

MODULAR HIGH RISE CONSTRUCTION

OVERVIEW

- Introduction
- Difference between modular and prefab
- Modular construction process
- Types of modular construction
- Modular units for construction
- Inter-module joining techniques
- Application of modular techniques in high-rise construction
- Construction approaches for stacking modules
- Case studies
- Advantages and limitations of modular high-rise construction
- Conclusions
- References



INTRODUCTION

- In prefabricated construction, building units are fabricated in factory and are transported to site for assembly
- The three classes of prefabricated construction are: 1D single element, 2D panelized system and 3D volumetric construction
- The panelized and volumetric construction is also known as modular construction
- It is the most efficient class- 70 to 85% prefabrication in factory
- Enables faster, safer, sustainable, economical construction with better quality control





INTRODUCTION (Cond...)

- It can reduce:
 1. Onsite waste generation up to 90%
 2. Construction time by 50%
 3. Cost of construction by 20%
- Modular construction is preferred in structures with repeated units(modules) such as offices, schools, apartments
- High rise buildings consists of large number of repeated modules in them
- Therefore, the use of modular construction is highly beneficial for high risers





Fig 1: Croydon Tower, London (Source: www.dezeen.com)

DIFFERENCE BETWEEN MODULAR AND PREFAB

- The terms modular and prefab are used interchangeably but they are different
- Prefab construction includes any construction work done in factories away from the site
- Parts of building including panels and modules are made in factory
- They are transported to the site and assembled
- Modular construction is only a type of prefab construction
- Construction of modular buildings are mostly completed in the factory
- It involves the installation of modules on site





Fig 2: Assembling of panels in prefabricated construction (www.frozen.com)



Fig 3: Assembling of modules in modular construction (www.frozen.com)

MODULAR BUILDING PROCESS

- The processes involved in modular building construction include:
 1. Design approval by the regulating authorities and end users
 2. Construction of modular components in controlled atmosphere
 3. Transportation of materials to desired location
 4. Erection of modules to form a finished building

Design approval by the regulating authorities and end users

- Beginning phase-interior and exterior plans are created using BIM and other softwares
- After getting approval from the client, plan is submitted for getting administrative and technical sanction
- After the sanction from the competent authorities, components are manufactured
- Modular buildings must follow the local building codes and zoning regulations

Construction of modular components in a controlled atmosphere

- The modules for construction are built in a controlled offsite factory environment
- The site excavation and grading are going on at the same time at the site
- About 60%-90% work can be performed in factory
- The amount of work completed in factory depends on user requirements
- Assembling of basic structural components , exterior and interior finishes are done
- Mechanical, plumbing and electrical components can be installed in the factory

Construction of modular components in a controlled atmosphere (Continued...)

- Labour force in the factory include carpenters, plumbers, electricians, painters etc.
- Inspection by engineers at various stages of construction
- After completion of each modules, they are prepared for transportation



Fig 4: Modular construction factory (Source: www.modular.org)

Transportation of modules to desired location

- The building modules are transported on carriers pulled by trucks
- They are loaded and unloaded by cranes
- Each module must be built to independently withstand travel and installation requirements
- They should withstand high winds and manipulation by cranes
- The resiliency of modules contributes to greater structural strength of the building

Transportation of modules to desired location(Contd...)

- Transportation of the modules depends upon:
 1. Method of transport
 2. Cost of transport
 3. Travel distance
 4. Restrictions along the roadways
 5. Weight of the modules
- The size of the modules that can be transported also depends on these factors



Fig 5: Transportation of building modules in trucks
(Source:www.bennettig.in)



Fig 6: Placing building modules in trucks from the
factory (Source:www.bennettig.in)

Erection of modules to form a finished structure

- The modules are placed using a crane in a variety of styles and configurations
- The modules can be placed side by side, end to end or stalked
- After placement, modules are connected using inter-module connections
- In the final construction stage:
 1. Internal and external finishes are done
 2. Stairs and elevators are added
 3. Cabinets, countertops, appliances etc. are added

TYPES OF MODULAR CONSTRUCTION

Permanent Modular Construction (PMC)	Relocatable buildings (Relocatable building)
Completely constructed structures	Partially or completely constructed
Installed for long term use	Installed for a short period of time
Made of wood, steel, concrete or in combinations	Usually made of wood
Designed to be located in the same place	Designed to be transported and reloacted
Endless options for customisation	Fewer options for customisation
Takes more time for assembling at site	Lesser assembling time
Eg: Apartments, Hotels, Schools, Hospitals etc.	Eg: Work camps, Medical camps etc.

