प्रधान मंत्री आवास योजना-शहरी
Pradhan Mantri Awas Yojana-Urban

GLOBAL HOUSING TECHNOLOGY CHALLENGE INDIA

सत्यमेव जयते
Ministry of Housing & Urban Affairs
Government of India

आत्मनिर्भर भारत

स्वच्छ भारत
एक कदम स्वच्छता की ओर

LIGHT HOUSE PROJECT
AT RAJKOT, GUJARAT

3D View of the Project

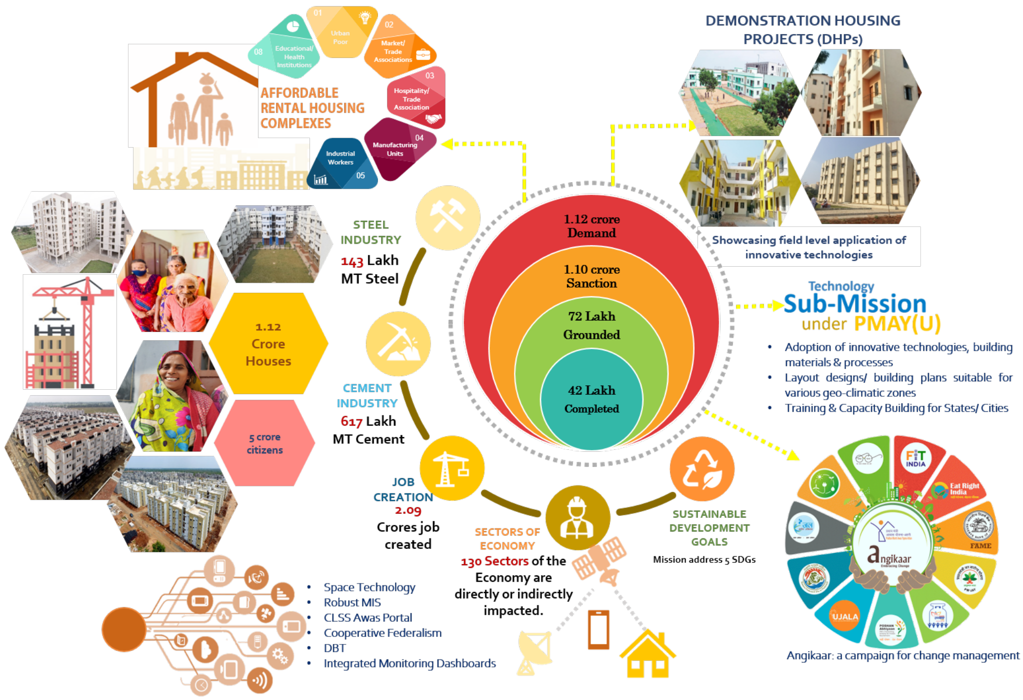
"The country is going to get a new technology to build houses for the poor and the middle class. In technical parlance, you call it the Light House Project. I believe these six projects are really like light towers. These six light house projects would give a new direction to the housing construction in the country. The coming together of states from the east-west, north-south and every region of the country is further strengthening our sense of cooperative federalism. These light house projects will be constructed through modern technology and innovative processes. This will reduce the construction time and prepare the more resilient, affordable and comfortable homes for the poor. In a way, these projects will be incubation centres and our planners, architects, engineers and students will be able to learn and experiment with new technology."

Narendra Modi
Prime Minister of India
1.1.2021

1. Background

The Ministry of Housing and Urban Affairs (MoHUA) is implementing Pradhan Mantri Awas Yojana-Urban (PMAY-U) Mission, one of the largest public housing programs in the world, with a goal of providing all weather pucca houses to all eligible urban families by 2022. Against an assessed demand of 1.12 crore houses, so far over 1.08 crore have been sanctioned; out of this over 72 lakh have been grounded for construction and nearly 42 lakh have been completed and delivered to the beneficiaries.

Under PMAY(U), a Technology Sub-Mission (TSM) has been set up with an aim to provide sustainable technological solutions for faster & cost-effective construction of houses suiting to geo-climatic and hazard conditions of the country". TSM promotes adoption of modern, innovative & green technologies and building material for faster and quality construction of houses. It also facilitates for preparation and adoption of layout designs and building plans suitable for various geo-climatic zones.



