss. The storage shall be an area where natural curing occurs. Product stacks shall be moved into and out from the stock area by a forklift.

Restacking

After pre-curing the products are strong enough to stand automatic handling. Products shall be separated from the base molds. Base molds shall be returned back to circulation trough a cleaning and oiling unit. The products shall be restacked to form delivery stacks with 4 - 10 products on top of each other. The stack shall be pushed against a wooden delivery pallet and turned on its side. Delivery stacks shall be strapped before transportation to delivery storage. Stacks must stay in the delivery storage where they shall be kept moist by external manual water sprinkling for at least 7 days before transporting to a construction site after 15 days on a Truck or Flat-bed Trailer. Loading of trucks shall be done with Forklift or Hydraulic Cranes.

PERFORMANCE CRITERIA

Walltec wall panels shall meet the following performance criteria:

S.No	Properties	Test Method	Requirements as per relevant Standards	
			92mm	120mm
1.	Dry density (kg/m^2)	IS 516:1959	140 min.	170 min.
2.	Flexural strength N/mm^2	IS 516:1959	2.4 max.	3.5 max.
3.	Compressive strength N/mm^2	IS 516:1959	15 min.	25 min.
4.	Moisture content (%)	IS 516:1959	4.8 max.	4.8 max.
5.	Impact strength (Falling weight) (N)	ISO 179 2: 1997	>5	--
6.	Drying shrinkage (%)	IS 2185 (Part 1):1979	0.04 min.	0.04 min.
7.	Thermal conductivity (m^2.k/W)	IS 3346:1980	0.4 min.	> 0.4
8.	Sound transmission Class (dB)	IS 9901:1981	42 max.	44 max

INSTALLATION PROCEDURE

i) Only two stacks shall be put on top of each other during stocking and transportation.
ii) Panel stacks shall always be lifted from under wooden pallet with a lifting fork or belt.
iii) The panel stacks shall be moved by forklift or trolley to construction site. Individual panel may easily be moved by a simple wheel. Panels can also be moved manually by inserting a short tube (500mm) into the second hollow as handle. These shall always be transported sideways.
iv) Gluing agents (cement based adhesives) as per IS 9103:1999 shall be mixed as per the manufacturer's instructions.
v) The line of wall shall be marked on the floor and ceiling before start of installation.

vi) Guiding boards shall be fixed on the floor and ceiling. The guiding support will automatically align the wall when lifting the panels straight into upright position.
vii) The gluing agent shall be spread on the side of the already installed panel.
viii) Before the panel shall be lifted to upright position, it should be moved so that the panel bottom is as close as possible to its correct position. After that the panel shall be lifted to upright position.
ix) This panel shall be pushed against the previous panel (and move up and down) so that tongue and groove are carefully positioned against each other and gluing agent is squeezed out. Correct thickness of joint between two panels shall be 1 to 2 mm.
x) The panel shall be positioned to correct level by using wooden wedges at the bottom and top of the panel erected earlier. The height of the panel should be about 10 to 50 mm shorter than free-room height.
xi) The top joint shall be filled with polyurethane foam. Correct thickness of joint shall be 5 to 10 mm.
xii) Alternatively, when same gluing agent as in sides is used for top joint, the panel shall be pushed against ceiling so that gluing agent is squeezed out. Correct thickness of joint shall be 1 to 2 mm. The surplus gluing agent shall be removed from joints after installation.
xiii) Bottom joint of the panel shall be filled with mortar or concrete. Correct thickness of joint shall be 10 to 40 mm.
xiv) 'Shoulders' shall be sawed or flat steel bar for door top portion fixed to the panels next to the door. The door top piece shall be glued by using polyurethane foam or gluing agents. The joints should be as thin as possible.
xv) All corners shall be strengthened with nail plugs (3 per corner).
xvi) Paper or fibre tape shall be glued on to the corner joints and to the joints at a door top portion before plastering.
xvii) Flexible joints between panels shall be built after each 5 - 6m. Polyurethane foam or mineral wool may be used as elastic joint material.
xviii) The hollow boxes may be used for the cables and electrical boxes shall be fixed at the desired points after drilling.
xix) The panels need only a very thin skin coating (1-2 mm) before surface finishing. It may be easier to do with a wide trowel.
xx) All kinds of drilling and sawing can be easily made in the panels.
xxi) The necessary tools required for installation shall be hammer, saw, screw driver, level, meter rule, trowel, drill, trolley concrete cutter, steel bar, buckets and lifting bars.

Plumbing & Electrical

Walltec panels shall have hollows of 53mm dia. in 92mm wall and 74mm dia. in 120mm wall to allow the passage of water pipes, electrical wiring, HVAC and hydraulic installations without making holes/chases. Plumbing and Electrical service fittings shall be pre-planned and shall be passed through hollow portions of the wall panels.

Painting, Tiling and Cladding

Painting shall be done directly or after applying a 2mm wall putty coat. Texture paint coat shall be directly applied to external surface for decorative effect.

All tiling and cladding shall be directly fixed using regular cement mortar or tile adhesive.

USE OF THE WALLTEC WALLS & ITS LIMITATIONS

Uses

These walls shall be used as non-load bearing walls/partition walls and compound/ boundary walls in residential/ commercial/ industrial/ institutional buildings.

Limitations of Use

For non-load bearing walls only. Not to be used as load bearing walls.

CERTIFICATION

Under Performance Appraisal Certification Scheme, the present formwork system has been evaluated and certified by BMTPC PAC No. 1022-P/2015 has been issued to M/s B. N. Precast Pvt. Ltd., Gandhinagar.

STANDARDS AND REFERENCES

IS 383:2016	Specifications for coarse and fine aggregate for concrete (third revision)
IS 516:1959	Method of test for strength of concrete (Reaffirmed 2013)
IS 2386(Part 3):1963	Methods of test for aggregates for concrete - Part 3 specific gravity, density, voids, absorption and bulking (Reaffirmed 2016)
IS 3346:1980	Method of determination of thermal conductivity of thermal insulation materials
IS 3812 (Part 1):2013	Specifications for pulverized fuel ash - part 1 : for use as pozzolana in cement, cement mortar and concrete
IS 9103:1999	Specifications for concrete admixtures (Reaffirmed 2013)
IS 9142:1979	Specifications for artificial light weight aggregates for concrete masonry units (Reaffirmed 2016)
IS 9901:1981	Measurement of sound insulation in buildings and of building elements
IS 12269:2013	Specifications for 53 grade ordinary Portland cement
IS 15916:2010	Code of practice for building design and erection using prefabricated concrete (Reaffirmed 2014)
ISO 179-2:1997	Determination of charpy impact of plastics

APPENDICES

Appendix-1

F.No.JS/Works/OM/2016
Government of India
Ministry of Urban Development

Maulana Azad Road,
NirmanBhawan,
New Delhi

Dated: 30/05/2016

OFFICE MEMORANDUM

Sub: Adoption of New & Emerging Technologies in construction work of value not less than Rs.100 crores in Metropolitan cities, undertaken by CPWD, DDA and NBCC – reg.