TYPES OF MODULAR CONSTRUCTION

Permanent Modular Construction



Fig 7: Hawaii film studio
(Source: www.modular.org)

Relocatable buildings



Fig 8: Modular work camps
(Source: www.modulargenius.com)

MODULAR UNITS FOR CONSTRUCTION

- Modular units-sections joined together to make a modular building
- Number of modules used depends on size and style of project
- Based on load transfer mechanism, 3D module is classified:
 1. **Load Bearing Wall**- The gravity load transferred to the base through the four side walls
 2. **Corner Supported Frame**-Load transfer through edge beams and four corner posts

MODULAR UNITS FOR CONSTRUCTION

Load Bearing wall



Fig 9: Load bearing wall
(Source: www.researchgate.net)

Corner Supported Frame



Fig 10: Corner supported Frame
(Source: www.researchgate.net)

INTER-MODULE JOINING TECHNIQUES

- Connection between modules ensures structural integrity, overall stability and robustness
- Welded connections are not preferred onsite
- They required skilled labour, large working space and time consuming inspections
- Joining techniques for steel buildings are:
 1. Connection using tie rod
 2. Using connector
 3. Using bolt

INTER-MODULE JOINING TECHNIQUES

- Inter-module connections in concrete high rise buildings increase cost, reduces speed of construction
- Significant labour for rebars and site grouting

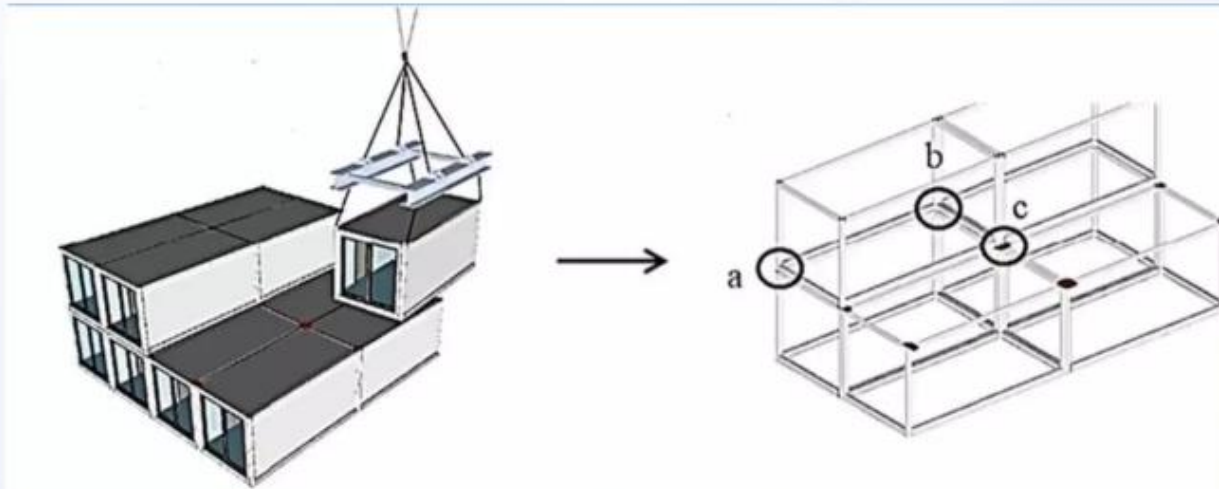


Fig 11: Module stacking in modular construction
(Source: www.modulargracious.com)