The Country being in development phase, massive construction activities are undergoing and planned in all the States/UTs for creating affordable shelters & related infrastructures. Traditionally, houses in the country are constructed using conventional technology as in-situ reinforced cement concrete (RCC) frame & burnt clay brick masonry. With the massive construction requirement & taking into consideration the important factors such as fast depleting natural resources, achieving Sustainable Development Goals (SDGs) & international commitments to reduce Carbon Dioxide emissions, there is urgent need to find alternate, sustainable and resource efficient solutions.

Globally, there has been technological advancement in the area of building materials and fast track prefabricated/pre-engineered construction practices. However, the use of alternate construction technologies in our country is in a limited extent so far. Hence, there was a need to look for new emerging, disaster-resilient, environment-friendly, cost-effective and speedy construction technologies which would form the basis of housing construction in India. Hon'ble Prime Minister envisaged a paradigm shift through technology transition using large scale construction under PMAY(U) as an opportunity to get the best available construction technologies across the globe.

In the light of above, MoHUA initiated Global Housing Technology Challenge India (GHTC-India) in January, 2019 which aimed to identify and mainstream globally best available proven construction technologies that are sustainable, green and disaster resilient through a challenge process which could bring a paradigm shift in construction practices for housing sector.

2. Construction Scenario in India

Housing for All by 2022 is the firm resolve of the Government to provide pucca shelter to each household of India and is a humble beginning towards building New India. The number of housing units that need to be constructed are huge. There is a requirement of 11.2 million dwelling units in urban areas by 2022. Also, construction sector is emerging as third largest sector globally to take India towards $5 trillion economy.

Conventionally, houses are built with traditional materials, i.e., burnt clay bricks, cement, sand, aggregates, stones, timber & steel. Sand and aggregates are already in short supply and due to irrational mining, it is banned in number of states in India. Burnt clay bricks use top fertile soil as raw material and also, its production makes use of coal, a fossil fuel. Cement and steel are also energy intensive materials and produced from natural resource, i.e., limestone rock and iron ores respectively. Further, the construction requires clean drinking water which is already in short supply even for drinking.

The way out is:

i. To make use of alternate materials which are based on renewable resources & energy
ii. Optimize the use of conventional materials by bringing mechanization in the construction
iii. Utilize agricultural & industrials waste in producing building materials.

In conventional method, the materials are gathered at the site and then construction takes place by laying bricks layer by layer to construct walls and pouring concrete over steel cages (reinforcement) to make floors, vertical members, i.e., columns and horizontal members i.e. beams through a labour intensive process with little control on quality of finished product. Also, this construction process is slow paced. Further, in being cast in situ construction, there is ample wastage of materials and precious resources and at the same time there is enormous dust generated polluting the air. Therefore, there is need to bring construction methodologies which impart speed to the construction, bring in optimum use of materials, cut down wastages and produce quality product.

In today's context, a few more terms have become significant with construction and need to be dovetailed with future construction practices. These are sustainability, climate responsiveness and disaster resilience. The construction industry poses a major challenge to the environment. As per the UN Environment Programme (UNEP), more than 30% of global greenhouse gas emissions are building related and emissions could double by 2050 on a business-as-usual scenario. As per report of the Green Rating for Integrated Habit Assessment (GRIHA), globally, buildings consume about 40% of energy, 25% of water and 40% of resources. In addition, building activities contribute an estimated 50% of the world's air pollution, 42% of its greenhouse gases, 50% of all water pollution, 48% of all solid wastes and 50% of all CFCs (chlorofluorocarbons) to the environment.

Further, disasters due to natural hazards i.e. earthquakes, cyclones, floods, tsunamis and landslides have been happening with ascending frequency and effects. Every year due to faulty construction practices and bad performance of built environment during disasters, there are not only heavy economic losses but also losses of precious lives of humans leaving irrevocable impact on human settlements and therefore, disaster-resilient construction is also paramount.

In view of the above, it is obvious that construction sector requires a paradigm shift from traditional construction systems by bringing innovative construction systems which are resource-efficient, environmentally responsible, climate responsive, sustainable, disaster-resilient, faster, structurally & functionally superior. These kinds of systems are being practiced world over successfully and have shown their versatility through the passage of time.