The subject of using Modern Technologies in the construction works of CPWD, DDA and NBCC under the Ministry of Urban Development has been under consideration of the Ministry. CPWD has recommended to MOUD, adoption of the following three Technologies, which are validated by Building Materials and Technology Promotion Council (BMPTC) under the Ministry of Housing and Urban Poverty Alleviation:

1. Monolithic Concrete Construction System using Aluminium Formwork.
2. Industrialized 3-S System using Cellular Light Weight Concrete Slabs & Precast Columns (Precast/ prefab)
3. Monolithic Concrete Construction System using Plastic - Aluminium Formwork.

2. CPWD has recommended that the adoption of the above 3 new technologies will result in the following benefits: -

(a) Significant reduction in air & noise pollution and construction waste
(b) Optimum use of water
(c) No use of timber/ plywood for shuttering
(d) Form finish elements, good workmanship, assured quality and durable construction
(e) Increased labour productivity due to working in controlled environment
(f) All weather site execution

(g) Cost saving due to compressed completion time and rental cost reduction

(h) Better site organization, utilization of resources

3. CPWD has stated that adoption of the above mentioned 3 technologies will ensure neat and tidy work place with minimal environmental pollution and will be in sync with the objectives of 'Swatch Bharat Mission'. Further, adoption of these technologies will result in skill up-gradation of workers.

4. Accordingly, the Ministry of Urban Development has decided that CPWD, DDA and NBCC would mandatorily adopt the 3 Technologies enumerated in para 1 above and validated by BMPTC at their construction sites initially in the Metropolitan Cities of India, and where the value of works is Rs.100 crores or more. It has also been decided that these organizations (CPWD, DDA and NBCC) will also invariably obtain Third Party Certification related to Green Building Concept from agencies recognized by MoEF, apart from installing rooftop solar power plants, wastewater recycling and rainwater harvesting in all such projects.

5. This issues with the approval of Hon'ble Minister for Urban Development.

B. Anand 30/5/16

(B. Anand)
Joint Secretary (W&H)

To

1. Vice Chairman, DDA, Vikas Sadan, INA, New Delhi- 110 023.
2. Director General, CPWD, Nirman Bhawan, New Delhi – 110 011.
3. CMD, NBCC Limited, NBCC Bhawan, Lodhi Road, New Delhi – 110 003.

Copy for information to :

1. PS to Hon'ble UDM, PS to Hon'ble MoS, PPS to Secretary(UD), PPS to AS(UD) & PPS to AS(SC).
2. All Joint Secretaries/Economic Adviser/OSD(UT)/JS&FA in M/o UD.
3. All Director/D.S. in M/o UD.
4. Office Memorandum file – US(W-3).
5. IT Cell for uploading in e-office.

Ps to. JS(H)
114-C

Appendix-2

CENTRAL PUBLIC WORKS DEPARTMENT

OFFICE MEMORANDAM

DG/DSR/011

ISSUED BY AUTHORITY OF DIRECTOR GENERAL, CPWD

NIRMAN BHAWAN NEW DELHI DATED 17/08/2016

OFFICE MEMORANDAM

Subject: Adoption of New & Emerging Technologies in projects/ Works of value not less than100 crores in Metropolitan Cities.

MoUD vide No. JS/Works/OM/2016 dated 30th May, 2016 has issued an office memorandum for use of following three technologies in CPWD works:-

1. Monolithic Concrete Construction System using Aluminium Formwork.
2. Industrialized 3-S system using Cellular Light Weight Concrete Slabs & Precast Columns (Precast/Prefab)
3. Monolithic Concrete Construction System using Plastic – Aluminium Formwork.

Adopting the above technologies, a Turnkey project item with scope and payment schedule is here by added to DSR 2016. The rates of the items are according to the scope of work as mentioned in annexure and are indicative only; the NIT approving authority may modify and add or delete these rates as per the work/ project requirements/conditions/scope.

Construction shall be done on turnkey basis by adopting monolithic concrete construction system using customized aluminium /plastic aluminium form, or industrialized system using partly / fully precast slabs, beams and columns (Precast / prefab) with cast in situ joints for the superstructure and cast in situ methodology for foundation.

Payment shall be made stage wise; a payment schedule is provided as guideline. Payment schedule is indicative, NIT approving authority shall further breakup the payment stages but above percentage limits must not be exceeded for any particular stage.

The industrialized 3-S system using Cellular Light Weight Concrete Slabs & Precast Columns (Precast/Prefab) is restricted up to seismic Zone IV only.

The technology is new and idea of turnkey project/work based on these technologies is not experienced by the CPWD hence experience/suggestions/ inputs are also invited for future refinements.

This issued with the approval of DG, CPWD.

17.08.16

(Kunwar Chandresh)
Executive Engineer
CSQ, CPWD, Nirman Bhawan, New Delhi

No.133/SE(TAS)/CS-DSR-2016/2016-17/ 197-E Dated: 17.08.2016

Copy to: All the SDG/ADG/CEs/CPMs through CPWD website http://cpwd.gov.in

17.08.16

Executive Engineer
CSQ, CPWD, Nirman Bhawan, New Delhi

S.No.	Item	Unit	Rate in Rs.
1	**TURNKEY PROJECTS (Item)** Construction of multi-storeyed RCC residential buildings six storeys and above including planning and designing by incorporating stipulated specifications, internal and external services (E&M and Civil), external development, horticulture works on design built and handover basis adopting monolithic concrete construction system using customised aluminium/plastic aluminium form, or industrialised system using partly/fully precast slabs, beams and columns (Precast/prefab) with cast in situ joints for the superstructure as detailed in the Annexure all complete		
	1.1 Foundation work upto plinth level (without basement) (Complete in all respect as detailed in Annexure).	Per sqm of plinth area of ground floor	
	1.1.1 Isolated footing		4620
	1.1.2 Raft foundation		10110
	1.1.3 Pile foundation		14610
	NOTE: NIT approving authority will pick up any one type of the foundations. Rates of raft foundation not to be included in single basement.		
	1.2 Single Basement (Complete in all respect as detailed in Annexure) NOTE: Single basement rate includes raft foundation in addition to items in the Annexure.	Per sqm of plinth area of basement	17770
	1.3 Stilt portion (Complete in all respect as detailed in Annexure)	Per sqm of plinth area of stilt.	9440
	1.4 Super Structure (Complete in all respect as detailed in Annexure)	Per sqm of plinth area of superstructure	16820
	1.5 Development works (Complete in all respect)	Per sqm of area developed	*

* The scope and rate of development works shall be decided by the NIT approving authority as per requirements and site conditions.

NOTE:

1. These rates are indicative; the NIT approving authority may modify and add or delete these rates as per the work/ project requirements/conditions.
2. Development area means plot area minus plinth area at ground floor.
3. Mumty and appendages shall not be counted towards a storey.
4. The industrialised 3-S system using Cellular Light Weight Concrete Slabs & Precast Columns (Precast/Prefab) is restricted up to seismic Zone IV only.

