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CE3003- PREFABRICATED STRUCTURES

UNIT 1-NOTES

UNIT 1 INTRODUCTION

Need for Prefabrication - Advantages and Limitation - Principles of Prefabrication - Modular coordination - Standardization- Loads and Load combinations – Materials – Production – Transportation – Erection.

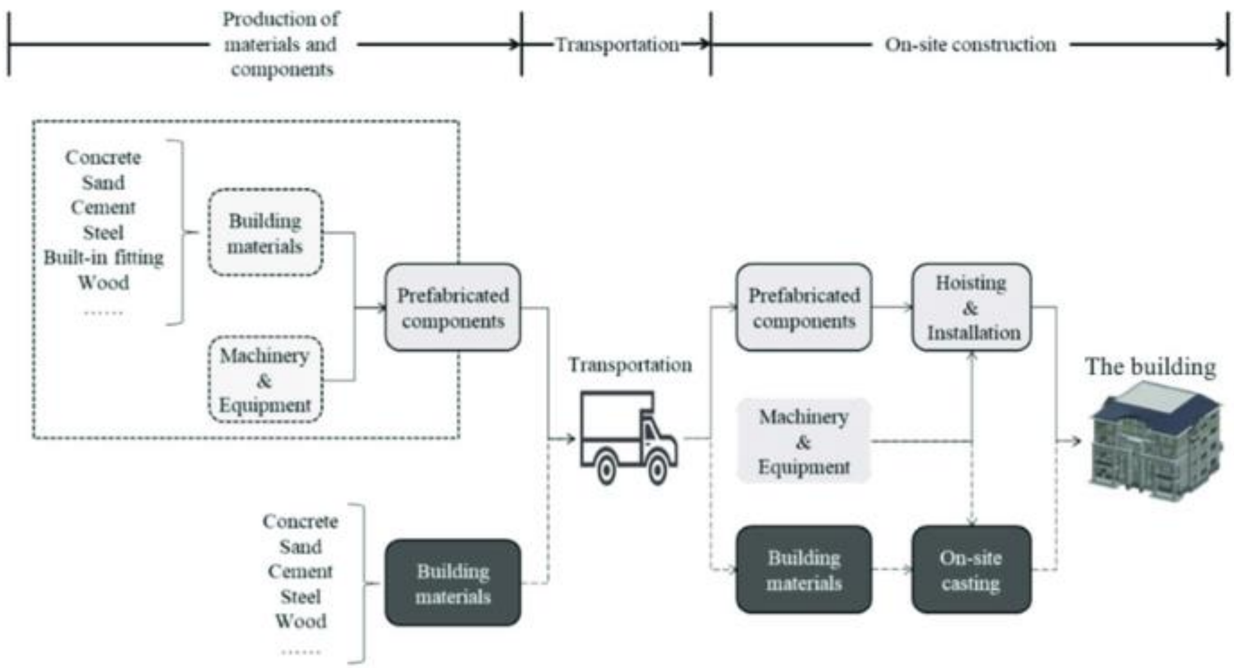
1.1 PREFABRICATION

Prefabrication, often referred to as "prefab," is a construction method involving the manufacturing of building components or entire structures in a controlled factory environment before transporting them to the construction site for assembly. This process allows for increased efficiency, quality control, cost-effectiveness, and safety compared to traditional on-site construction methods. Prefabricated elements can include wall panels, floor systems, roof trusses, and entire modular buildings, among others. The goal of prefabrication is to streamline the construction process and deliver high-quality structures with reduced time and resources.

Prefabricated structures are buildings or constructions that are manufactured off-site in a factory or controlled environment, using standardized components or modules, and then transported to the intended location for assembly. These structures are designed to be easily transported, rapidly assembled, and often feature standardized components that can be mass-produced. Prefabricated structures can range from small modular units like cabins or storage sheds to larger buildings such as residential homes, commercial offices, schools, or even industrial facilities.

1.1.1 STAGES INVOLVED IN PREFABRICATION

- The Structure is divided into number of units.
- The different units are precast in permanent factories (Plant fabrication) or temporary plants (Site fabrication)
- Transported to the site
- Hoisted set into their final places and assembled to form a complete structure.



1.1.2 PLANS AND SPECIFICATIONS (IS 15916)

- Drawing shall describe the elements and structures and assembly including all required data of physical properties of component materials (Material specification)
- Details of connection joints
- Site or Shop location of services (Installation of piping, wiring and other accessories)
- Location of inserts (Doors, Windows and Ventilators)
- Handling arrangement to avoid failure.

1.2 NEED FOR PREFABRICATION

The need for prefabrication arises from various challenges and demands faced by the construction industry. Here's a detailed explanation of the factors driving the need for prefabrication:

1. **Speed of Construction**: Prefabrication offers significantly faster construction times compared to traditional on-site building methods. With prefabricated components manufactured concurrently with site preparation, construction projects can be completed in a fraction of the time required for traditional construction. This speed is particularly advantageous for projects with tight deadlines, emergency situations, or in rapidly growing urban areas where quick completion is essential.

2. **Labor Shortages:** Many regions face shortages of skilled construction labor, leading to delays and increased costs for traditional construction projects. Prefabrication reduces reliance on on-site labor, as much of the work is done in factories with specialized machinery and processes. This can help alleviate the impact of labor shortages and ensure projects are completed on schedule.

3. **Cost Efficiency:** Prefabricated construction can be more cost-effective than traditional methods due to several factors. These include reduced labor costs, streamlined manufacturing processes, bulk purchasing of materials, and minimized waste. Additionally, the controlled factory environment enables better quality control, reducing the likelihood of errors or rework that can drive up costs during on-site construction.

4. **Quality Control:** Prefabrication allows for meticulous quality control throughout the manufacturing process. In factory settings, manufacturers can closely monitor the production of components, ensuring they meet stringent quality standards. This results in higher-quality buildings with fewer defects compared to those constructed using traditional methods, where quality control is often more challenging to maintain.

5. **Design Flexibility:** Contrary to the misconception that prefabricated structures lack design flexibility, advancements in technology have enabled highly customizable prefabricated solutions. Modular construction techniques allow for the creation of diverse

building designs, layouts, and configurations to meet specific project requirements. Architects and designers can leverage prefabricated components to achieve innovative and aesthetically pleasing designs while maintaining efficiency and cost-effectiveness.

6. **Sustainability:** Prefabrication can contribute to sustainability goals in several ways. By optimizing material usage and minimizing waste in factory settings, prefabricated construction generates less construction debris and reduces environmental impact compared to traditional methods. Additionally, the controlled manufacturing environment enables better energy efficiency and resource management, further reducing the carbon footprint of construction projects.

7. **Safety**: Safety is paramount in construction, and prefabrication offers several safety advantages over traditional building methods. Factory environments typically have stricter safety protocols and regulations in place, reducing the risk of accidents and injuries during the construction process. Additionally, by minimizing on-site construction activities, prefabrication reduces exposure to hazards such as falls, electrical accidents, and inclement weather conditions.

8. **Consistency and Reliability:** Prefabricated components are manufactured to precise specifications in controlled factory conditions, ensuring consistency and reliability across multiple units or buildings. This uniformity helps guarantee the structural integrity and performance of prefabricated structures, providing peace of mind to developers, contractors, and building occupants.

1.3 PRINCIPLES OF PREFABRICATION

The principles of prefabrication encompass a set of key concepts and practices that guide the design, manufacturing, transportation, and assembly of prefabricated components or structures. These principles aim to maximize efficiency, quality, and safety throughout the prefabrication process. Here are the fundamental principles of prefabrication:

1. **Standardization**: Standardization involves designing prefabricated components to conform to established specifications, dimensions, and quality standards. By standardizing components, manufacturers can streamline production processes, optimize

material usage, and facilitate interchangeability and compatibility between different modules or structures.

2. **Modularity**: Modularity refers to the division of a building or structure into standardized modules or units that can be independently manufactured and assembled. These modules are designed to fit together seamlessly, allowing for flexible configurations and easy customization. Modularity enables rapid assembly, simplifies transportation, and facilitates future expansion or modification of the structure.

3. **Design for Manufacturability (DFM)**: Design for Manufacturability involves designing prefabricated components with manufacturing efficiency and ease of assembly in mind. This principle emphasizes simplifying construction details, minimizing the number of unique parts, and optimizing material usage to reduce waste. DFM also involves selecting materials and construction methods that are well-suited for factory production and transportation.

4. **Integration of Services**: Prefabrication involves integrating various building services, such as plumbing, electrical, HVAC (heating, ventilation, and air conditioning), and telecommunications, into prefabricated components during the manufacturing process. This integration minimizes on-site installation time, reduces coordination issues, and ensures compatibility between different building systems.