3. Innovative Construction Technologies: Salient Features

i. Resource Efficiency

A conventional building tends to focus on the use of basic materials namely cement, bricks, sand, aggregates, steel which are based on natural resources. Also, there is over dependence on fossil fuels for production & transportation. These natural resources are finite and cannot be replenished quickly. Also, their extraction and manufacturing have direct and indirect consequences on environment & energy requirements and pose danger to our planet in terms of greenhouse gas emissions, land & air pollution etc. Therefore, natural resources are to be used efficiently which is one of the key features of alternate construction systems as they employ industrial techniques to produces building components and use cement, steel and other aggregates optimally. The other feature of alternate construction systems is to make use of renewable resources.

ii. Structural Design Efficiency

The alternate systems follow the path of optimization. Right from the concept & design stage, the building components, including structural configuration, is designed in a manner to optimize the performance. The performance-based design instead of prescriptive design philosophy is the key for design efficiency while dealing with these alternate construction systems.

iii. Disaster Resilience

The alternate construction systems are designed to be resilient in terms of natural hazards as it entails performance-based design of buildings.

iv. Cost & Payoff

The most criticized issue about alternate construction systems is the price. The stigma is between the knowledge of up-front cost vis-à-vis life cycle cost. The cost of a building is defined as follows:

Total Cost = Initial construction cost + Running cost during life of building + disposal cost
(This is also known as life-cycle cost)

Most of the time, the criterion in selection of technology is cost per m^2, which is initial cost and can be incongruous if green aspects are to be considered. The buildings with alternate systems may cost 10-15% higher initially as of now (It can also be questioned as today these systems require initial push but once mainstreamed the initial cost will also be equivalent to cost of conventional construction) but will be less by couple of times over the entire life of the building. During the life span of a building, the financial payback will exceed the additional initial cost of using alternate systems several times. And broader benefits, such as reductions in greenhouse gases (GHGs) and other pollutants have large positive impacts on surrounding communities and on the planet.

v. Energy Efficiency

Alternate construction systems often include measures to reduce energy consumption, i.e., the embodied energy required to extract, process, transport and install building materials and the operating energy to provide services such as heating and power for equipment. The buildings with alternate systems use less operating energy, embodied energy. These buildings will have a lower embodied energy than those built primarily with brick, mortar, concrete, or steel.

vi. Water Efficiency

The conventional construction systems primarily are cast-in-situ reinforced concrete systems which require large quantity of potable water for curing and most of the time, the water of curing go waste. The new systems employ better techniques of curing such as pressurized curing, chemical curing etc. which help in conserving the water during construction.

vii. Material Efficiency

Building materials are typically considered to be sustainable if they are based on renewable/waste resources and can be reusable and recyclable. Most of the alternate construction systems either make use of industrial waste, renewable resources, energy efficient building materials or optimize the use of basic raw materials, i.e., cement, sand, aggregates, steel consumption. For example, The Glass Fiber Reinforced Gypsum (GFRG) panels make use of phospho-gypsum which is a by-product of fertilizer plant, sandwich panels make use of EPS beads which are energy efficient.

viii. Indoor Environmental Quality Enhancement

The Indoor Environmental Quality refers to providing comfort, well-being, and productivity of occupants. Indoor Air Quality seeks to reduce volatile organic compounds, or VOCs, and other air impurities such as microbial contaminants. The alternate systems employ construction materials and interior finish products with zero or low VOC emissions during the design and construction process which enhance indoor air quality. Also, well- insulated and tightly sealed envelope reduce moisture problems which often leads to dampness.

ix. Operation & Maintenance Optimization

The construction systems identified are based on factory made building components which are manufactured with high precision under strict quality control and therefore, more durable, requiring no or minimum maintenance. The alternate technologies are industrial products having SOPs for building's Operations and Maintenance (O&M).