Annexure

Scope of Work

The work shall be executed on Turnkey (Design, Built and handover) basis from conception to commissioning, including all services (E&M and Civil), in situ & pre cast RCC components, in accordance with layout plan and architectural / structural / Services / landscaping / Horticulture works drawings. All drawings shall be prepared by the contractor and got approved from CPWD and also from the statutory bodies. However, the scope of the work shall include but not limited to as under.

1. PLANNING

1.1 Architectural Planning.

1.1.1 Architectural planning shall be done by the agency on the basis of requirement and Architectural control parameters supplied by CPWD Architect / Senior Architect / Chief Architect based on local byelaws/government norms, OM No. 22011/01/2008-W3 DG/Arch/6 dated 07/08/2013 etc. (NIT approving authority to give these parameters in NIT)

1.1.2 All Architectural provisions shall conform to local byelaws, ECBC and minimum three star GRIHA rating. Presentation drawings including 3D modeling, walk-through and building models may be prepared by the contractor to obtain approval from CPWD before submitting it to local bodies / authorities.

1.1.3 Contractor has to obtain all required statutory approval before starting the construction works from authorities concerned for example local bodies, NGT, PCBs, Ground water board etc.

1.1.4 Contractor shall carry out site survey of its own to verify the details including dimensions and levels of the available site.

1.2 Structural Design

1.2.1 Structural designs shall be carried out by the contractor based upon approved Architectural designs / drawings.

1.2.2 Structural design shall be done in accordance to National building code 2005 and referred IS Codes therein; International good practices and sound Engineering practices in that order of precedence.

1.2.3 All structural designs shall be got proof checked from agency to be decided by NIT approving authority.

1.2.4 The soil investigation shall be carried out by the contractor as per IS codes before commencing the design works.

1.3 Planning and designing of Mechanical, Electrical and Civil services.

1.3.1 Contractor shall plan and design all possible services including Civil, Electrical and Mechanical services etc. as per site requirements and Architectural requirements conforming to relevant IS codes and local bye-laws.

1.3.2 Designs shall be got proof checked from agency to be decided by NIT approving authority.

1.4 Horticulture / landscaping works: contractor shall prepare Horticulture / landscaping works as per local byelaws and requirements specified.

2. CONSTURCTION

Construction shall be done on turnkey basis by adopting monolithic concrete construction system using customized aluminum/plastic aluminum form, or industrialized system using partly / fully precast slabs, beams and columns (Precast / prefab) with cast in situ joints for the superstructure and cast in situ methodology for foundation. The different component shown in schedule shall have the following scope.

2.1 Foundation up to plinth level - Construction of foundation shall be done as per the approved structural drawings.

2.1.1 Isolated footing (cast in situ) - It includes Excavation, lean concreting, reinforcing, shuttering and casting of footing, columns, beams up to plinth level as per the approved concrete design mix, all complete.

2.1.2 Raft foundation (cast in situ) - It includes Excavation, lean concreting, reinforcing, shuttering and casting of raft foundation, columns, and beams up to plinth level as per the approved concrete design mix, all complete.

2.1.3 Pile foundation - It includes all types of piles (Pre cast, bored cast in situ etc.), pile caps, including reinforcement, concreting, columns, and beams up to plinth level as per the approved concrete design mix, all complete.

2.2 Single Basement including foundation - Construction of Single basement includes excavation , leveling of surface ,lean concreting, reinforcement ,shuttering and casting by concrete of design mix as approved, all works required for raft foundation and all columns beams, slabs upto roof level of basement, including concrete retaining wall all around in the basement up to the basement roof height (Height of the basement taken 3.35 metre below soffit of beam),Pressurized mechanical ventilation system, Firefighting with sprinkler system, Automatic fire alarm system, lifts serving basement, Water proofing of basement, flooring and finishing with electrical light fittings drainage system

etc, all complete but excluding equipments pertaining to DG set , Air-conditioning, Substation.

2.3 Stilt portion - Construction of stilt includes flooring and finish as per the specifications with all services required in the stilt portion (E&M and Civil) including Fire fighting, Automatic fire alarm system, lifts serving stilt floor and finishing all complete with electrical lighting, fan fittings, internal services etc. all complete but excluding equipments pertaining to DG set , AC, Substation.

2.4 Super structure shall be constructed adopting monolithic concrete construction system using customized aluminum/plastic aluminum form, or industrialized system using partly / fully precast slabs, beams and columns (Precast / prefab) with cast in situ joints or any combination thereof including all internal Civil, Electrical and Mechanical services including plumbing ,drainage, fire fighting, fire alarm, lifts , lighting etc, all complete but excluding equipment pertaining to DG set , Air-conditioning and sub-station etc.

2.5 Development work - The scope of development works shall be decided by the NIT approving authority as per requirements and site conditions and accordingly rates are to be worked out based upon area to be developed.

2.6 Specifications / Amenities - The Specifications / Amenities shall conform to MOUD office memo OM No. 22011/01/2008-W 3 DG/Arch/6 dated 07/08/2013

2.7 The construction in general shall be carried out as per the CPWD Specifications Vol-I and Vol-II 2009

3. HANDING OVER

3.1 The contractor shall hand over the completed work / project to CPWD after removing all defects and after :

3.1.1 Obtaining completion certificate from local bodies.

3.1.2 Obtaining GRIHA certificate.

3.1.3 Water and sewer line connection.

3.1.4 Road / path connection.

3.1.5 Electricity connection.

3.1.6 Fire clearance certificate.

3.1.7 Obtaining certificate for lift operation.

3.1.8 And any such certificate / compliance that may be required as per prevailing Bye Laws, Rules / Regulations and Court Order / Judgment etc.

3.2 The contractor shall submit all such certificate and receipt to CPWD as mentioned above for their verification and acceptance.

4. Measurement:- Methodology of measurement shall conform to Annexure-III of CPWD Plinth Area Rates 01.10.12 (PAR 2012) for payment.

4.1 Foundation work upto plinth level (without basement) - Plinth area of the ground floor shall be measured for payment.

4.2 Single Basement upto plinth level - Plinth area of the basement floor shall be measured for payment. Considered height of single basement is minimum 3.35 meter below soffit of beam.

4.3 Stilt portion - Plinth area of the stilt floor shall be measured for payment.

4.4 Super Structure:-

4.4.1 Plinth area of the superstructure shall be measured for payment.

4.4.2 Plinth area of the stilt floor shall be measured separately for payment

4.5 Development works - Development area shall mean plot area minus plinth area at ground floor. Developed area shall be measured for payment.