5. **Quality Control**: Quality control is paramount in prefabrication to ensure that prefabricated components meet specified standards and performance requirements. Quality control measures include rigorous testing, inspection, and monitoring throughout the manufacturing process to detect defects, deviations, or deficiencies promptly. By maintaining high quality standards, manufacturers can deliver durable, reliable, and safe prefabricated structures.

6. **Logistics and Transportation**: Efficient logistics and transportation are essential for the successful implementation of prefabrication. This involves carefully planning the transportation routes, selecting appropriate transportation modes (such as trucks, trains, or ships), and optimizing load configurations to minimize transportation costs and

maximize delivery efficiency. Proper logistics management ensures timely delivery of prefabricated components to the construction site while avoiding delays and disruptions.

7. **Safety**: Safety is a priority in prefabrication, both in the factory environment and during on-site assembly. Manufacturers implement stringent safety protocols and practices to protect workers from accidents and injuries during component fabrication. On-site construction crews follow safety guidelines and procedures to ensure a safe working environment and prevent accidents during assembly, lifting, and installation of prefabricated components.

8. **Lifecycle Considerations**: Prefabrication extends beyond the construction phase to consider the entire lifecycle of the structure, including maintenance, repair, and eventual decommissioning. Designing for durability, accessibility, and ease of maintenance allows for efficient lifecycle management and prolongs the service life of prefabricated structures.

1.4 ADVANTAGES OF PREFABRICATION

1. **Speed of Construction**: Prefabrication significantly reduces construction time by enabling parallel manufacturing and site preparation.

2. **Cost Efficiency**: Prefabrication can lower overall construction costs through reduced labor expenses, streamlined processes, and minimized waste.

3. **Quality Control**: Factory-controlled environments ensure consistent quality, fewer defects, and higher precision compared to traditional construction.

4. **Design Flexibility**: Prefabrication allows for customization and versatility in design, accommodating diverse architectural styles and project requirements.

5. **Sustainability**: Prefabrication reduces environmental impact through optimized material usage, reduced waste, and enhanced energy efficiency.

6. **Safety**: Prefabricated construction mitigates on-site safety risks by minimizing exposure to hazards and implementing stringent safety measures in factory environments.

7. **Reduced Site Disruption**: Prefabrication minimizes on-site disruption, noise, and waste generation, making it suitable for urban environments or sensitive areas.

8. **Predictability**: Prefabrication offers greater predictability in construction schedules, costs, and outcomes due to standardized processes and components.

1.5 LIMITATIONS OF PREFABRICATION

1. **Initial Investment**: Establishing prefabrication facilities and transitioning to prefabricated construction methods may require significant upfront investment.

2. **Transportation Challenges**: Transporting large prefabricated components to the construction site can pose logistical challenges, particularly for projects in remote or inaccessible locations.

3. **Limited Site Adaptability**: Prefabricated components may not always align perfectly with site conditions or requirements, requiring additional adjustments or modifications during assembly.

4. **Design Constraints**: Designing for prefabrication may impose certain constraints on architectural creativity or complexity, limiting design options for some projects.

5. **Dependency on Supply Chain**: Prefabrication relies on a robust and reliable supply chain for materials, components, and equipment, making projects susceptible to disruptions or delays.

6. **Assembly Complexity**: While prefabricated components streamline construction, their assembly on-site may still require skilled labor and careful coordination, particularly for larger or more complex structures.

7. **Transportation Costs**: Transportation expenses for delivering prefabricated components to the construction site can add to overall project costs, especially for projects located far from manufacturing facilities.

8. **Limited Scale**: While suitable for a wide range of projects, prefabrication may not always be practical or cost-effective for very large or specialized structures.

1.6 COMPARISON BETWEEN PRECAST COMPONENTS AND CAST IN SITU COMPONENTS

Comparing precast components and cast-in-situ components involves examining various aspects such as production process, quality control, cost, speed of construction, design flexibility, and sustainability. Here's a detailed comparison between the two:

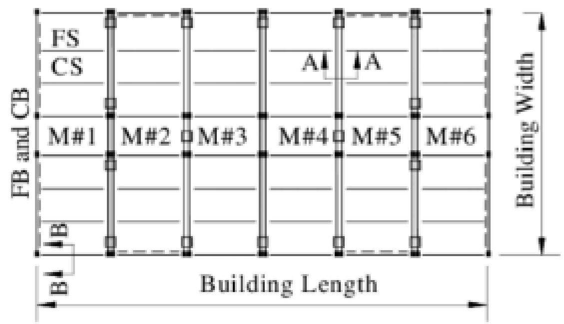
Sl.No	Description	Precast Elements	Cast-in-situ Elements
1	**Production Process:**	• It is manufactured off-site in a controlled factory environment. • Production involves casting concrete into molds, curing, and finishing to achieve desired specifications. • Precast elements are transported to the construction site for assembly.	• Cast-in-situ components are constructed directly at the construction site. • Concrete is poured into formwork and allowed to cure in place. • Formwork is typically assembled on-site and removed after the concrete has hardened.
2	**Quality Control:**	• Precast production allows for rigorous quality control measures in a controlled factory environment. • Components are manufactured to precise specifications, resulting in consistent quality and fewer defects. • Quality control processes can include testing of materials, monitoring production	• Quality control for cast-in-situ components is typically more challenging due to variability in on-site conditions. • Factors such as weather, site preparation, and concrete placement can impact quality. • Quality control measures may include testing of concrete mixtures, monitoring curing conditions, and inspecting formwork integrity.

		conditions, and inspecting finished components.	
3	**Cost:**	• Initial costs for setting up precast facilities and molds can be higher. • However, economies of scale and efficiency in production can result in cost savings over time. • Reduced labor costs and shorter construction schedules can also contribute to overall cost-effectiveness.	• Initial costs for formwork, labor, and equipment may be lower. • However, on-site construction may be subject to delays, labor inefficiencies, and material waste, which can increase costs. • Long-term maintenance costs should also be considered, as cast-in-situ components may require more frequent repairs or replacements.
4	**Speed of Construction:**	• Precast construction is typically faster due to simultaneous manufacturing and site preparation. • Components can be installed quickly upon delivery, minimizing on-site construction time. • Prefabricated elements allow for faster assembly and reduced project duration.	• Cast-in-situ construction may be slower due to sequential processes and on-site limitations. • Concrete pouring, curing, and formwork removal require time, leading to longer construction schedules. • Weather conditions and site constraints can further impact construction speed.
5	**Design Flexibility:**	• Precast construction offers high design flexibility, with a wide range of shapes, sizes,	• Design flexibility for cast-in-situ components may be limited by formwork constraints and on-site

		and finishes available. • Custom molds and architectural details can be incorporated into precast elements. • Modularity allows for easy integration of precast components into various building designs.	construction methods. • Customization options may be more restricted compared to precast components. • Complex architectural features may require specialized formwork and construction techniques.
6	**Sustainability:**	• Precast construction can be more sustainable due to reduced material waste, improved quality control, and optimized resource usage. • Factory-controlled environments enable efficient energy usage and minimize environmental impact. • Transporting precast components to the construction site may incur carbon emissions, but overall sustainability benefits can outweigh these drawbacks.	• Cast-in-situ construction may result in more material waste, particularly from formwork and excess concrete. • On-site construction activities can generate higher levels of pollution and environmental disturbance. • However, locally sourced materials and reduced transportation distances may contribute to sustainability.

1.7 MODULE

Module refers to a standardized unit or measurement or dimension that used as a basis for designing and manufacturing prefabricated components. The concept involved in breaking down the building components into standardized units that can be easily manufactured in a controlled factory environment and assembled on a site. These standard units designed to fit together seamlessly according to predetermined dimensions or specification. Typical module measurements are given in the figure.



Key characteristic of module in prefabricated structures are:

1. **Standardization**: Modules in prefabrication are based on standardized dimensions, typically multiples of a specific unit such as millimeters or inches. This standardization ensures consistency and compatibility between different prefabricated components.

2. **Design Flexibility**: While modules adhere to standardized dimensions, they also offer flexibility in design. Architects and engineers can vary the arrangement and configuration of modules to accommodate specific project requirements, layouts, and architectural styles.

3. **Modular Components**: Prefabricated modules can include a wide range of building components, such as wall panels, floor systems, roof trusses, bathroom pods, and entire modular units. Each component is manufactured as a self-contained module, complete with finishes, fixtures, and fittings.

4. **Efficiency in Production**: Prefabrication allows for the mass production of standardized modules in a controlled factory environment. This results in streamlined production processes, optimized material usage, and reduced waste, leading to cost savings and shorter project timelines.

5. **Transportability**: Prefabricated modules are designed to be transported to the construction site using trucks, trains, or shipping containers. Standardized dimensions and modular construction methods ensure that modules can be easily transported and assembled on-site, even in remote or inaccessible locations.