x. Waste Reduction

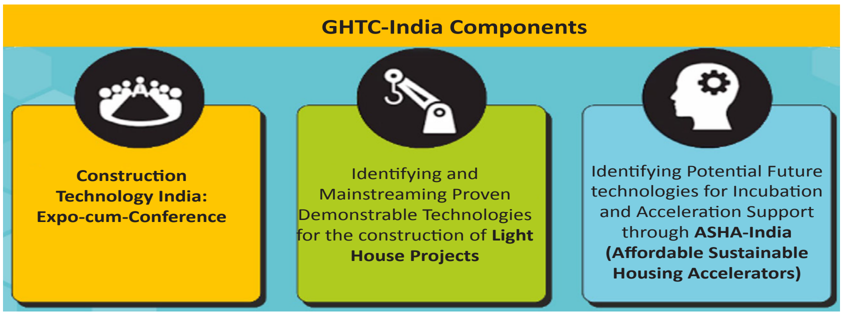
Alternate construction systems not only seek to reduce waste of energy, water and materials used during construction but also generate less construction & demolition waste after completion of the building. Well-designed buildings also help reduce the amount of waste generated by the occupants. When buildings reach the end of their useful life, they are typically demolished and disposed to landfills. In case of alternate systems, most of the deconstructed components can be reclaimed into useful building materials.

End-User Benefits
• Improved structural & functional performance
• Safer and disaster resilient house
• Better quality of construction
• Low maintenance, minimum life cycle cost
• Speedy construction resulting in early occupancy
• Cost-effective and environment-friendly
• Better fire resistance & thermal efficiency
• Less air pollution and waste generation

4. Global Housing Technology Challenge-India

MoHUA has initiated the Global Housing Technology Challenge-India (GHTC-India) which aims to identify and mainstream a basket of innovative construction technologies from across the globe for housing construction sector that are sustainable, eco-friendly and disaster-resilient. They are to be cost effective and speedier while enabling the quality construction of houses, meeting diverse geoclimatic conditions and desired functional needs. Future technologies will also be supported to foster an environment of research and development in the country. GHTC-India aspires to develop an eco-system to deliver on the technological challenges of the housing construction sector in a holistic manner.

Construction Technology India (CTI) – 2019: 1st Biennial Expo-cum-Conference was inaugurated by Hon'ble Prime Minister on 2nd March 2019. He also declared the year 2019-20 as the 'Construction Technology Year' to promote new and alternate technologies at a large scale in the country. The Expo brought together multiple stakeholders from across the world involved in innovative and alternative housing technologies for exchange of knowledge and business opportunities and master classes.



MoHUA, through a Technical Evaluation Committee (TEC), shortlisted 54 innovative proven technologies suiting different geo-climatic conditions that could be considered for demonstration through actual ground implementation of six Light House Projects (LHP) in six different States/UTs of PMAY(U) regions across the country. These 54 technologies were further categorized into following six broad categories:

1. Precast Concrete Construction System - 3D Precast volumetric

2.Precast Concrete Construction System - Precast components assembled at site

3.Light Gauge Steel Structural System & Pre-engineered Steel Structural System

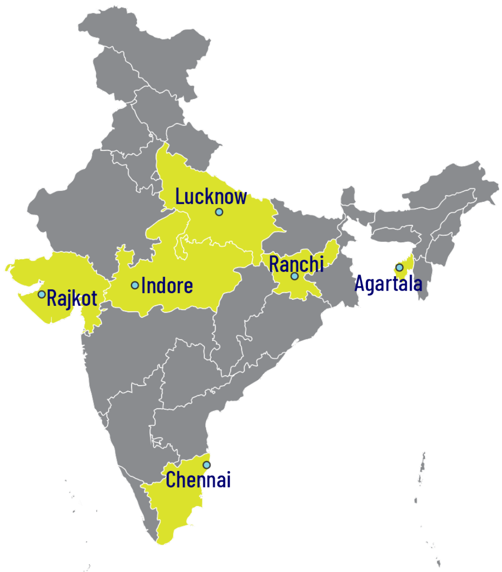
4.Prefabricated Sandwich Panel System

5.Monolithic Concrete Construction

6.Stay In Place Formwork System

The details of the shortlisted 54 technologies are available at https://ghtc-india.gov.in.