PAYMENT SCHEDULE (Guidelines only)

S.No.	Description	Individual %age	Cumulative %age
1	Submission and approval of all architectural drawings, layout, building plans containing all details, specifications required for execution of work including development plans.	0.40	0.40
2	Submission and approval of foundation designs and complete structural drawings for superstructure, UG Tank complete and other works to be executed at site for its completion.	0.40	0.80
3	Submission and approval of all services plans from local bodies/Authorities etc.	0.10	0.90
4	EIA and Environmental Clearance	0.10	1.00
5*	Completion of structure work including foundation, superstructure and corresponding electrical and civil works etc.	50.00	51.00
6*	Finishing all complete including all civil ,electrical and mechanical works/services etc. fully functional	40.00	91.00
7	On completion of project	5.00	96.00
8	On handing over of flats as per scope of work.	4.00	100.00

(*) Payment schedule is indicative NIT approving authority shall further breakup the payment stages according to factual situation of project and for maintaining regular cash flow, but the sum total of percentages of the breakup stages shall not exceed the above percentage limits.

Appendix-3

F.No.28012/7/2016-W-3
Government of India
Ministry of Urban Development
(Works Division)
****

Nirman Bhawan, New Delhi
Dated the 28th December, 2016

OFFICE MEMORANDUM

Subject:- Adoption of New & Emerging Technologies in construction work of value not less than Rs.100 crores in Metropolitan cities, undertaken by CPWD, DDA and NBCC – reg.

Reference is invited to Ministry of Urban Development's OM dated 30.05.2016 on the above mentioned subject wherein inter alia it was mandated that CPWD, DDA and NBCC would adopt 3 (three) new Technologies viz. (i) Monolithic Concrete Construction System using Aluminium Formwork, (ii) Industrialized 3-S System using Cellular Light Weight Concrete Slabs & Precast Columns (Precast/prefab) and (iii) Monolithic Concrete Construction System using Plastic – Aluminium Formwork, initially in the Metropolitan Cities of India, where the value of works is Rs.100 crore or more.

2. The matter has been considered further. It has been now decided that the aforesaid new technologies may be mandatorily adopted for all projects across the country, irrespective of location and project cost **with effect from 01.04.2017**. In case, it is not found feasible to implement these provisions in a particular project, specific permission should be accorded by DG, CPWD/CMD, NBCC/Vice Chairman DDA respectively on case to case basis, with detailed justification.

3. This has the approval of Hon'ble UDM.

(J. Roy Chowdhury)
Deputy Secretary (Works)
Tel. No. 23062425

To
1. Vice Chairman, DDA, Vikas Sadan, INA, New Delhi-110023.
2. Director General, CPWD, Nirman Bhawan, New Delhi -110011.
3. CMD, NBCC Limited, NBCC Bhawan, Lodhi Road, New Delhi-110003.

Copy for information to :
1. PS to Hon'ble UDM, PS to Hon'ble MoS, PPS to Secretary(UD), PPS to AS(UD) & PPS to AS(SC).
2. All Joint Secretaries/Economic Adviser/OSD(UT)/JS&FA in M/o UD.
3. All Director/D.S. in M/o UD.
4. Office Memorandum file – US(W-3).
5. IT Cell for uploading in e-office.

Appendix-4

F.No.28012/7/2016-W-3
Government of India
Ministry of Housing and Urban Affairs
(Works Division)
*****

. 1041017

Nirman Bhawan, New Delhi
Dated: 20.03.2018

OFFICE MEMORANDUM

ıb:- Adoption of New & Emerging Technologies in construction works undertaken by CPWD, DDA and NBCC – regarding.

******

In continuation of this Ministry's O.M. JS/Works/OM/2016 dated 30.05.2016 and O.M.).28012/7/2016-W-3 dated 28.12.2016 it has been decided that CPWD, DDA & NBCC may opt the following technologies, which have been validated by Building Materials and chnology Promotion Council (BMTPC) under the Ministry of Housing and Urban Affairs, in their projects irrespective of location and project cost:

a. Monolthic concrete construction system using Aluminium Formwork
b. Monolithic concrete construction system using Plastic – Aluminium Formwork
c. Expanded Polystyrene Core Panel System
d. Light Gauge Sheet Framed Structures (LGSF)
e. Industrialized 3-S System using RCC precast with or without shear walls, columns, beams, Cellular Light Weight Concrete Slabs/Semi-Precast Solid Slab
f. Speed Floor System
g. Glass Fibre Reinforced Gypsum (GFRG) Panel Building System
h. Factory Made Fast Track Modular Building System.

As decided earlier, in case, it is not found feasible to implement these provisions in licular project, specific permission should be accorded by DG, CPWD/CMD, NBCC/Vice irman, DDA respectively on case to case basis, with detailed justification.

The aforesaid modern technologies may be incorporated as per the Schedule of es (SoR) issued by CPWD. Further, in future, new emerging technologies, as validated BMTPC and for which DG, CPWD has issued the SoR will also be included in the list. For purpose, DG, CPWD is authorized to issue directions in continuation of this Office norandum.

This has the approval of Hon'ble HUAM.

(J. Roy Chowdhury)
Deputy Secretary (Works)
Tel. no. 23062425

1. Director General, CPWD, Nirman Bhawan, New Delhi.
2. Vice Chairman, DDA, Vikas Sadan, INA, New Delhi-110023
3. Chairman-cum-Managing Director, NBCC Limited, NBCC Bhawan, Lodhi Road, New Delhi-110003

/ to:
1. PS to HUAM
2. Sr. PPS to Secretary (HUA)

Appendix-4

SCHEDULE OF RATES ISSUED BY CPWD ON NEW TECHNOLOGIES

A - DELHI SCHEDULE OF RATES 2016 (VOLUME 2)

Code No.	Description	Unit	Rate ₹
	NEW TECHNOLOGY ITEMS		
26.41	Designing, providing, installing and fixing factory finished custom designed cold form Light Gauge Steel Framed super structure comprising of steel wall panel, trusses, purlins etc manufactured out of minimum 0.75 mm thick steel sheet as per design requirements. The steel sheet shall be galvanized (AZ-150 gms Aluminium Zinc Alloy coated steel having minimum yield strength 300- 550 Mpa) conforming to AISI specifications and IBC 2009 for cold formed steel framing and construction and also as per IS: 875-1987, ISO 800-1984 and IS: 801- 1975. The wind load shall be as per provisions of IS 875 (part -III). LGSFS frame shall be designed as per IS: 801 using commercially available software such as Frame CAD Pro-11.7/ STAAD PRO-V8i/ArchitekV2.5.16/ Revit architecture-2011 or equivalent. Proper usage of Connection Accessories like Heavy Duty Tension Ties, Light Duty Hold-ons, Twist Straps (to connect truss with wall frames), Strong Tie, Tie Rod, H-Brackets, Boxing Sections, L-Shaped Angles for better structural stability. The framing section shall be cold form C-type having minimum web depth 89 mm x 39mm flange x 11mm lip in required length as per structural design requirement duly punched with dimple/slot at required locations as per approved drawings. The slots will be along centre line of webs and shall be spaced minimum 250mm away from both ends of the member. The frame can be supplied in panelized or knock down condition in specific dimensions and fastened with screws extending through the steel beyond by minimum of three exposed threads. All self drilling tapping screws for joining the members shall have a Type II coating in accordance with ASTM B633(13) or equivalent corrosion protection of gauge 10 & 12, TPI 16 & 8 of length 20mm. The frames shall be fixed to RCC slab or Tie beam over Neoprene rubber using self expanding carbon steel anchor bolt of dia as per approved drawings. design subject to minimum 12mm diameter and 121mm length conforming to AISI 304 and 316 at 500mm c/c with minimum embedment of 100mm in RCC (RCC to be paid separately) and located not more than 300mm from corners or termination of bottom tracks complete in all respects. The item also includes the submission of stability reports duly examined and issued by any NIT/IIT.The rate includes the concept design, detailed design, fabrication of sections, transportation, installation and all required fixing arrangement at site as described above.	Kg	174.10
26.42	Providing and fixing of external wall system on Light gauge steel frame work with . Outer face having 6mm thick heavy duty fiber cement board fixed on 9mm thick heavy duty fiber cement board confirming to IS 14862:2000, category IV type A (High pressure steam cured) as per standard sizes fixed with self-drilling / taping screws / fasteners @ 60cm c/c of approved make. A grove of 2 mm to 3mm shall be maintained and groves shall be sealed with silicon based sealant. The board shall be fixed in a staggered pattern.Screws		

