Emerging Technologies in Housing Construction in India

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Sustainable Development & Habitat
Issues of Concern

- **Affordability**: cost-effective housing
- **Sustainability**: embodied energy, CO$_2$ emission, recycling
- **Local availability / scarcity**: of materials (river sand)
- **Rapidity** in construction: fast delivery
- **Structural stability and strength**: earthquake resistant
- **Functionality**: space utility, lighting, ventilation
- **Aesthetics**
- **Constructability**: quality, planning, skill
- **Durability**: life of structure with lesser maintenance costs
- **Government policies, subsidies**
Basic Requirements of Building

- Strength and stability
- Utility
- Comfort and convenience
- Durability
- Economy
- Aesthetics
- Security
- Resistance to moisture ingress
- Fire protection
- Thermal insulation
- Day lighting and ventilation
- Sound insulation
- Termite protection

“Development that meets the needs of the present without compromising the ability of future generations to meet their own needs”

- Brundland Commission
Modern Methods in Housing Construction

- Hollow block construction
- Shear wall concept
- Large area formwork
- Tunnel form
- Precast construction
- GFRG building system
- Cold formed steel wall panel
- Light weight concrete construction

Hollow block construction

Shear wall concept

Large area formwork

Tunnel form

Precast construction

GFRG building system

Cold formed steel wall panel

Light weight concrete construction
Modern Methods in Housing Construction

Hollow Block Construction

Shear Wall Building Construction

Large area formwork

Aluminium formwork

Tunnel form
Modern Methods in Housing Construction

Precast Concrete Construction

Light-weight Concrete Building

Cold-formed Steel Construction

GFRG Building Construction
Hollow Block Construction

Horizontal bed joint, bond beam and vertical reinforcement in a hollow block masonry wall

URM structure - concrete blocks (16" × 8" × 6") with cement mortar

Horizontal bed joint, truss-type reinforcement and vertical reinforcement in a hollow block masonry wall
Shear wall concept

3d model of a building with shear walls

Tall building with shear walls
Large Area Formwork
Flex Table System
Aluminium Formwork System - MIVAN

- Light weight
- Simple connection arrangement
- Easy to handle
- More than 100 repetitions
- Eliminates use of P & M
- Improves Labour productivity

MIVAN formwork used for the construction of South City residential complex, Bangalore
Systems Housing

- Use of Tunnel form and Pre-fabricated building elements
- Slabs & walls of a building are cast in continuous pour

- Structural steel mould
- Mechanized construction process
- Ideal for a repetitive structure
- For economy, speed & ease of construction
Tunnel Form Construction

- 750 Dwelling units each of built-up area 70 sq.m
- Tunnel Form system & Precast concept

Precast elements used:

- Facade panels
- Balconies
- Sunshades
- Landings
- Stair flights
- Cup boards
- Kitchen platforms
- Water tanks
Types of PreCast Elements and Construction Sequence

Types of precast elements used (for a typical floor)

Typical construction sequence
Construction of Rehab Buildings at Bhoiwada, Mumbai

- **No. of Blocks**: 6 nos.
- **Floors**: G+23 storeys
- **Dwelling units**: 2024 nos.

**Project Strategy:**

- Pile Foundation
- Ground floor by conventional method
- 1st floor to 23rd floor constructed using precast elements
- Finishes of all floors except WC and bath done at site

Precast Construction
Residential Projects

TISCO HOUSING, JAMSHEDPUR

APSEB HOUSING, MUDDANUR
Ministry of Defense Township

TOWNSHIP FOR
MINISTRY OF DEFENSE AT KARWAR
NO. OF HOUSES 946
Zernograd Township

- Total Built Up Area - 110,000 Square meters
- 600 Flats + Community Buildings
- Completion Time 3 Years
Cold-formed Steel (CFS) Housing System

- CFS system is an alternative to existing masonry and wood frame construction
- Can be used for single and multi-storey houses
- Cold-Formed Steel Shear Wall panel (CFSSWP) is the main lateral load resisting element in CFS system
- Use of recycled waste products
- Failure is due to the failure of screw connections between the sheathing and CFS framing

Mechanized Construction Process
GFRG wall panel (Rapidwall®)

– Glass Fibre Reinforced Gypsum - an alternative building material, introduced in Australia (1990)

GFRG panels can be used as walls and floor / roof slabs in combination with RC
Segment of GFRG panel and cross-section

- The hollow cores inside the wall panels can be filled with:
  - in-situ concrete
  - reinforced concrete
  - thermal insulates

Gypsum plaster, reinforced with chopped glass fibres, 300 – 350 mm long (spread at 0.8 kg/m²)

Tensile strength of glass fibre (single filament) is 3100 – 3800 MPa
Outline

1. Introduction
2. Manufacture of GFRG panels in India
3. GFRG Panel as a Structural Material
4. R&D outcome and ongoing research works
5. Deliverables from R&D works
6. Finished GFRG Buildings
India has 64 million tonnes of stockpiled gypsum.