6. **Assembly**: On-site assembly of prefabricated modules is typically faster and requires less labor compared to traditional construction methods. Modules are designed to fit together seamlessly, allowing for efficient assembly using simple tools and techniques.

7. **Quality Control**: Prefabricated modules undergo rigorous quality control measures throughout the manufacturing process. Components are manufactured to precise specifications, ensuring consistency, durability, and high-quality finishes.

8. **Sustainability**: Prefabrication offers sustainability benefits such as reduced material waste, improved energy efficiency, and minimized environmental impact. By optimizing production processes and materials usage, prefabricated modules contribute to more sustainable construction practices.

9. **Adaptability**: Prefabricated modules can be easily customized and adapted to suit various project requirements. Design changes can be implemented quickly and efficiently, allowing for greater flexibility and responsiveness to client needs.

1.7.1 CLASSIFICATION OF MODULE

Module

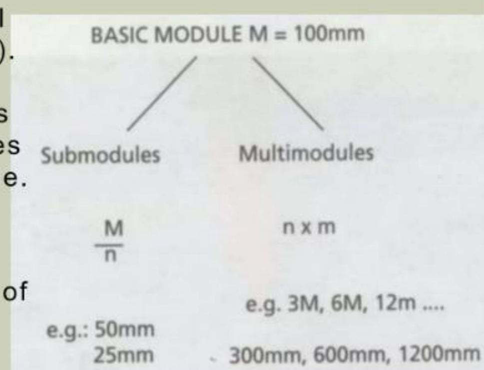
Standard unit size used to coordinate the dimensions of buildings and components

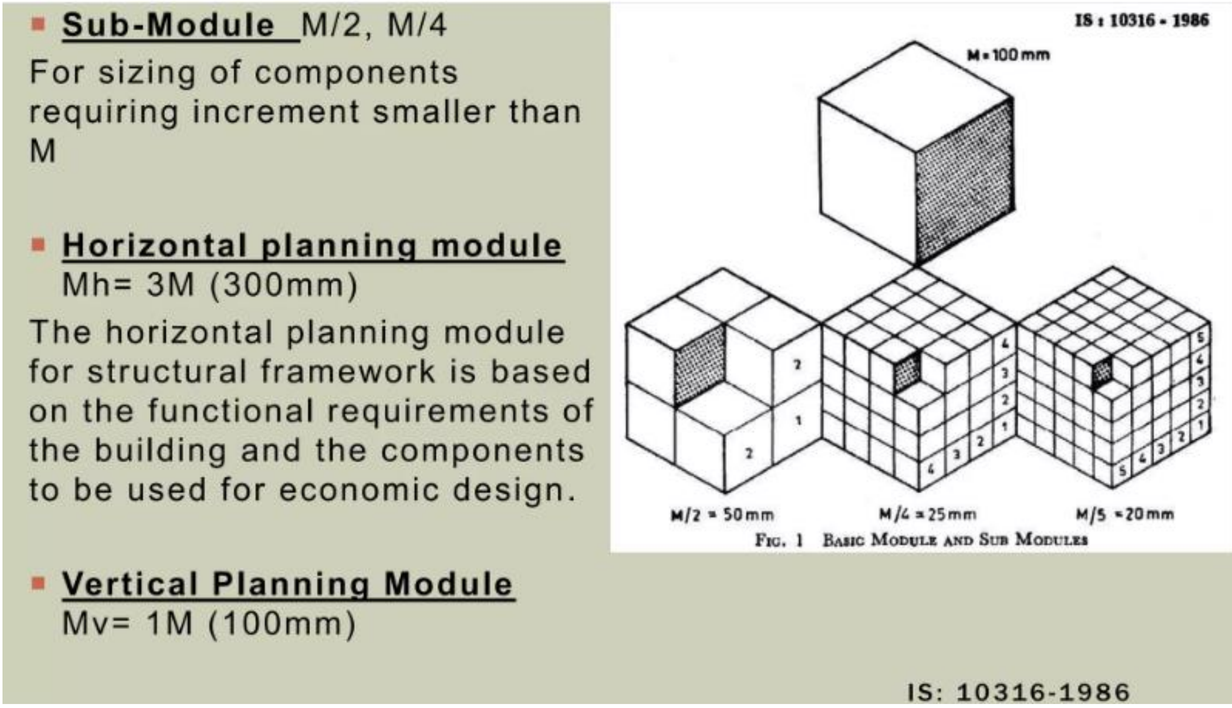
- **Basic module** M = 100 mm

  The basic module is the fundamental unit of size in modular co-ordination). The co-ordinating sizes of building components, of the parts of buildings they form and of buildings themselves shall be multiples of the basic module.

- **Multi-Module** 2M, 3M ..

  Multimodules are selected multiples of the basic module; different multimodules will suit particular applications.





1.8 MODULAR COORDINATION

Modular coordination is a concept of coordination of dimension and space in which buildings and components are dimensioned and positioned in terms of basic unit or module. The basic module is known as 1M, which is equivalent to 100 mm. It is internationally accepted by the International Standard Organization.

It also acts as a tool towards rationalization and industrialization of the building industry. The industrial standardization is possible with dimensional coordination. Dimensional coordination is possible when the dimensions of the precast building material to be erected are in multiples of one basic dimensional unit known as basic module. Such dimensional coordination is referred as modular coordination.

1.8.1 AIM AND OBJECTIVES OF MODULAR COORDINATION

The principle objectives of modular systems are to provide practical and coherent solution for the coordination of the position and dimensions of the elements, components and space in building design.

This process can contribute to increase design freedom and improved balance between quality and cost in manufacture and construction.

1.8.2 BASICS OF MODULAR COORDINATION

The main purpose of modular coordination is to achieve the dimensional compatibility between the building dimensions, span or spaces and size of the components and equipment using related modular dimension.

Modular coordination generally provides the easy grasped layout of the positioning of the building components in relation to each other and to the building and facilitates the collaboration between the planners, manufacturers, distributors and contractors.

1.8.3 STANDARD RULES IN MODULAR COORDINATION

Modular coordination is essentially based on the use of modules (Basic module and multi module) and reference system to define coordinating spaces and zones for building elements and for components which form them.

There are standard rules to abide by

- Rules for locating building elements within reference system
- Rules for sizing building components in order to determine their work sizes
- Rule for defining preferred sizes for building components and coordinating dimensions for the buildings.
- IS 7922-1987; Recommendation for Modular coordination in Building Industry

1.8.4 PURPOSE OF MODULAR COORDINATION

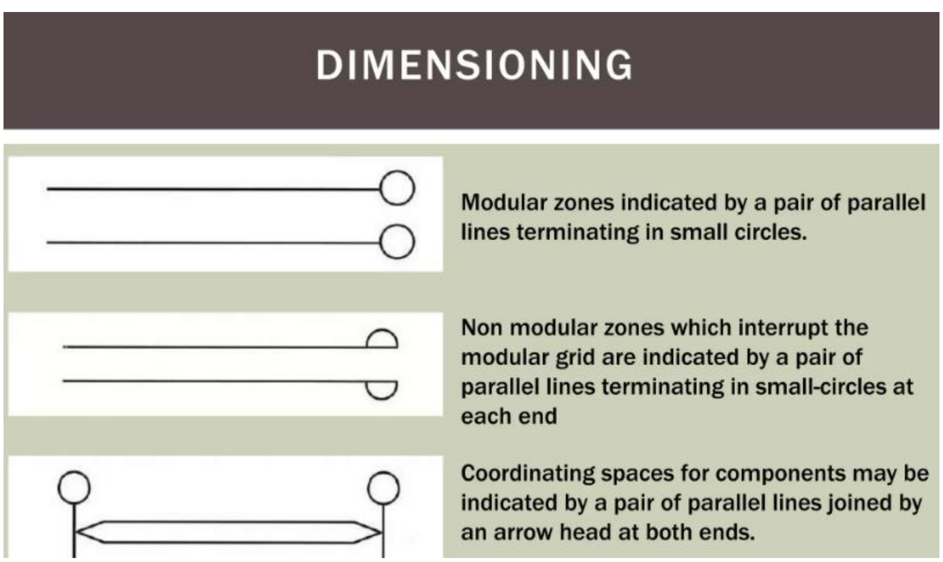
- To reduce the component size produced and to use standard size of the building blocks in the design
- To aid the cooperation between building designer, manufacturer, contractor and distributor.
- To determine the size and position of each component in relation to each component and the building as a whole.
- To increase the balance between cost and quality between the manufacture and

construction.