5. Light House Projects



Six distinct innovative technologies have been selected from among 54 globally best technologies that participated in GHTC-India for constructing six Light House Projects (LHPs) of about 1,000 houses each with allied infrastructure at Indore, Rajkot, Chennai, Ranchi, Agartala and Lucknow.

Hon'ble Prime Minister Shri Narendra Modi laid the foundation stone of these LHPs on January 1, 2021 and Hon'ble Governors, Hon'ble Chief Ministers of six states along with State Ministers joined the event from the LHP sites through video conference. The LHPs are model housing projects comprising of nearly 1,000 houses at each location with allied services are being constructed for showcasing use of the best of new-age technologies, materials and processes in the construction sector.

The houses are being constructed using the innovative technologies shortlisted under GHTC-India suitable to the geo-climatic and hazard conditions of the region and will be completed in challenges mode within 12 months time. LHPs will pave the way for a new eco-system where globally proven technologies will be adopted for cost effective, environment-friendly and speedier construction.

LHPs will serve as Live Laboratories for different aspects of transfer of technologies to field application, such as planning, design, production of components, construction practices, testing, etc., for both faculty and students, builders, professionals of private and public sectors and other stakeholders involved in such construction.

Details of six Light House Projects are as given below:

Location	DUs (Storeys)	Technology	Construction Agency
1. Indore, Madhya Pradesh	1,024 (S+8)	Prefabricated Sandwich Panel System	M/s KPR Projectcon Private Limited
2. Rajkot, Gujarat	1,144 (S+13)	Monolithic Concrete Construction using Tunnel Formwork	M/s Malani Construction Co.
3. Chennai, Tamil Nadu	1,152 (G+5)	Precast Concrete Construction System – Precast Components Assembled at Site	M/s B. G. Shirke Construction Technology Pvt. Ltd.
4. Ranchi, Jharkhand	1,008 (G+8)	Precast Concrete Construction System – 3D Volumetric	M/s SGC Magicrete LLP
5. Agartala, Tripura	1,000 (G+6)	Light Gauge Steel Structural System & Pre-engineered Steel Structural System	M/s Mitsumi Housing Pvt. Ltd.
6. Lucknow, Uttar Pradesh	1,040 (S+13)	PVC Stay In Place Formwork System	M/s JAM Sustainable Housing LLP

Light House Projects : Salient Features

- LHPs are model housing project with approximately 1,000 houses built at each location with shortlisted alternate technology suitable to the geo-climatic and hazard conditions of the region.
- Constructed houses under LHPs will include on site infrastructure development such as internal roads, pathways, common green area, boundary wall, water supply, sewerage, drainage, rainwater harvesting, solar lighting, external electrification, etc.
- Houses under LHPs are designed keeping in view the dimensional requirements laid down in National Building Code (NBC) 2016 with good aesthetics, proper ventilation, orientation, as required to suit the climatic conditions of the location and adequate storage space, etc.
- Convergence with other existing centrally-sponsored Schemes and Missions such as Smart Cities, Atal Mission for Rejuvenation and Urban Transformation (AMRUT), Swachh Bharat (Urban), National Urban Livelihood Mission (NULM), Ujjwala, Ujala, Make in India were ensured during the designing of LHPs at each site.
- The structural details were designed to meet the durability and safety requirements of applicable loads including earthquakes, cyclone, and flood as applicable in accordance with the applicable Indian/International standards.
- Cluster design may include innovative system of water supply, drainage and rainwater harvesting, renewable energy sources with special focus on solar energy.
- The period of construction will be maximum 12 months. Approvals were accorded through a fast track process by the concerned State/UT Government.
- For the subsequent allotment of constructed houses under LHPs to the eligible beneficiaries in States/ UTs, procedures of existing guidelines of PMAY (U) will be followed.