Code No.	Description	Unit	Rate ₹
	shall be of counter sunk rib head of 1.60mm to 4 mm thick of 8 to 10 gauge of length varying from 25 to 45 mm and internal face 12.5mm thick gypsum plaster board fixed on 8mm thick fiber cement board confirming to IS 14862:2000 of category III type B (High pressure steam cured) as per standard sizes fixed with self-drilling / taping screws / fasteners @ 60cm c/c of approved make, proper taping and jointing to be done using fiber mesh tape and epoxy and acrylic based jointing compound for seamless finish.(cost of frame work to be paid for separately).	Sqm	2783.65
26.43	Providing and fixing internal wall panels on Light gauge steel frame work with 12.5mm thick gypsum plaster board conforming IS 2095:2011 fixed on 8mm thick fiber cement board conforming to IS 14862:2000 of category III type B (High pressure steam cured) as per standard sizes fixed with self-drilling / taping screws / fasteners @ 60cm c/c of approved make, Screws shall be of counter sunk rib head of 1.60mm to 4 mm thick of 8 to 10 gauge of length varying from 25 to 45 mm. Proper taping and jointing to be done using fiber mesh tape and epoxy and acrylic based jointing compound for seamless finish.(cost of frame work to be paid for separately)	Sqm	1738.45
26.44	Providing and fixing in all exterior face panels breathable vapour barrier underneath the cement fiber board as per National Building Code 2009 complete as per direction of Engineer-in-charge.	Sqm	238.05
26.45	Supplying and installation of moisture resistant/fire resistant 6 mm thick Heavy duty fiber cement board (High pressure steam cured) conforming to IS 14862:2000 of category III type B as per standard sizes fixed with self-drilling / taping screws. Screws shall be of counter sunk rib head of 1.60mm to 4 mm thick of 8 to 10 gauge of length varying from 25 to 45 mm.	Sqm	869.15
26.46	Providing and fixing in position, 200 mm thick factory made Expanded Polystyrene Core (EPS Core) wall panels consisting of EPS core sandwiched between two Engineered sheets of welded wire fabric mesh duly finished with shortcrete materials on outer faces. The fabric mesh shall be made of 3 mm dia G.I. wire mesh with 50 mm pitch in both the directions and on both faces of the wall, kept at 120-135 mm gap and connected by the zig zag G.I. wire of 3 mm dia at alternate row by welding (at an angle ranging from 50-70 degree) . The EPS core shall consist of 100 mm thick EPS of density not less than 20 kg/ per cum. Both the outer faces of the panel shall be finished by applying the layer of 50 mm thick cement mortar 1:3 {1 cement: 3 coarse sand (not having more than 40% stone chips of size upto 6 mm)} À with the help of shotcreting/guniting equipment etc at a pressure not less than 1 bar (100Kn/m2) and both surfaces finished with trowel. Fixing operations of wall panels shall be completed in all respect as per drawings and specifications and under the overall direction of the Engineer-in-charge.	sqm	3246.15
26.47	Providing and fixing in position, 230mm thick factory made Expanded Polystyrene Core (EPS Core) roof/floor panels made of 3 mm dia G.I. wire mesh with 50 mm pitch in both the directions and on both faces of panel, kept at 120-135 mm gap and connected by the zig zag G.I. wire of 3 mm dia at alternate row by welding (at an angle ranging from 50-70 degree). The EPS core shall consist of 100 mm thick EPS of density not less than 20kg/ per cum. The bottom side of the panel shall be finished by applying a layer of 60-65 mm thick cement mortar 1: 3 {1 cement: 3 coarse sand (not having more than 40% stone chips of size upto 6 mm)} À with the help of shotcreting		

Code No.	Description	Unit	Rate ₹
	equipment etc at a pressure of not less than 1 bar (100Kn/m2) and surface finished with trowel. The top face of the panel shall be provided and finished by applying 70-75 mm thick layer of cement concrete 1:1.5: 3 (1 cement :1.5 coarse sand : 3 graded stone aggregate 20 mm nominal size). Fixing operations of roof/floor panels shall be completed in all respect as per drawings and specifications and under the overall direction of the Engineer-in-charge.	sqm	3436.35
26.48	Providing and fixing of costomized Aluminium formwork for monolithic construction RCC members with a repetitive usage of 100 times using grade 5052 aluminium for panel sheets of minimum 4 mm thick and grade 6061 (Type-6) aluminium for extruded sections. The form work includes of beam components i.e.beam side panel,prop head for soffit beam,beams soffit panel,beam soffit bulk head and deck componets i.e. deck panel, deck prop, prop length, deck mid, soffit length, deck beam bar and wall components i.e. wall panel, rocker, kiker and internal soffit corner, external soffit corner,external corner,internal corner etc.,The panels are held in position by a simple pin and wedge system that passes through holes in the out side rib of each panel.The tolerance of finished panels to be (-1 mm), and shall conform to IS 14687-1999. Pins and wedges to be made of high grade mild steel,all complete as per direction of Engineer-in-charge.(Cost of RCC work shall be paid seperately)	sqm	149.45

SUB HEAD : 26.0 NEW TECHNOLOGIES AND MATERIALS

B - DELHI SCHEDULE OF RATES 2016 (CORRECTION SLIPS)

Directorate, CPWD
DG/DSR/20
NIRMAN BHAWAN, NEW DELHI – 110011.

This issue with the approval of DG, CPWD.

NIRMAN BHAWAN NEW DELHI DATED: 10/11/2017

OFFICE MEMORANDUM

Sub:- Correction slip no.8 Delhi Schedule of Rates 2016.

The following new items of EPS cement sandwich light weight solid core panels to be included in DSR-2016 after item No 26.48 of SH: 26 (New Technologies and Materials).