1.8.5 MODULAR COORDINATION DIMENSIONS

The following set of rules will be adequate for meeting the requirements for prefabricated construction:

- The planning grid in both directions of the horizontal plan shall be
  - 3M for residential and institutional buildings
- For industrial buildings
  - 15M for spans up to 12m
  - 30M for spans between 12m to 15m
  - 60M for spans over 18m
- The centre lines of load bearing walls shall coincide with the grid lines.
- The grid wall shall coincide with the centre line of the wall or a line on the wall 5cm from the internal face of the wall for external walls.
- In vertical direction, the planning module shall be up to 1M and including a height of 2.8M
- For sill heights, doors, windows etc the preferred increment shall be 1M
- The grid line coincides with the centre line of the columns, in case of internal columns. In case of external columns and columns near the lift or stair case, the grid line shall coincide with the centre line of the columns in the top most storey or a line in the column 50mm from the internal face of the column in the top most storey.



1.8.6 PRINCIPLES OF MODULAR COORDINATION

Following are the key components involved in the principles of modular coordination

- Basic Module
- Multi module
- Modular dimension
- Planning module
- Placing of components
- Modular grid
  - Basic modular grid
  - Rectangular grid
  - Square grid
  - Tartan grid
  - Multi-modular planning grid
- Preferred dimensions
- Tolerance

Basic Module: Fundamental unit of size in modular coordination. 1 basic module=100 mm

Multi module: Multi modules are selected in multiples of the basic module

Planning module: The planning in modular coordination consists of horizontal and vertical planning. The two basic approaches in planning are face planning and axial planning.

Modular dimension: Dimensions based on a standard module for easy designing, manufacturing and assembly.

Modular grid: A rectangular coordinate reference system in which the distance between the consecutive lines is the basis module or multi-module. The basic module design is kept uninterrupted due to the use of modular grid. Dimensions in the form of horizontal and vertical projections of the modular space grid helps in expressing the plan sections and elevations. The basic modular grid is shown on a small scale drawing to show the relation between the components. It is the smallest planning grid used as a basis for developing other grids.

Structural grid: It is used to locate structural components such as beam and column. The structural grid recommended is 3M or multiple of 1M.

Planning grid: It is based on any convenient modular multiple for regulating space requirements. Controlling grid based on any convenient modular multiple for the location internal walls, partition walls, etc.

Tartan grid: It is an interrupted modular planning grid in which the interval or bands of interruption are regular spaced in both directions are of different modular order to the general modular planning grid.

Preferred dimension: 5mm rule is applied to all the structural elements of the building. The wall, slab and other components which is a structural part of the vertical horizontal divisions are placed on joint proportion of the modular plane. The actual dimension as rule for the structural elements are 5mm less on all modular boundary. 5mm rule is due to tolerance is given by IS codal provisions. Because tolerance is required to fit the component into available space grid space. The following are basic dimension conditions for designing precast elements:

- Flooring and roofing
    - Length-multiple of 3M
    - Width-multiple of 1M
    - Thickness-multiple of M/4
- Beams
    - Length-multiple of 3M
    - Width-multiple of M/4
    - Depth-multiple of M/4
- Columns
    - Height-multiple of 1M for height upto 2.8M and height above 28M is multiple of 2M
    - Lateral dimension-multiple of M/4
- Wall
    - Thickness-multiple of M/4
- Staircase

- Width-multiple of 1M

- Lintels
    - Length-multiple of 1M
    - Width-multiple of M/4
    - Depth-multiple of M/4
- Sunshade
    - Length-multiple of 1M
    - Projection-multiple of 1M

1.9 TOLERANCES

- The permissible deviation from a specified value of a structural dimension, often expressed as a percent.
- Amount of variation permitted or "tolerated" in the size of a machine part.
- Manufacturing variables make it impossible to produce a part of exact dimensions; hence the designer must be satisfied with manufactured parts that are between a maximum size and a minimum size.
- Tolerance is the difference between maximum and minimum limits of a basic dimension.
- For instance, in a shaft and hole fit, when the hole is a minimum size and the shaft is a maximum, the clearance will be the smallest, and when the hole is the maximum size and the shaft the minimum, the clearance will be the largest.

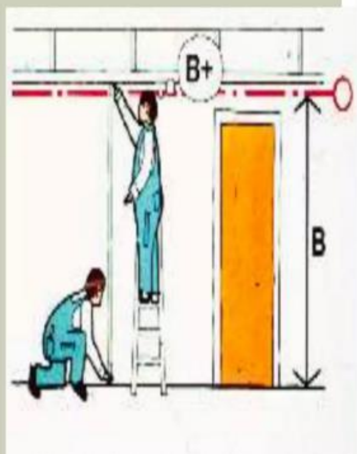


Figure.5: Tolerances in Construction meant that components sometimes lay outside their own 'basic'

1.10 REFERENCE SYSTEM

The **reference system** is a system of points, lines and planes to which the sizes and positions of building components or assemblies relate.

A reference system should be used during the design stage, and may also form the basis of the system of lines from which measurements on site are set out.

MODULAR SPACE-GRID

- A modular space-grid is a three-dimensional system of planes within which a building and its components are located. The distance between the planes in such a system is equal to the basic module, or to a multimodule.

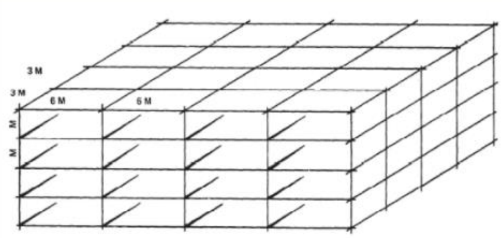
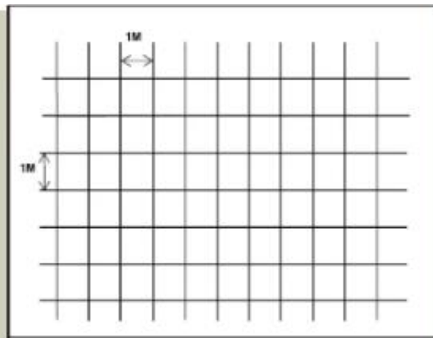


FIGURE 1 – Example of a modular space-grid

BASIC MODULAR GRID

- The fundamental modular grid is that in which the spacing of consecutive parallel lines is equal to the basic module.
- 1M x 1M.



Basic Multi Modular Grid

MULTI MODULAR GRIDS

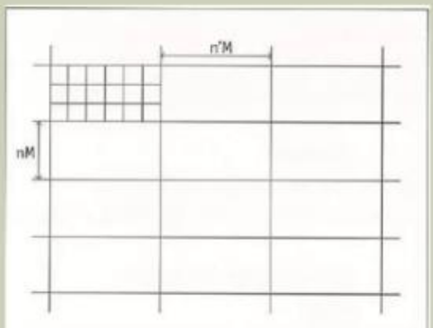
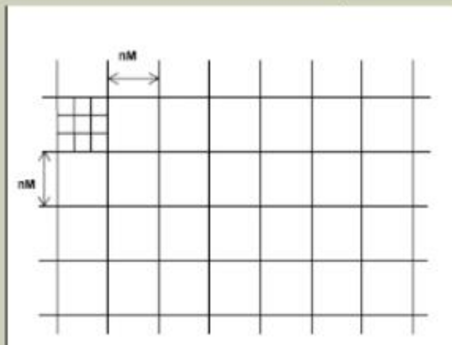


Fig 3-2b: Rectangular Multi-Modular Grid



Square Multi Modular Grid

ISO: 2848-1974
IS: 10600-1983

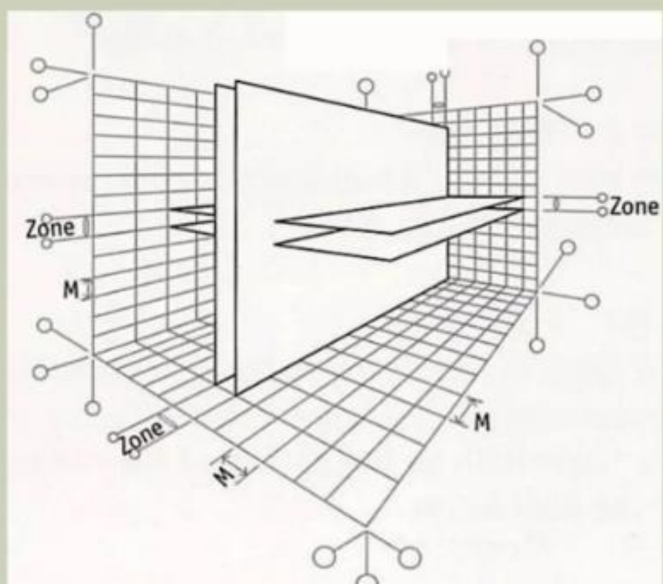
The Building Reference System

Reference system

A system of points, lines and planes to which sizes and positions of a building com or assembly may be related.

Reference plane

A plane of a reference system.



1.11 GRIDS

STRUCTURAL GRID

- used to locate structural components such as beams and columns.

PLANNING GRID

- based on any convenient modular multiple for regulating space requirements such as rooms.