Light House Project at Rajkot, Gujarat

Project Brief	
Location of Project	Raiya Smart City Area, TPS No-32, FP63/10
No. of DUs	1,144 (S+13)
Plot area	39,599sq.mt.
Carpet area of each DU	39.77 sq.mt.
Total built up area	62,369sq.mt.
Technology being used	Monolithic Concrete Construction using Tunnel Formwork
Other provisions	Community Centre and Health Centre
Broad Specifications	
Foundation	RCC raft foundation
Walling	Monolithic RCC walls cast through tunnel formwork
Floor Slabs/Roofing	Monolithic RCC Slabs/Roofing cast through tunnel formwork
Joinery & Finishing	***Door Frame/ Shutters:*** • Pressed steel door frame with flush shutters • PVC door frame with PVC Shutters in toilets. ***Window Frame/ Shutter:*** • UPVC frame with glazed panel and wire mesh shutters. ***Flooring:*** • Vitrified tile flooring in Rooms & Kitchen • Anti-skid ceramic tiles in bath & WC • Kota stone Flooring in Common area. • Kota stone on Staircase steps. ***Wall Finishes:*** • Weather-proof acrylic emulsion paint on external walls • Oil Bound distemper over POP on internal walls
Infrastructure	Internal Water Supply, Laying of Sewerage Pipe Line, RCC storm water drain, Provisions for Fire Fighting, Internal Electrification, Internal Road & Pathway (CC Road and Bituminous Road), Providing Lifts in building blocks, Landscaping of site, Street light with LED lights, Solar Street Light System, Sewerage Treatment Plant, External Electrification, Water Supply System including underground water reservoir, Compound wall with Boundary Gates, Horticulture facilities, Rain Water Harvesting, Solid Waste Management.

Project Layout Plan

Block Plan

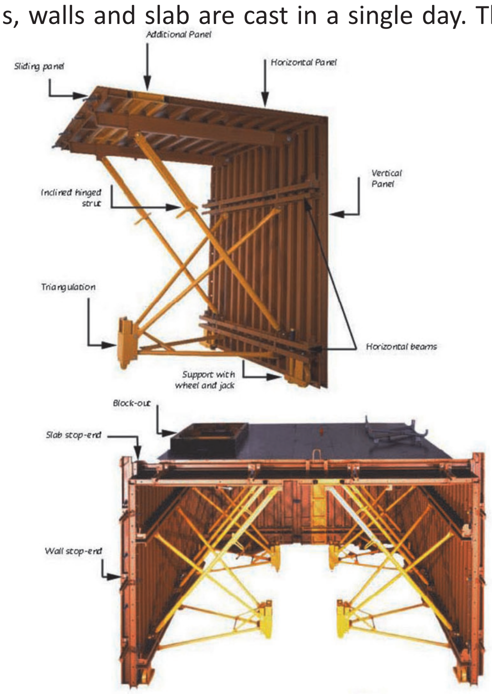
Unit Plan

Unit 3D VIew

Technology Details

A. INTRODUCTION

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 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.

B. TYPES OF FORMWORK SYSTEM

i. 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:	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:	110 Kg/m^2
Handling:	Lifting triangle or sling
Transportation:	180 m^2 per truckload.

ii. 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.

These Wallforms are tools specially designed to be used on specific buildings and structures. This vertical wall-form 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

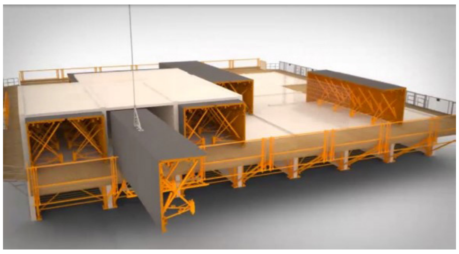
Inner and outer angle configurations are designed to attach to 1.25 m wall forms to obtain a 160 mm wall. Spacers shall be installed for producing wall thicknesses.

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.



iii. 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.

iv. Box Out

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

C. MATERIAL REQUIREMENTS

High carbon steel as per specification.

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.

D. 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.

E. 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.

F. 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
- Jail building etc.

G. SPECIAL FEATURES

i. 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 form-work, environment, site condition loads on formwork and combination of loads shall be taken in accordance with the clause 7.3 of IS 14687:1999.

ii. 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.