Code No	Description	Unit	Rate (Rs)
26.49	Providing and fixing in position factory made EPS cement sandwich wall/roof/floor light weight solid core panels made of core material of EPS granule balls/beads (conforming to IS 4671:1984 and shall have density not less than 15kg per cum) adhesive, cement, sand, flyash and other bonding material in mortar state processed to form in a preset mould. The outer face on both sides of the panels will be non asbestos fibre cement board confirming to IS 14862:2000 or Calcium silicate board confirming to EN 14306:2009 of 5mm thick each. Panel shall be laid on 6mm thick cement mortar (1 cement: 2 fine sand) mixed with chemical adhesive of 0.5kg per 50kg of cement or shall be preferably fixed into 'C' channel made of 1.2mm thick MS plate screwed/fastenened to the slab/column/beam etc. The panel shall fixed vertically with tongue and groove joint and horizontally locked with steel bar between each other and floors and filled with cement mortar and adhesive. Panels should be used as floor & roofing with additional structural support, steel or RCC depending upon the design. All the operation shall be completed in all respect as per drawings, Manufacturers specifications and under the overall direction of Engineer-in-Charge (Cost of all the material is included except "C channel" which will be paid separately).		
26.49.1	Non load bearing panels 50mm thick of required size	sqm	1123.30
26.49.2	Non load bearing panels 60mm thick of required size	sqm	1277.45
26.49.3	Non load bearing panels 75mm thick of required size	sqm	1561.90
26.49.4	Non load bearing panels 90mm thick of required size	sqm	1871.70
26.49.5	Non load bearing panels 100mm thick of required size	sqm	2215.00

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No. 133/SE (TAS)/CS-DSR-2016/ 263-ते० Dated: 10/11/2017

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This issue with the approval of DG, CPWD.

NIRMAN BHAWAN NEW DELHI DATED: 02 /01/2018

OFFICE MEMORANDUM

Sub:- Correction slip no.11 Delhi Schedule of Rates 2016.

The following new items of Non asbestos fibre reinforced aerated cement sandwich wall/roof/floor light weight solid core panels to be included in DSR-2016 after item No 26.49 of SH: 26 (New Technology & Materials).

Code No	Description		Unit	Rate (Rs)
26.50	Providing and fixing in position factory made non asbestos fibre reinforced aerated cement sandwich wall/roof/floor light weight solid core panels made of light weight cement concrete core composed of OPC cement, pulverized flyash, quick lime, cotton pulp & Gypsum in mortar state mixed with aeration agent in a preset mould. The outer face on both sides of the panels will be non asbestos fibre cement board confirming to IS 14862:2000. These solid wall panels are installed using Galvanized iron steel tracks/C channel of 1mm thick of required sizes as recommended by manufacturer's and fixed to floor and RCC soffit in plumb to each other with steel screw/fasteners. The panel shall be fixed vertically with tongue & groove joint with cement based polymer modified jointing compound. The exposed surface finished with fibre mesh/glass fibre tape with polymer based jointing compound having superior flexibility. Panels should be used as floor & roofing with additional structural support, steel or RCC depending upon the design. All the operation shall be completed in all respect as per drawings, Manufacturers specifications and under the overall direction of Engineer-in-Charge (Cost of all the material is included except "tracks/C channel" which will be paid separately).			
	26.50.1	Non load bearing panels 50mm thick of required size (minimum 4mm thick fibre cement board)	sqm	1200.00
	26.50.2	Non load bearing panels 75mm thick of required size (minimum 5mm thick fibre cement board)	sqm	1417.75

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This issue with the approval of DG, CPWD.

NIRMAN BHAWAN NEW DELHI DATED: 13 /08/2018

OFFICE MEMORANDUM

Sub:- Correction slip no.13 Delhi Schedule of Rates 2016.

The following new items of GFRG items to be included in DSR-2016 item No 26.51 to 26.61 of SH: 26 (New Technologies and Materials).

Code No	Description	Unit	Rate
26.51	Supplying of standard quality GFRG panel of 124 mm thickness with modular cavities purchased from GFRG panel manufacturing plant in the country, cut to required wall sizes and floor/ roof slab sizes in correct length and height, including cutting of door, window and ventilator opening as per the cutting drawing prepared by architects /design engineers for the construction of GFRG building and loaded in stillages for transportation to the construction site. Cost of panel includes security deposits, hire charges of stillages & jaws, cost of transportation in trucks/ lorries without any damages upto 300kms including all leads and lifts from GFRG manufacturing plant to construction site and unloading at site using suitable fork lift/ crane. (Payment shall be made on the basis of area of one side of panel without reduction of opening of door/ window / ventilator). For transportation above 300kms, additional charges to be paid.	sqm	1290.05
26.52	Erection of GFRG Panels in walls in all floors using suitable crane as per instructions of Engineer-in-Charge, as per cutting drawings and structural drawings, in perfect line and plumb, above RCC plinth beam/GFRG panel below and provide necessary lateral/ slanting support to keep the wall panel in safe position, providing & tieing of Reinforcement as per structural drawings and applying a coat of water repellant coating Zycosil/equivalent or equivalent product (1 Zycosil/equivalent compound :10 water) to saturation level over RCC plinth beam to provide water proofing treatment to joint between wall panel & plinth beam as per the guide lines / instruction by the engineer in charge. (Cost of reinforcement, water proofing of walls and plinth beam/GFRG panel below joints and installation of door/ window frames before filling of concrete shall be paid separately). The rate quoted shall include making provision for laying of lintels, beams, sunshades, staircase		

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Code No	Description	Unit	Rate
	Beams, lofts, plumbing work, electrical conduits and any structural insertion etc., as per the drawing and direction of the engineer in charge. The payment shall be made based on the actual exposed area (one side only) of the panel. The work shall be carried out as per the Special Conditions For Glass Fibre Reinforced Gypsum (GFRG) Structures mentioned in NIT. **Note:** 1) When cutting panel, "A" side is to be for outside or external surface of respective external wall and B side is to be for internal surface of wall. 2) Erection of panel is to be with reference to both building plan & cutting drawing by following notational mark indicated in the cutting drawing as well as notional mark written on each panel cut as per cutting drawing.	sqm	213.70
26.53	Filling of empty cavities (as shown in the structural design drawing) with quarry dust mixed with 5% cement (by volume). After initial infill of 50 mm thick with M25 concrete at base/bottom of cavities to seal off, infill wall panel cavities in 3 stages as detailed below, (i) 1st pour / infill to be limited to 0.3 to 0.50 m height from bottom of the panel. (ii) 2nd Pour/ infill: infilling shall be done only after 90 minutes interval between successive pours. The maximum height of infill shall be restricted to 1.5m height or up to the top level of door / window. (iii) 3rd pour/infill: After an interval of 90 minutes of second pour, infill or pour the balance height up to the bottom of embedded RCC tie beam. Pour enough water just required to dampen the dry mix enough to form cake form after each stage. (cost of laying M25 concrete shall be paid separately) (If any rain falls in between any stages of concrete pour, make sure to cover the panel top to prevent ingress of water or water falling into the cavities. In case of water collection over the concrete inside the panel, drill 10mm hole in GFRG panel immediately above concrete filled level to drain out water before pour/in-fill of balance concreting)	cum	2021.75
26.54	Laying of GFRG panel as roof / floor slab panel and staircase panel using suitable crane as per instructions of Engineer-in-Charge, including providing support system with 25mm x 300mm-400 mm wide plywood, as runner with proper prop below proposed micro beams including (a) Cutting of top flange of panel to 180 mm wide (leaving 25mm projection on either side) to provide RCC embedded		