CONTROLLING GRID

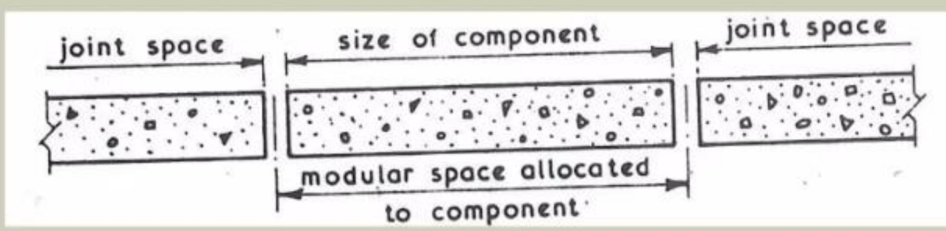
- based on any convenient modular multiple for location of internal walls, partitions dc.

BASIC MODULE GRID

- used for detail location of components and fittings.
- All the above grids, being based on a basic module, are contained one within the other and are therefore interrelated.
- These grids can be used in both the horizontal and vertical planes thus forming a three dimensional grid system.
- If a first preference numerical value is given to M dimensional coordination is established

DIMENTIONAL GRID

- The modular grid network defines the space into which dimensionally coordinated components must fit. An important factor is that the component must always be undersized to allow for the joint which is sized by the obtainable degree of tolerance and site assembly.



Recommended Modular Dimensions

Basic Module	:	1M = 100mm
Structural Grid	:	**3M** (**1M** as the second preference)
Horizontal Multi-Module	:	**3M** (**1M** as the second preference)
Vertical Multi-Module	:	**1M** (**0.5M** as the second preference)
Doors	:	Multiples of **1M** (width and height)
Windows	:	Multiples of **1M** (width and height)
Sub-modular increment	:	**0.5M** and **0.25M**

1.12 STANDARDISATION

It is the repeated production of standard sizes or layout of components or complete structures. It is defined as the creation and use of guidelines for the production of uniform interchangeable components especially for use in mass production.

Standardization of components is done by providing a national scale, mandatory for whole country, by the competent authorities and publish their catalogues for standard prefabricates, standard housing units or even for a whole building.

1.12.1 OBJECTIVES OF STANDARDISATION

- To start to design with recommended dimensions by the designers
- Facilitate and provide necessary design guidelines and considerations when adopting standard prefabrication elements.
- Reduces the error and rectification process which occurs during in-situ construction
- Encourage the industry to move from labor-intensive to labor- saving construction methods
- Promote wider use of standard prefabricated building components.

1.12.2 ADVANTAGES:

- Manufacturing process is made easy
- During erection and completion of prefabricated components, standardization

helps to make use of repeated equipment which leads to economy in all aspects

- Designing process is made easy due to the elimination of unwanted choices

1.12.3 DISADVANTAGES

- Since the joints are at corners that are at places where the moments reach their maximum values, the forming of joints is difficult.
- The forming of in-situ joints is very difficult, hence the joint must be over dimensioned
- Numbers of joints are reduced and if larger precast members are needed.

1.12.4 FACTORS INFLUENCING STANDARDISATION

- To select the most rational type of member for each element from the point of production assemble, serviceability of types of elements and to use them in large quantities.
- To limit the number of types of elements and to use them in large quantities.
- To use the largest size to the extent possible, resulting in less number of joints.
- To limit the size and number of prefabricate by the weight in the overall dimension that can be handled by the handling and erection equipment and by limitation of transportation.
- To have all the prefabricated elements approximately of same weight very near to the lifting capacity of the equipment.

2 SYSTEMS OF PREFABRICATION

There are several systems and methods used in prefabrication, each with its own advantages and applications. Here are some common systems of prefabrication:

1. **Volumetric Modular Construction**: In this system, entire rooms or sections of buildings, known as modules, are constructed off-site in a factory. These modules are fully outfitted with fixtures, finishes, and sometimes even furniture. They are then transported to the construction site and assembled into the final structure. Volumetric

modular construction can significantly reduce on-site construction time and offers high quality control since modules are constructed in a controlled factory environment.

2. **Panelized Construction**: Panelized construction involves fabricating building components such as walls, floors, and roofs as panels in a factory. These panels are then transported to the construction site and assembled to form the building's structure. Panelized construction offers flexibility in design and can be customized to meet specific project requirements. It also allows for faster construction compared to traditional stick-built methods.

3. **Prefab Concrete Systems**: Prefabricated concrete systems involve manufacturing concrete components such as beams, columns, slabs, and panels off-site and then transporting them to the construction site for assembly. These systems offer high strength and durability and are commonly used in various types of construction projects, including residential, commercial, and industrial buildings.

4. **Steel Framing Systems**: Prefabricated steel framing systems consist of steel components such as columns, beams, and trusses that are fabricated off-site and then delivered to the construction site for assembly. Steel framing offers strength, durability, and versatility in design. It is commonly used in commercial and industrial construction but is also gaining popularity in residential construction due to its speed of construction and sustainability.

5. **Prefabricated Timber Systems**: Timber framing involves manufacturing building components such as walls, floors, and roofs using timber or engineered wood products in a factory. These components are then transported to the construction site for assembly. Timber framing offers sustainability, as wood is a renewable resource, and it also provides excellent thermal insulation properties. It is commonly used in residential construction but is also suitable for some commercial and institutional buildings.

6. **Hybrid Systems**: Hybrid prefabrication systems combine different materials and construction methods to leverage the advantages of each. For example, a hybrid system might use prefabricated concrete panels for the building's exterior walls and volumetric modular construction for interior spaces. Hybrid systems offer flexibility and can be tailored to meet specific project requirements.

7. **Bathroom pods**: It is a complete bathroom units that are prefabricated off-site, including all fixtures fittings and finishes. These pods are transported to the construction site and installed as a single unit, reducing on-site construction time and minimizing disruption.

8. **Façade System**: Façade system involves the prefabrication of building façade, including cladding panels, curtain walls, and glazing systems in a factory. These prefabricated façade elements are then transported to the construction site and installed onto the building structure.

These are just some of the systems of prefabrication used in the construction industry. Each system has its own benefits and limitations, and the choice of system depends on factors such as project requirements, budget, timeline, and site conditions.

3 LOADS ON PREFABRICATED STRUCTURES

In structural engineering, understanding the loads acting on a building is fundamental to designing a safe and stable structure. Prefabricated structures, which are manufactured off-site and then assembled on-site, face similar load considerations as traditional construction but often require unique considerations due to their assembly process and material characteristics. Let's delve into the various types of loads that affect prefabricated structures in detail:

1. **Dead Loads**: Dead loads represent the permanent, stationary forces exerted by the structure itself and any fixed attachments or components. In prefabricated structures, dead loads include the weight of prefabricated elements such as panels, beams, columns, slabs, as well as the weight of the building envelope, interior finishes, and permanent equipment. These loads are relatively consistent over time and are essential for calculating the overall weight the structure must support.

2. **Live Loads**: Live loads are temporary or moving forces imposed on the structure due to occupants, furniture, equipment, and environmental factors. Live loads can vary significantly depending on the building's function and occupancy. For instance, in residential buildings, live loads may primarily consist of people and furniture, while in commercial or industrial structures, they may include heavy machinery and storage loads. Prefabricated structures must be designed to accommodate these varying live loads safely.

3. **Snow Loads**: Snow loads refer to the vertical forces exerted by the weight of accumulated snow on the roof and other horizontal surfaces of the structure. The magnitude of snow loads depends on factors such as geographic location, climate, roof slope, and local building codes. Prefabricated structures in regions prone to heavy snowfall need to be designed to support the expected snow loads to prevent roof collapse or structural damage.

4. **Wind Loads**: Wind loads are horizontal forces exerted by wind pressure on the building's surfaces, including walls, roofs, and facades. The intensity of wind loads varies based on factors such as wind speed, building height, exposure, and local topography. Prefabricated structures must be designed to withstand wind loads and resist wind-induced movements and vibrations. Proper anchoring and connection details are crucial to ensure structural stability during high winds.

5. **Seismic Loads**: Seismic loads are dynamic forces generated by earthquakes that can cause lateral movement, vibration, and deformation of the structure. The intensity of seismic loads depends on factors such as seismic activity, soil conditions, building height, and structural characteristics. Prefabricated structures located in seismic zones require seismic-resistant design strategies, such as reinforced connections, ductile framing systems, and energy dissipation devices, to withstand seismic forces and minimize damage.

6. **Temperature and Thermal Loads**: Temperature variations and thermal expansion and contraction can impose stresses on the structure's materials and components. These thermal loads can lead to deformation, cracking, or differential movement within the structure. Prefabricated structures must be designed to accommodate temperature fluctuations and thermal expansion without compromising structural integrity. Proper insulation and thermal bridging details are essential to minimize energy losses and thermal stress on the building envelope.