APPLICATION OF MODULAR TECHNOLOGY FOR HIGH RISE CONSTRUCTION

Table 1: Ten of the world's tallest buildings

No.	Project	Storey	Year	Location	Modular type	Material	Highlight
1	Collins House	60	2019	Melbourne, Australia	2D panel and 3D volume	Concrete	The tallest building combined both penalised and volumetric methods
2	J57 Mini Sky City tower	57	2015	Changsha, China	2D panel	Steel	The fastest built buildings upon completion (in 19 days)
3	Croydon Tower	44	2020	London, UK	3D volume	Steel	The tallest volumetric modular building upon completion
4	Atira Student Accommodation	44	2018	Melbourne, Australia	2D panel and 3D volume	Concrete	Combining both penalised and volumetric methods
5	La Trobe Tower	44	2016	Melbourne, Australia	2D panel and 3D volume	Concrete	Combining both penalised and volumetric methods
6	Clement Canopy	40	2019	Singapore	3D volume	Concrete	The tallest volumetric modular building
7	B2 Tower	32	2016	New York, USA	3D volume	Steel	The tallest volumetric modular building upon completion
8	T30 Tower	30	2011	Xiangyin, China	2D panel	Steel	The fastest built buildings upon completion (in 15 days)
9	Apex House	29	2017	London, UK	3D volume	Steel	The tallest volumetric modular building in Europe
10	SOHO Tower	29	2014	Darwin, Australia	3D volume	Steel	The tallest volumetric modular building upon completion

Source: www.researchgate.in

CONSTRUCTION APPROACHES FOR STACKING MODULES

Three main approaches for stacking of modules:

1. Core based approach
2. Podium based approach
3. Infilled frame method

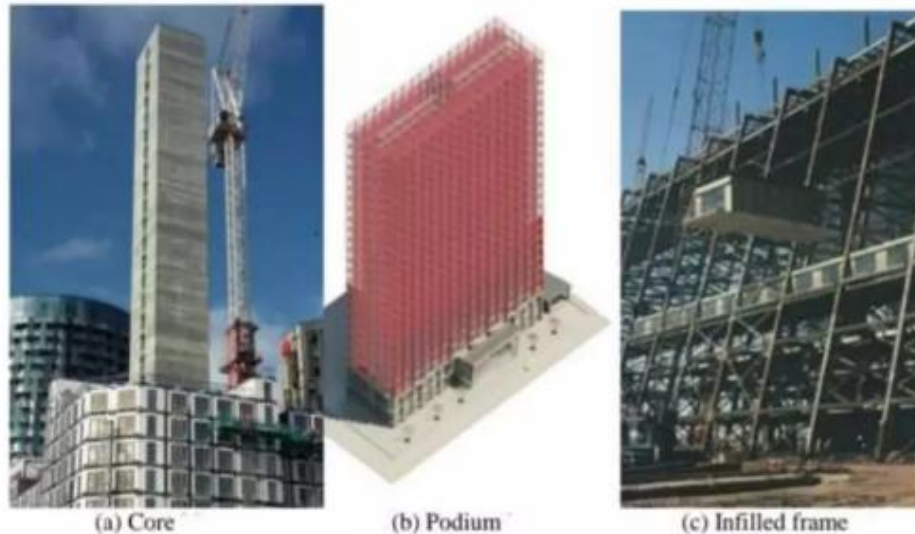


Fig 12: Core, Podium and Infilled frame method of construction

(Source: www.researchgate.in)

1.Core-based approach

- Modules are stacked around one or more stability cores
- Modular units-resist vertical gravity loads
- Cores- lateral forces due to wind and earthquake
- Lateral diaphragms and connections between core and modules should be strong
- This is for safe transfer of lateral loads to the core
- Material of core-precast concrete, cast-in-site steel-concrete composite walls
- Additional bracing system within floor and ceiling-maximise building height

2.Podium-based approach

- Modules are placed above a podium or platform
- Podium is designed as a traditional steel, concrete or hybrid steel-concrete structure
- Podium acts as a foundation for modules stacked or clustered around cores for tall buildings
- Beneficial for mixed use buildings
- Podium provide open space for commercial purpose and underground parking

3.Infilled frame method

- Modular units are placed between the beams and columns of a primary framing structure
- The overall stability of the modular buildings is ensured
- The primary framing structure is constructed onsite by conventional methods.

Case Study 1: Collins House, Melbourne, Australia



Fig 13: Collins House, Melbourne (Source: www.facadexs.com)