EE(CTAS)

Code No	Description	unit	Rate
	micro beam as per cutting drawings and structural drawings. (b) Reinforcement for micro beams and tie beams to be provided in position with proper anchorage as per structural drawings. (c) Provision for Electrical cabling, fan hooks and laying of pipes for plumbing work. (d) Concreting of Tie beam, micro beam and top of GFRG panels (50 mm thick) with M-25 cement concrete mix using coarse aggregate of size less than 20 mm including laying of 10 gauge 100x100 size weld mesh with 25 mm effective cover from the panel top.	sqm	237.30
26.55	Supplying and fixing 10 Gauge weld mesh of size 100mm x100 mm for floor/roof slab concrete screed over the micro beams as reinforcement. The weld mesh shall be fixed as per drawing.	sqm	225.90
26.56	Application of ZMB 60/equivalent solution (100 Kg ZMB 60/equivalent, 1 litre ZMB Nano Thinner, 20 litre water & 1 Litre Zycoprime/equivalent = 122 litre/kg) over already applied coat of Zycosil/equivalent & Zycoprime/equivalent solution on the top of all the RCC plinth beams by brush/spray coat before erection of GFRG over RCC plinth beams in GF. In the case of upper floors 150 mm wide on floor slab for all the external walls, bath/toilet/wet areas (3 hrs drying time) before erection of wall panel on upper floors including erection of parapet wall.	sqm	229.80
26.57	After erection of GFRG wall panels, seal all GFRG wall joints with paper tape temporarily. Water proofing treatment of vertical joints with Zycosil/equivalent water proofing Solution (1 litre of Zycosil/equivalent & 20 litres of water stirred first & 2 litres of Zycoprime/equivalent added and stirred (total 23 litres)) with 50 ml syringe till the gap and in filled concrete is completely saturated. After removing the paper seal, seal off the vertical joints with water proofing material "Grout RW/equivalent" (Sealing cost excluded.)	metre	65.30
26.58	Filling of joints between RCC plinth beam / floor slab and wall panel of external walls, toilet / bath room / wet areas walls on all floor and parapet wall over roof slab, stair case head room at the time of erection of GFRG panels with Grout RW/equivalent sealant compound after the erection of panel before the infill of concrete in panel cavities and fine finish. This applies for all horizontal and vertical joints between GFRG wall and slab panels.	metre	29.10

Code No	Description	unit	Rate
26.59	Water proofing treatment of Vertical joints (of external side and internal side) between door frame, window & ventilator frames (on all four sides) of outer wall over the Zycosil/equivalent & Zycoprime/equivalent solution already applied (before the installation of door / window / ventilator frames in position) and fine finish with Grout RW/equivalent.	metre	29.90
26.60	Water proofing treatment of RCC sunshade with Zycosil/equivalent water proofing Solution (1 litre of Zycosil/equivalent & 20 litres of water stirred first & 2 litres of Zycoprime/equivalent added and stirred (total 23 litres)) till it meets the saturation level and testing as per RILEM or by water drops test in which water drops do not absorb but drops remain or rolls.	sqm	112.10
26.61	In-filling / sealing of joint between RCC lintel cum sunshade and wall (on external side) in all floors by pushing in Grout RW/equivalent in paste form and coving 20 mm x 20 mm after applying a coat of Zycosil/equivalent & Zycoprime/equivalent solution before cement plastering of top, bottom and sides of RCC sunshade.	metre	29.90

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No. 133/SE (TAS)/CS-DSR-2016/ 113-E Dated: 13/08/2018

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NIRMAN BHAWAN NEW DELHI DATED: 13 /08/2018

OFFICE MEMORANDUM

Sub:- Correction slip no.14 Delhi Schedule of Rates 2016.

The following new items of Speed Floor System New Technology items to be included in DSR-2016 item No 26.62 to 26.64 of SH: 26 (New Technologies and Materials).

Code No	Description	Unit	Rate
26.62	Designing, Providing, installing and fixing factory finished customed design pregalvanized high tensile steel joists manufactured from G350 Z275 confirming to IS:277-1992, minimum coating of galvanizing 275 gm/sqm, minimum yield stress 35 MPa & minimum tensile strength of 380 MPa placed 1.23 metre apart to support the load of slab etc as per the design & directions of Engineer-in-Charge.	kg	133.10
26.63	Providing and fixing special adjustable lock bars of mild steel E-250 to support the temporary plywood for work between joists during construction as per design & directions of the Engineer-in-charge.	kg	14.00
26.64	Centering and shuttering with 12mm thick shuttering plywood confirming to IS 4990:2011 and removal of form at all heights. Plywood will be supported on lock bars.		
	26.64.1 Suspended floors, roofs, landings, balconies and access platform.	sqm	82.75

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NIRMAN BHAWAN NEW DELHI DATED: 13 /08/2018

OFFICE MEMORANDUM

Sub:- Correction slip no.15 Delhi Schedule of Rates 2016.

The following new items of Factory Made Fast Track Modular Building System Technology items to be included in DSR-2016 item No 26.65 to 26.66 of SH: 26 (New Technologies and Materials).

Code No	Description	Unit	Rate
26.65	Providing and fixing roofing consist of 0.8 mm thick galvanized steel deck sheet confirming to IS 277:1992 used as permanent shuttering over which MS wire mesh 3mm laid at 100x100 mm grid including edge trim covered with concrete. This metal deck will be supported on structural steel beam with shear studs. (Structural steel like Beam, column, joists etc. & concrete of different grade as per design will be paid separately).	sqm	1394.95
26.66	Providing and fixing in position, **130** mm thick factory made Expanded Polystyrene Core (EPS Core) wall panels consisting of EPS core sandwiched between two Engineered sheets of welded wire fabric mesh duly finished with shortcrete materials on outer faces. The fabric mesh shall be made of 3 mm dia **zinc coated** G.I. wire mesh with 50 mm pitch in both the directions and on both faces of the wall **and connected by GI wire of 3mm dia at alternate row by welding**. The EPS core shall consist of **60** mm thick EPS of density not less than **16** kg/ per cum. Both the outer faces of the panel shall be finished by applying the layer of **35** mm thick cement mortar 1:3 {1 cement: 3 coarse sand (not having more than 40% stone chips of size upto 6 mm)} with the help of shotcreting/guniting equipment etc at a pressure not less than 1 bar (100KN/m2) and both surfaces finished with trowel. Fixing operations of wall panels shall be completed in all respect as per drawings and specifications and under the overall direction of the Engineer-in-charge.	sqm	2171.30

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NIRMAN BHAWAN NEW DELHI DATED: 20 /07/2017

OFFICE MEMORANDUM

Sub:- Correction slip no.6 Delhi Schedule of Rates 2016.