By carefully considering these various loads during the design and construction of prefabricated structures, engineers can ensure the structural safety, durability, and performance of the building throughout its lifespan. Prefabricated construction offers opportunities for efficient load management through standardized manufacturing processes, quality control measures, and innovative structural systems tailored to meet specific project requirements.

3.1 LOAD COMBINATIONS

In India, the load combinations for prefabricated structures are typically defined by the Indian Standard Codes, specifically IS 875 (Part 1): 1987, which provides guidelines for the design loads for buildings and structures. The load combinations specified in this code are used to assess the structure's response under different loading conditions and ensure its safety and stability. Here's how the load combinations are expressed according to the Indian Standard Codes:

1. **Basic Load Combinations**:

The basic load combinations for prefabricated structures in India are defined considering various permanent and variable loads. These loads include dead loads (D), live loads (L), wind loads (W), and other environmental loads such as snow loads (S) and seismic loads (E). The basic load combinations are expressed as follows:

$1.5D+1.5L$

$1.2D+1.2L+1.2W$

$1.2D+1.2L+1.2W+1.2S$

$1.2D+1.2L+1.2W+1.2E$

2. **Construction Load Combination**:

During the construction phase, additional temporary loads are considered to ensure the stability and safety of the structure. These loads account for construction materials, equipment, and activities. The construction load combination for prefabricated structures in India is typically expressed as:

$1.5D+1.5L$

Where D represents dead loads and L represents live loads.

3. **Service Load Combination**:

Service loads include loads due to mechanical, electrical, plumbing, and other building systems. The service load combination for prefabricated structures in India is expressed as:

$1.2D+1.2L+1.2W$

Where W represents service loads.

These load combinations are examples and may vary depending on specific project requirements, local building codes, and engineering judgment. Engineers must carefully analyze and select appropriate load combinations in accordance with the Indian Standard Codes to ensure the safety, stability, and performance of prefabricated structures in India. Additionally, load combinations may be adjusted based on factors such as structural redundancy, reliability, and risk assessment.

4. MATERIALS USED IN PREFABRICATION

Precast materials are carefully selected based on their properties, durability, and suitability for the intended application. Here are some common materials used in precast elements:

1. **Concrete:** Concrete is the primary material used in precast elements. It consists of a mixture of cement, aggregates (such as sand, gravel, or crushed stone), water, and often additives or admixtures. Concrete offers several advantages for precast production, including versatility in design, high compressive strength, durability, and resistance to fire and weathering. Precast concrete elements can be cast into various shapes and sizes, making them suitable for a wide range of applications in construction.

2. **Reinforcement:** Reinforcement, typically in the form of steel bars, mesh, or fibers, is often incorporated into precast concrete elements to enhance their structural performance. Reinforced concrete offers improved tensile strength and resistance to cracking and deformation, making it suitable for applications requiring high load-bearing capacity, such as beams, columns, and structural panels.

3. **Prestressed Concrete:** Prestressed concrete is a specialized type of concrete in which internal stresses are introduced to improve its structural efficiency and performance. In

precast elements, prestressing is commonly achieved using pre-tensioning or post-tensioning techniques. Prestressed concrete elements offer higher strength, longer spans, and reduced deflection compared to conventionally reinforced concrete, making them suitable for applications such as beams, slabs, and bridge girders.

4. **Steel**: Steel is often used in precast elements as reinforcement or as structural components, such as embedded plates, connectors, and anchors. Steel offers high strength, ductility, and versatility in design, allowing for complex shapes and connections in precast construction. Additionally, steel components can be prefabricated off-site and easily integrated into precast elements during manufacturing.

5. **Fiber Reinforced Polymers (FRP):** Fiber reinforced polymers, such as carbon fiber, glass fiber, or aramid fiber, are increasingly used in precast elements for their high strength-to-weight ratio, corrosion resistance, and durability. FRP materials can be used as reinforcement or as external strengthening systems for precast concrete elements, enhancing their structural performance and longevity.

6. **Architectural Finishes:** Precast elements can incorporate various architectural finishes to achieve the desired appearance and texture. Common architectural finishes include exposed aggregate, sandblasting, acid etching, and architectural coatings. These finishes enhance the aesthetic appeal of precast elements and allow for customization to match the surrounding architectural context.

7. **Additives and Admixtures**: Additives and admixtures are often added to the concrete mixture to modify or enhance specific properties of precast elements. These may include water reducers, set retarders, set accelerators, air-entraining agents, and pigments. Additives and admixtures help improve workability, durability, curing characteristics, and aesthetic qualities of precast concrete elements.

Overall, the selection and combination of these materials depend on factors such as structural requirements, design considerations, environmental conditions, and project specifications. Precast elements offer numerous advantages in terms of quality control, efficiency, and sustainability, making them a popular choice for a wide range of building and infrastructure projects.

1.5 PRODUCTION OF PREFABRICATED COMPONENTS

(NOV/DEC 2012), (MAY/JUNE 2012)

The series of operation of manufacturing of precast units with the help of raw materials and special equipment for moulding, casting, curing, hoisting is termed as production of precast units.

Based on the site of production of precast units, it is divided into two types.

1. Factory production
2. On-site production

Based on the method adopted for the production technique it is classified into three types.

1. The stand system
2. The conveyor belt or production line system
3. The aggregate system

1.5.1 Factory Production

The manufacturing of precast units is done in centrally located factory which is suitable for source and storage of raw materials, transporting, erection and overall production. In this the work is done throughout the year under a covered shed to avoid the seasonal effects. High level of mechanization is introduced in this system which brings out high quality products. Elements with any size and shape can be manufactured in factory production.

The only disadvantage in this system is transporting the precast unit to the site where it is executed is difficult if the distance is long or the size of the material is huge.

1.5.2 Site Prefabrication

The components are manufactured at the site where the work is to be done. It is adopted for specific job for a specific duration. The efficiency or the quality of the unit manufactured is less when compared to the factory made products due to the lack of high mechanized equipment. This will reduce the transportation cost. The equipment used are of mobile in nature.

1.5.3 The Stand System

As the word implies, the prefabricated material matures at the point where they are moulded. The production team will move to the successive stands to start the another set of production process.

In this method the beds are fixed or movable or can be tilted. Individual mould method, longlinePrestressing bed method are best examples for stand system.

1.5.4 The Conveyor Belt System

In this method, a series of operations are carried out where the whole production process is split into series of operations at separate, successive and permanent points. Here the movement of prefabricated elements will be achieved with the help of conveyor belts, trolleys, cranes, etc.

1.5.5 The Aggregate System

The method in which large, complex, permanently installed set of machines and mechanical applications are involved to carry the maximum operations involved in casting concrete elements. Best example for this type of method is battery mould method, where the shuttering panels can be adjusted in the form of a battery at the required distance equal to the thickness of the concrete members. Interior walls, panels can be made using this method.

1.6 PROCESS INVOLVED IN MANUFACTURING OF PRACAST UNITS

The following are the three processes involved in the production of precast units:

1. Main process
2. Auxiliary process or secondary process
3. Subsidiary process

1.6.1 Main Process

The following steps are involved in main process:

✓ Assembling the moulds, placing reinforcement cage in position for reinforced concrete work.

✓ Fixing of inserts and tubes where necessary.

✓ Placing the concrete in to the moulds.

✓ Vibrating the deposited concrete into the moulds.

✓ Demoulding the forms.

✓ Curing (steam curing if necessary).

✓ Stacking the precast products.

In start of any manufacturing process, the fundamental process which helps in the efficiency of the output is referred as main process. In prefabricated industry, assembling the moulds and demoulding the formworks, placing of concrete, reinforcement and curing of the concrete panels, etc are considered to be the main process. In production of wall panels, the placing of tubes and inserts is also required. With the help of labours, these work are possible and consideration should be given to the quality of the work.

1.6.2 Auxiliary Process

Auxiliary process is essential for the successful completion of the precast unit which are:

✓ Mixing or manufacture of fresh concrete (done in a mixing station or by a matching plant).

✓ Prefabrication of reinforcement cage (done in a steel yard of workshop)

- ✓ Manufacture of inserts and other finishing items to be incorporated in the main precast products.
- ✓ Finishing the precast products.
- ✓ Testing the precast products.

Auxiliary process is referred as the most important process which plays a major role in the manufacturing of the prefabricated elements. For a precast concrete components, mixing of concrete is a major part. The efficiency of the product lies in the quality and strength of the concrete which can be achieved through the mix design. The mixing of concrete takes place in the mixing plant followed by the batching plant. In steel yards, the prefabrication of the necessary reinforcement cage is done which is to be inserted before the placing of concrete. Finishing of the product is given a higher importance and at the same time testing of the precast elements is given priority which satisfies the customer requirement in terms of strength. Compressive strength, flexural strength, flow table test, vicat's apparatus test are the few basic tests to be carried out in the precast industry.