GFRG is manufactured from waste gypsum (phosphogypsum) in India.

<table>
<thead>
<tr>
<th>Location</th>
<th>Quantity (Mi tonnes)</th>
<th>Location</th>
<th>Quantity (Mi tonnes)</th>
</tr>
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<tr>
<td>TATA, WB</td>
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<td>STERLITE, Tuticorin</td>
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<td>PPL, Paradip</td>
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<td>GSFC, Gujarat</td>
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</table>
Manufacturing Process - GFRG Panels

GFRG Manufacturing Plant – FRBL Kochi

Panel being shifted to dryer chamber for 1-1.5 hrs drying

Mfd. wet panel taken from casting table
Air drying

Automised cutting of panels

Loading of stillages (packed with cut panels) into truck at factory
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Structural Action of GFRG Panels

- Axial Loads
- + Out of plane Bending
- + In plane bending
- + Lateral Shear
- Slabs under gravity loading
### Typical Mechanical Properties (unfilled panels)

<table>
<thead>
<tr>
<th>Mechanical Property</th>
<th>Characteristic Value</th>
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<tbody>
<tr>
<td>Unit Weight</td>
<td>44 kg/m²</td>
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<tr>
<td>Uni-axial Compressive Strength</td>
<td>160 kN/m (4.77 MPa)</td>
</tr>
<tr>
<td>Ultimate Shear Strength</td>
<td>21.6 kN/m</td>
</tr>
<tr>
<td>Uni-axial Tensile Strength</td>
<td>35 kN/m (1.04 MPa)</td>
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<tr>
<td>Ductility</td>
<td>4.0</td>
</tr>
<tr>
<td>Elastic Modulus</td>
<td>4000 – 7500 MPa</td>
</tr>
<tr>
<td>Coefficient of Thermal Expansion</td>
<td>12 x 10⁻⁶ mm/mm/°C</td>
</tr>
<tr>
<td>Water Absorption</td>
<td>1% in 1 hr, 2.85% in 24 hr</td>
</tr>
<tr>
<td>Fire Resistance</td>
<td>4 hr rating, withstood 700-1000 °C</td>
</tr>
</tbody>
</table>
## Typical Mechanical Properties (fully filled panels):

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<th>Mechanical Property</th>
<th>Characteristic Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Uni-axial Compressive Strength</td>
<td>1360 kN/m</td>
</tr>
<tr>
<td>Ultimate Shear Strength</td>
<td>61 kN/m</td>
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</table>

Infilled panels – (all cavities infilled with M20 concrete)
Advantages of GFRG building systems

- reduction in structural weight of building
- saving of cement, steel, sand, water
- more carpet area
- saving of construction time
- effective use of industrial waste product
- suited for affordable mass housing

Applications

- As lightweight **load bearing walls**
- As **shear walls** *
- As **floor slabs / roof slabs**: with reinforced concrete micro beams *

* Design and construction methodology developed at IIT Madras
Residential buildings

Manipal, Udupi (2013)

- **Architect** – Sudhir Acharya
- **Builder** – Hastha Pvt. Ltd., Bangalore

Mangalore (2013)
Nursing home, Trichur (2015)

built-area – 5,000 sq.ft.

- **Architect** – N.M. Salim & Asc.
- **Builder** – N.M.S. Rapidwall, Calicut
Malayalam University, Tirur

Library cum classroom building
(built-area – 10,000 sq.ft.)

Canteen building
(built-area – 1,600 sq.ft.)
Office Buildings of Kerala State Electricity Board

KSEB building, Haripad
(built-area – 10,000 sq.ft.)

KSEB building, Manimala
(built-area – 1,600 sq.ft.)
Luxury villa, Bangalore (2015)

- Architect – Sudhir Acharya
- Builder – Hastha Pvt. Ltd., Bangalore
School buildings

Perinjanam, Trichur (2016)
(16,000 sq.ft. built area)

Chennai (2017)
(6,000 sq.ft. built area)

Builder – Enness Constructions, Calicut
JCO quarters (2016) at Military Cantonment,
St. Thomas Mount - by MES (Military Engg. Service)
built-area – 2,500 sq.ft.
Commercial building, Coimbatore (2016)

(built-area – 22,000 sq.ft.)

- **Client** – Bace India Pvt. Ltd., Coimbatore
- **Builder** – Enness Constructions, Calicut
Take-a-Break Building, Trivandrum (2017)

Client – KTDC, Govt. Of Kerala

(built-area – 500 sq.ft.)

20 such buildings have been constructed along the NHs and SHs in Kerala
Typically, many such school buildings have been built in Kerala.
G+3 Hostel Building at IIT Tirupati (Elevation) under construction
G+3 Hostel Building at IIT Tirupati

under construction