iii. Productive

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

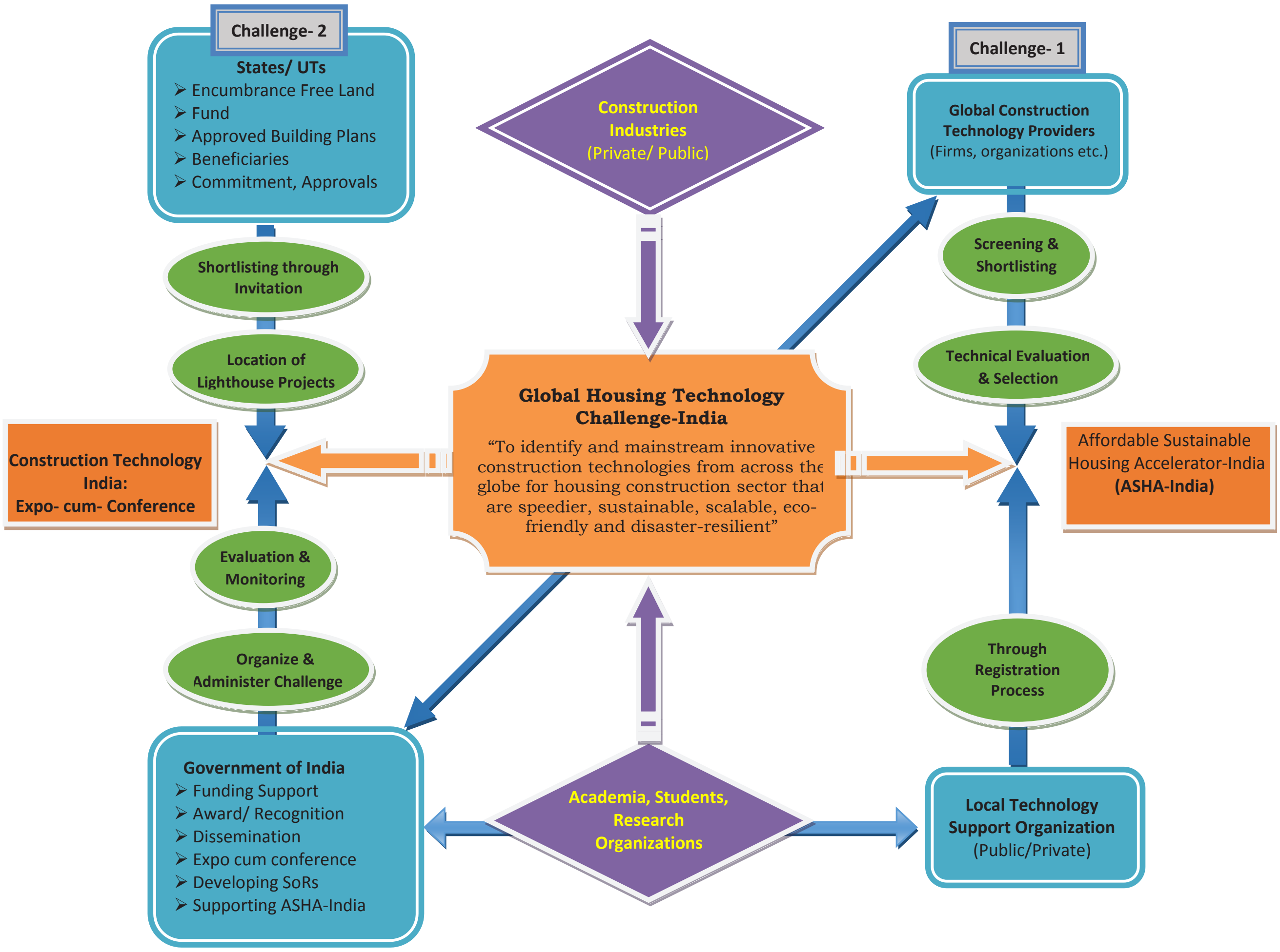
iv. Day-to-day basis

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.

H. LIMITATIONS

- The floor spans executed with movable forms shall not be more than 5.60 m, unless accessory units are used.
- Adequate working space is required to remove Tunnel formwork.
- Architectural design and planning should be suitable for Tunnel formwork.

Process Flow of GHTC-India



Notes:

Notes:

सत्यमेव जयते
The Joint Secretary & Mission Director (Housing for All)
Ministry of Housing and Urban Affairs
Government of India
Room No. 116, G-Wing, Nirman Bhawan, New Delhi
Tel: 011-23061419, Fax: 011-23061420
E-mail: jshfa-mhua@gov.in