1.6.3 Subsidiary Process

The other minor processes involved in the manufacturing of prefabricated units are as follows:

- Storage of materials
- Transport of cement and aggregate
- Transporting and stacking the precast elements
- Repairs and maintenance of tools, machines, etc.

The raw materials used in the precast industry are fine aggregate, coarse aggregate, cement, water, M sand. It is checked whether sufficient quantity of raw materials are available before the progress of precasting concrete elements. The precasting table should be verified for its good condition to undergo the casting process. Without any time lag materials should be transported to increase the efficiency of the project.

1.7 TRANSPORTATION OF PRECAST UNITS

The important part in constructing a prefabricated building lies in the efficient transporting of the precast elements from factory or site to the place where it is to be erected. Extreme care should be taken to avoid stress and flocks in the elements. The efficient structural usage of the precast elements lies in the transporting and erecting part. Inside the factory the transportation depends on the method of production.

The traffic rules and regulations as per transportation authority should be followed while transporting the prefabricated elements. The size and shape of the precast unit should be based on the availability of transportation mode. During the transportation, the vehicular movement should be in such a way that it resists the cantilever action and it is verified whether the desirable supports are maintained throughout the transportation process. Base packing for the supporting elements should be verified in a proper way.

The various transporting devices used are

- Trucks
- Cranes
- Wagons
- Narrow gauge rail road
- Hand truck
- Combined devices
- Dumpers

1.7.1 Trucks

Truck which is commercially referred as lorry is used for transporting prefabricated elements from factory to the site. Trucks vary greatly in size, configuration and power. Based on the size of the precast element to be carried out, trucks are chosen from medium trucks, heavy trucks or off-road trucks/very heavy duty trucks.

1.7.2 Hand Truck

It is a two-wheeled small truck, which is in L-shape moved manually for transporting precast units with less weight. The object to be moved are tilted forward, the ledge is inserted underneath them and the objects are allowed to tilt back and rest on the ledge. While transporting, the object and the truck are tilted backward until the weight is balanced over the large wheels.

1.7.3 Cranes

In precast construction, use of formwork or scaffolding is very limited. It is because, cranes will do the maximum work and helps in transporting the prefabricated elements. Different types of cranes are used based on the surrounding at the construction site. Inside the factory also for transportation purpose, few types of cranes like rubber tyred crane, gantry crane are used.

1.7.4 Wagons

Wagons are four-wheeled vehicle being pulled or operated by human beings in the precast construction unit. In olden days it is being pulled by using animals. Nowadays the manual operation or motorized operation of the wagons is being practised for transporting small precast elements inside the manufacturing unit and also in the construction site.

Fig. 1.1 Wagons used in precast unit

1.7.5 Narrow Gauge Rail Road

With the help of the gauge rail roads, the transporting of prefabricated elements inside the manufacturing unit is made easy. This forms a basic for movement of cranes on the rails. Operating of cranes in the rail road is made by using remote control.

1.7.6 Dumpers

Dumpers or dump trucks are vehicle used for carrying huge material in precast industries for transportation of raw materials.

Fig. 1.2 Dumpers

1.8 ERECTION OF PREFABRICATED UNITS

Erection is the process of assembling the transported prefabricated components in their final position as per the drawing. The efficiency of the erection process lies in the three steps.

1. Erection preparation.
2. Erection equipment
3. Erection platform

1.8.1 Erection Preparation

Prior to the commencement of erection process the following steps have to be considered.

✓ Checking crane access to the site

✓ Stability of the erection platform

✓ Ensuring the location of dowels and levelling shims.

- ✓ Ensuring the sufficient space for precast propping
- ✓ Check for the temporary supports and lifting inserts.
- ✓ Ensuring the availability of proper rigging equipment
- ✓ Slinging of the precast element
- ✓ Ensuring the safety precautions for the handling and erecting operations

1.8.2 Erection Equipment (MAY/JUNE 2014) (NOV/DEC 2013)

- ✓ Tying the erection ropes connecting to the erection hooks
- ✓ Operation of equipment should be done by skilled labours
- ✓ Adjustments to get the stipulated level, line and plumb.
- ✓ Welding of cleats
- ✓ Changing of the erection tackles
- ✓ Cleaning of the elements and the steel inserts before incorporation of the joints, lifting up of the elements

1.8.3 Erection Platform

- ✓ The erection platform should be kept clean at the time of erecting
- ✓ It should be verified whether the platform can support and withstand the load of precast units while erecting.

1.8.4 Equipment for Erection Process

The following are the type of cranes used for handling and erection process:

- ✓ Stationary cranes
  - Guyed derrick crane
  - Climbing crane
  - Tower crane with fixed base
- ✓ Cranes on rails
  - Portal crane
- ✓ Mobile crane
  - Truck mounted
  - Crawler mounted

1.8.4.1 Stationary Cranes

For lifting, lowering and horizontal movement of prefabricated elements different types of stationary cranes are used in the on-site.

Erection of prefabricated elements plays a major role in succeeding the concept of precast elements in construction era, which can be easily done with the help of various types of cranes. It is equipped with hoist rope, wire ropes or chains and sheaves.

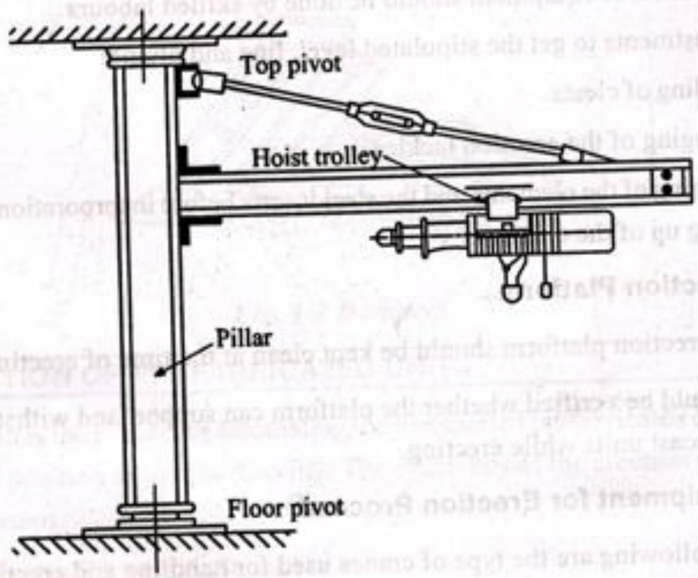


Fig. 1.3 Stationary crane

1.8.4.1.1 Guyed Derrick Crane

It is also known as boom Derrick crane. It has a fixed guyed mast derrick which helps in rotating and it is connected to the boom. Along with the base, the mast is kept in upright position with the base, which helps in rotating the mast. Guy wires are anchored to the ground to support the load, which is connected from the top of the moist.