The following new item of prefab technology to be included in DSR-2016 after item No 5.49 of SH:5 (Reinforced Cement Concrete).

Code No	Description			Unit	Rate (Rs)
5.50	Fabrication & Manufacturing of Prestressed Hollow Core slab (Hollow area 25 to 30%) of different thickness & modular width 1200 mm in Controlled Factory Environment with approved methodology, conforming to IS:10297-1982 by using long line casting method having arrangement of proper steel bed. Concreting should be done by batch mixing plant capable of producing zero slump concrete, transported through automatic shuttels of standard make & layed on bed with the help of extruder/Slipformer, finishing, curing and also provision of steam curing. Cutting, making necessary cutout/holes of required sizes for services in slab element after achieving required strength, yard handling & stacking all complete as per approved shop drawings & design mix as per the direction of the Engineer-in-charge. (Cost of strands should be paid separately). **Note: Excess/less cement over the specified cement content used as per design mix is payable/recoverable separately)**				
	5.50.1	Concrete Grade M-40 (Cement content 400kg)			
		5.50.1.1	100 mm thick hollow core slab	metre	878.65
		5.50.1.2	120 mm thick hollow core slab	metre	1032.55
		5.50.1.3	150 mm thick hollow core slab	metre	1263.45
		5.50.1.4	200 mm thick hollow core slab	metre	1546.55
		5.50.1.5	250 mm thick hollow core slab	metre	1905.95
		5.50.1.6	300 mm thick hollow core slab	metre	2265.30
		5.50.1.7	350 mm thick hollow core slab	metre	2624.70
		5.50.1.8	400 mm thick hollow core slab	metre	2984.10
	5.50.2	Extra for using M-50 (Cement content 425 kg) instead of M-40			
		5.50.2.1	100mm thick hollow core slab	metre	17.10
		5.50.2.2	120mm thick hollow core slab	metre	20.55
		5.50.2.3	150mm thick hollow core slab	metre	25.70
		5.50.2.4	200mm thick hollow core slab	metre	31.95
		5.50.2.5	250mm thick hollow core slab	metre	39.95
		5.50.2.6	300mm thick hollow core slab	metre	47.95
		5.50.2.7	350mm thick hollow core slab	metre	55.95
		5.50.2.8	400mm thick hollow core slab	metre	63.95
	5.50.3	Extra for using M-60 (Cement content 440 kg) instead of M-40			
		5.50.3.1	100mm thick hollow core slab	metre	27.40
		5.50.3.2	120mm thick hollow core slab	metre	32.90

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Code No	Description			Unit	Rate (Rs)
		5.50.3.3	150mm thick hollow core slab	metre	41.10
		5.50.3.4	200mm thick hollow core slab	metre	51.15
		5.50.3.5	250mm thick hollow core slab	metre	63.95
		5.50.3.6	300mm thick hollow core slab	metre	76.70
		5.50.3.7	350mm thick hollow core slab	metre	89.50
		5.50.3.8	400mm thick hollow core slab	metre	102.30
5.51	Fabrication and manufacturing of solid precast concrete element with provisions of shear keys, connecting loops, dowel tubes and proper lifting accessories for walls, beams, slabs, stairs, column etc, of various thickness, shape and size of different concrete grades manufactured in controlled factory environment with approved methodology including moulds (Pallet system, Tilts form, table moulds, battery moulds, vertical moulds, beam moulds, column moulds, staircase moulds, Façade mould, etc.), mixing, transporting and placing of concrete, vibrating, curing, finishing, making necessary cutout/holes of required sizes for services, yard handling & stacking all complete as per IS 11447:1985 and as per approved shop drawings and design mix as per the direction of Engineer-in-Charge (Cost of reinforcement, Mechanical, Electrical and Plumbing inserts will be paid separately). **Note:** Excess/less cement over the specified cement content used as per design mix is payable/recoverable separately)				
	5.51.1		Concrete grade M-35 (Cement content 370 kgs)	cum	13765.10
	5.51.2		Extra for using M-40 (Cement content 400 kg) instead of M-35	cum	228.30
	5.51.3		Extra for using M-50 (Cement content 425 kg) instead of M-35	cum	418.55
	5.51.4		Extra for using M-60 (Cement content 440 kg) instead of M-35	cum	532.75
5.52	Providing & laying in position Prestressing steel strands (low relaxation) on hollow core bed by using mechanical pulling arrangement like Rabbit/ Bed master including all accessories for Stressing & destressing operations as per approved make conforming to IS1343 & grade FY-1860 etc, complete as per drawings and direction of Engineer -in-charge.			kg	130.75
5.53	Transportation of Precast Elements by flat bed Trailor (Double / Triple axle 40ft Length with proper accessories like A frame etc) from factory, including the cost of loading, unloading & stacking at site with the help of required capacity cranes.				
	5.53.1		lead with in 15 km	MT	389.85
	5.53.2		Add/Deduct over item 5.53.1 for every additional lead of 5 km	MT	73.00
5.54	Erection & Installation of Precast/Prestressed Concrete elements in correct & final position with proper line level and plumb at site making all arrangements (i.e. cranes, push-pull jacks & all another T & P for lifting Placing & Alignment of elements, within erection tolerance as per IS 15916 as per approved shop drawings and all complete as per the direction of Engineer-in-Charge but excluding the cost of sim pads, non shrink grout and steel works i.e hangers. All work up to fifth floor.				

EE (TPS-II)

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Code No	Description		Unit	Rate (Rs)
	5.54.1	Prestressed hollow core slab up to 200 mm thickness	sqm	217.45
	5.54.2	Prestressed hollow core slab above 200 mm up to 400 mm thickness	sqm	367.15
	5.54.3	Solid concrete wall elements	cum	2642.60
5.55	Providing & Applying weather proof sealant on outer joints of approved make confirming to IS & directed by Engineer-in-charge.			
	5.55.1	Sealant 25mmX10mm at joints	metre	460.45
5.56	Providing & Laying of levelling sim pads required sizes (5x5cm to 10x10cm) of PVC / Rubber to adjust level of bearing surface of supporting members as per the direction of Engineer in charge.			
	5.56.1	2mm thick	each	17.55
	5.56.2	5 mm thick	each	23.40
	5.56.3	10 mm thick	each	35.00
5.57	Providing & Grouting of dowel tubes / Shear keys / Joints of precast members with M-60 grade cementitious grout (Non Shrink) of approved make by suitable means (Free flowing /pump), curing etc. Complete as per directions of Engineer-in-charge. (The payment shall be made on the basis of actual weight of approved grout injected.)			
	5.57.1	Stirrer mixed cementitious grout (non shrink) of approved make in dowel tubes / Shear keys / Joints of precast members.	kg	65.00

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