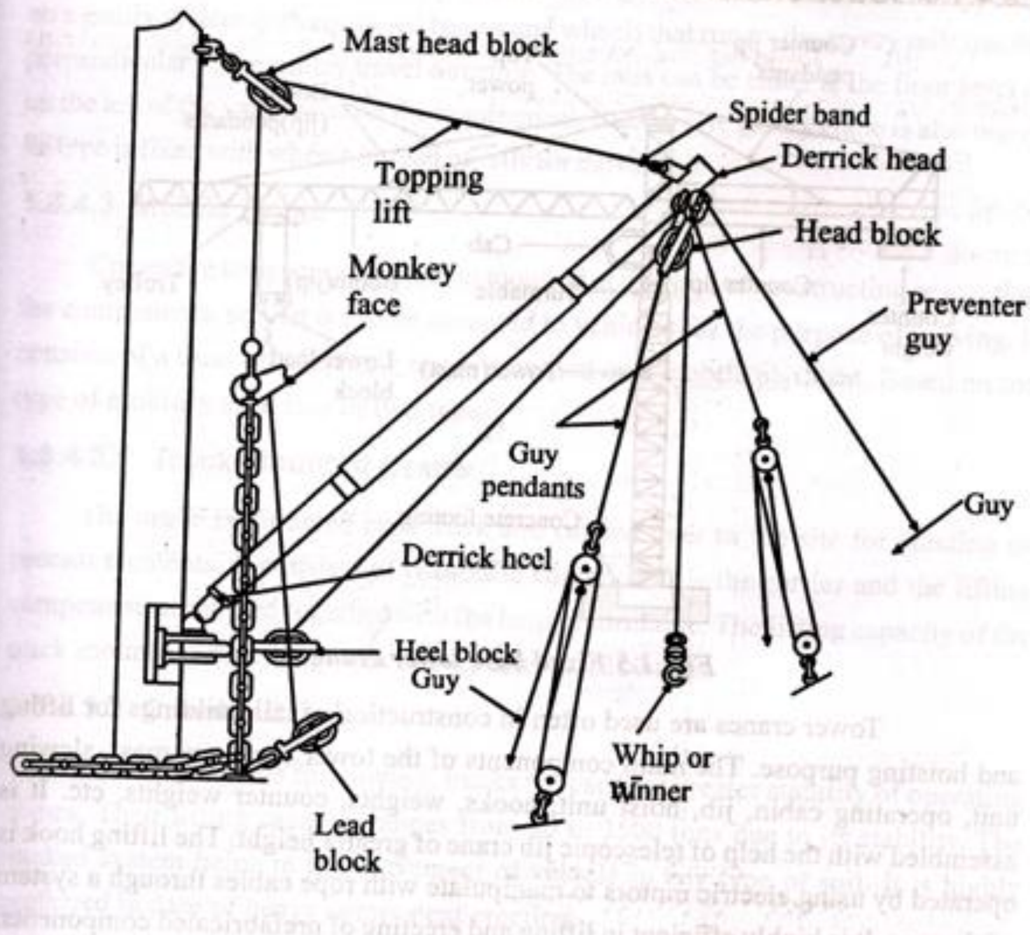


Fig. 1.4 Guyed derrick crane

1.8.4.1.2 Climbing Crane

It is a type of hoisting device used inthe erection process of high rise building. In this crane, a vertical mast is fastened to the structural members of the building framework and is moved up as the structure rises during construction. It is also called as creeper crane.

1.8.4.1.3 Tower Crane With Fixed Base

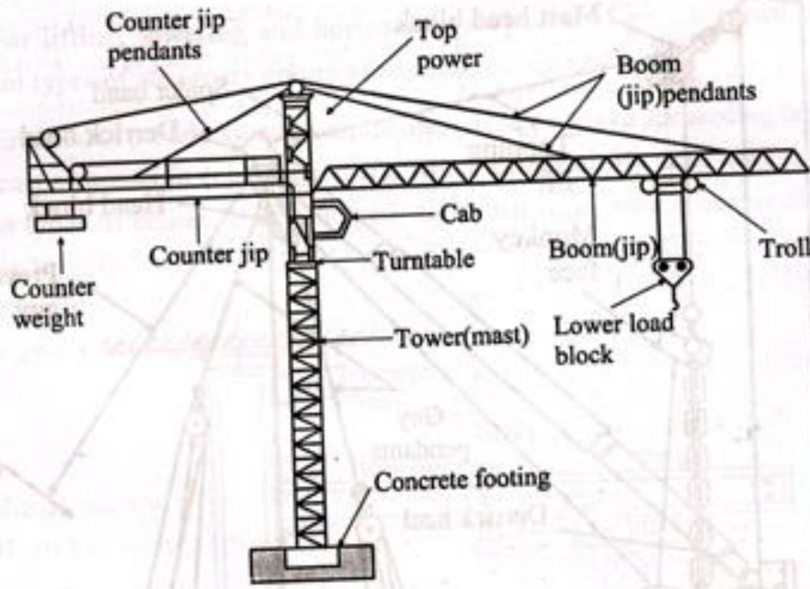


Fig. 1.5 Fixed base tower crane

Tower cranes are used often in construction of tall buildings for lifting and hoisting purpose. The main components of the tower crane are mast, slewing unit, operating cabin, jib, hoist unit, hooks, weights, counter weights, etc. It is assembled with the help of telescopic jib crane of greater height. The lifting hook is operated by using electric motors to manipulate with rope cables through a system of sheaves. It is highly efficient in lifting and erecting of prefabricated components.

1.8.4.2 Cranes on Rails

Cranes are placed on the top of the industrial building supplemented with rails which help in the movement of cranes for handling and lifting prefabricated components inside the yard. For the movement of elements placed outside is equipped with the provision of cranes having rails in the platform.

1.8.4.2.1 Portal Crane

It is also referred as gantry crane, which is a large crane mounted on a platform, beam or bridge carried at each end by a trestle, runs back and forth on parallel tracks in the work area. It consists of a hoist in a fixed machinery house which runs horizontally along rails supported by single or twin girders. The crane frame is supported on a gantry system with equalised beams and wheels that run on the gantry rails usually perpendicular to the trolley travel direction. The rails can be either at the floor level or on the top of the yard based on the requirement. Rubber tyre gantry crane is also one of its type is fixed with wheels instead of rails for movement.

1.8.4.3 Mobile Crane

Cranes are temporary equipment required at the time of constructing or erecting the components, so that it can be mounted to vehicles for the purpose of moving. It consists of a truss or telescopic boom mounted on a mobile platform. Based on the type of mobility used it is of two types.

1.8.4.3.1 Truck Mounted Crane

The crane is mounted on a truck and carried over to the site for erecting of precast elements. It consists of two basic components – the carrier and the lifting component, combined together with the help of turntable. The lifting capacity of the truck mounted crane ranges from 14.5 tons to 1300 tons.

1.8.4.3.2 Crawler Crane

Instead of wheels for moving, tracks are used for greater stability of operating cranes. Their lifting capacity ranges from 40 to 3500 tons due to its stability. The tracked system helps in the movement of vehicle in any type of soil. It is highly preferred in case of heavy component erecting.

1.8.5 Installation of the Precast Panels

The following steps should be given importance while installing precast components:

- Verification of delivered panels
- Setting out
- Setting out quality control point
- Hoisting, rigging and installation
- Grouting works
- Connecting joints

Erection Process:

The erection of prefabricated units involves the assembly and installation of precast or prefabricated components to form a complete structure. This process typically requires careful planning, coordination, and skilled labor to ensure that the units are safely and accurately positioned and connected. Here's a detailed explanation of the erection process for prefabricated units:

1. **Site Preparation:** Before the erection process begins, the construction site must be properly prepared. This may involve clearing the site of debris, leveling the ground, and ensuring adequate access for delivery trucks, cranes, and other equipment. Site preparation also includes setting up temporary facilities such as fencing, site offices, and storage areas.
2. **Delivery of Prefabricated Units:** The prefabricated units, which may include panels, beams, columns, modules, or other structural elements, are transported to the construction site. Delivery logistics are carefully coordinated to ensure timely arrival and offloading of the units. The units are typically transported on flatbed trucks or trailers and may require specialized handling equipment such as cranes or forklifts for unloading.
3. **Preparation for Erection:** Before erection begins, the prefabricated units are inspected to ensure they meet the required quality standards and specifications. Any damaged or defective units are identified and addressed before installation. The erection sequence is planned, taking into account factors such as the size, weight, and orientation of the units, as well as site conditions and safety considerations.
4. **Lifting and Positioning:** Once the units are ready, they are lifted and positioned into place using cranes, hoists, or other lifting equipment. Careful attention is paid to ensure that the units are accurately aligned, leveled, and supported during lifting and placement. Skilled operators and riggers oversee the lifting operations to ensure safety and prevent damage to the units or surrounding structures.
5. **Connection and Fastening:** After the units are positioned correctly, they are connected and fastened together to form a stable and integrated structure. This may involve welding, bolting, grouting, or other methods of connection, depending on the design and structural requirements. Connections are inspected and tested to ensure they meet the specified standards and provide adequate strength and stability.
6. **Alignment and Adjustment:** Once the units are connected, adjustments may be made to ensure proper alignment and fit between adjacent units. This may involve shimming, leveling, or trimming the units to achieve the desired tolerances and dimensions. Precise alignment is crucial to ensure the structural integrity and aesthetic appearance of the completed structure.

7. **Bracing and Temporary Supports:** Temporary bracing and supports may be installed to stabilize the structure during erection and until permanent connections are made. Bracing helps to resist lateral loads, prevent displacement, and maintain stability during construction. Temporary supports are gradually removed as permanent connections are completed and the structure becomes self-supporting.
8. **Finishing and Integration:** Once all prefabricated units are erected and connected, finishing and integration work begins. This may include applying architectural finishes, installing roofing materials, exterior cladding, windows, doors, and interior finishes. Mechanical, electrical, plumbing, and HVAC systems are also integrated into the structure to provide functionality and comfort.
9. **Final Inspection and Testing**: After the erection process is complete, the structure undergoes a final inspection to ensure that all components are installed correctly and meet the required standards and specifications. Structural integrity, connections, finishes, and systems are inspected and tested to verify compliance with regulatory requirements and project specifications.
10. **Occupancy and Handover:** Once the structure is deemed complete and compliant, it is ready for occupancy. The client takes possession of the building, and any remaining items or deficiencies are addressed during the final stages of construction. The structure is officially handed over to the client, and regular maintenance and upkeep procedures are implemented to ensure its long-term performance and durability.

By following these steps carefully, the erection process of prefabricated units can be completed efficiently, safely, and with high quality. Effective planning, coordination, and execution are essential to ensure successful construction and delivery of prefabricated structures.