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Precast Buildings – Design And Detailing Process

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Precast building structures are made of precast concrete components of various sizes and shapes, which are manufactured using special equipment and machinery. The precast concrete components are later transported to the construction site where they are assembled by cranes, which will lift the precast elements to their final position (Figure 1). For the purpose of precast production, transportation and construction it is required to prepare structural design calculations and detailed drawings of each precast component. This article describes the aspects of the structural design process and drawing preparation of precast buildings.

Fig. 1: Precast Construction

Design Process

The decision to make a building structure or part of it in precast concrete is initially based on the recommendations given by the architect and the structural engineer who have been appointed by the owner. During the concept design phase, the team must investigate how precast technology can reduce cost, shorten the construction time or increase the energy efficiency. There can be many other reasons to opt for precast construction and even at a later stage it can be implemented in the project. The architect and structural engineer shall have to prepare contract documents, which will include the specifications and drawings with the sizes of the precast members, the orientation and how they are to be connected to each other. These drawings will enable the contractor and precast fabricator to assess the total size of the work and the difficulties and complexities of execution.

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The contract drawings, however, will not be sufficient to start executing the work. At that stage additional design calculations and detailed drawings will have to be prepared, which can be used for fabrication and execution of the project. This work is generally done by specialized precast engineering firms who employ precast engineers and precast detailers for the preparation of the precast design. These expert design companies have an in-depth understanding of the precast production and assembly process and how to analyse and design the prefabricated building structures.

Precast Engineering Team

Once the owner has awarded the project to the precast manufacturer the role of the precast engineering team (Figure 2) begins to take shape. The team generally consists of the following members:

1. Precast engineer
2. Project coordinator
3. Senior drafter
4. Checker
5. Precast detailer

Precast Engineer: The precast engineer performs the structural analysis and prepares the structural design calculations of each precast

Fig. 2: Precast Engineering Team

concrete component and their connections. The structural engineer shall also review all the drawings prepared by the drafting team and make sure they comply with his design. The engineer will also provide support to the field team in relation to the stability of the structure during construction.

Project Coordinator: Not all organizations will have a dedicated person working full time in the position of project coordinator and in many teams this role is covered by the senior drafter or engineer. The project coordinator will develop and monitor the overall project planning in assistance with the rest of the team. He will coordinate with the client and attend all project meetings and inform the team. Furthermore, he will coordinate the activities with other consultants and subcontractors involved in the project.

Senior Drafter: The senior drafter shall perform all drafting functions like preparing the precast shop drawings, erection drawings and material lists. The senior drafter needs to fully understand the contract documents and project information. He will coordinate with the project coordinator and precast engineer with respect to the project schedule. He must train new staff and improve the skills of the precast drafting team. He must estimate time required for new projects and monitor time spent on ongoing projects.

Checker: The checker reviews and checks the precast detailed drawings prepared by the drafters. He must ensure that contract documents are correctly interpreted and included on drawings. He must check the consistency of drawing presentation with production methods and precast detailing standards. He must check the accuracy of the precast element drawings, the panel geometry, tolerance conditions and check the bill of materials.

Precast Detailer: The precast detailer will work under supervision of the senior drafter and must prepare the precast erection drawings and precast shop drawings. He shall revise the drawings as per the mark-ups provided by the checker.

Following activities must be executed by the precast engineering team:

1. Design coordination
2. Structural analysis
3. Structural design
4. Precast drawing preparation

Precast Design Coordination: Contract drawings of architect and engineer must be converted to detailed drawings, which can be used for the production and execution of the project. In addition, many subcontractors are involved in a project such as floor manufacturers, structural steel fabricators, cast in-place contractors, electrical, plumbing, mechanical, window frame manufactures, railing fabricators etc. The precast engineering team shall have to work with a lot of information, which must be integrated in the precast production drawings. It is therefore imperative to control the flow of information and have checking procedures in place. Generally, the first set of precast detailed drawings will show the exact geometry of the precast elements with connections to other elements and structures. The project coordinator will have to send these drawings to the architect, structural engineer and other consultants for review and checking purpose. It is expected that the drawings are checked, and additional information is provided to finalize the drawings. The additional information can be provided as mark-ups on the drawings (redlines), or as digital CAD files or nowadays the use of 3D digital building models are becoming popular. The precast engineering team must process the information and prepare structural design calculations to finalize the precast production drawings. The major difference with conventional building technology is the integration of all design services in the final production drawings for which all information must be available and to be coordinated and checked.

Structural Analysis: The structural engineer shall perform the structural analysis to calculate the strength, rigidity and stability of the building structure and understand how the structure supports and resists the vertical and lateral loads. The engineer requires knowledge of the standard design codes and structural analysis techniques. The most commonly used structural analysis method is the finite element method (FEM).

Specialist FEM computer software can be used to prepare accurate 3D models for structural analysis (Figure 3). The structural engineer shall prepare the structural analysis model, which includes the geometry of all the structural precast members like columns, beams, walls and slabs. Material properties, supports and connections shall be modelled in such a way that they represent the actual behaviour of the precast structure. The engineer shall prepare a very detailed 3D model with exact size and positions of door and window openings,

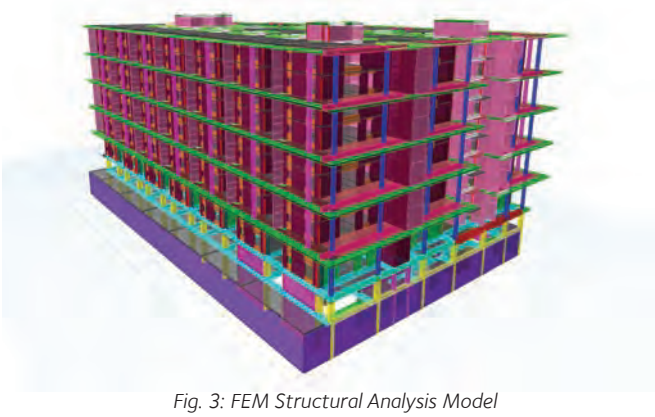

Fig. 3: FEM Structural Analysis Model

cut-outs and shafts. Precast walls and slabs shall be properly meshed and stiffness modifiers to be applied as per the prescriptions laid down in the standard design codes. The results of the structural analysis are used for the design of each structural member and therefore it is a key part of the engineering work.

Structural Design: Based on the output results from the structural analysis model the structural engineer can prepare the reinforcement and connection design for each precast concrete member. Precast design calculations shall be based on the standard design codes and generally the precast members shall have to get connected so that essentially the structure will behave the same as a cast in-situ concrete structure. Other precast systems with different behaviour can be used but might not be supported by the design codes and therefore research and actual testing must show their adequacy. Finally, the structural engineer must prepare the design report, which describes the structural analysis approach and results together with the detailed design calculations.

Precast Drawing Preparation: The precast detailed drawings are a translation of the contract documents and must be prepared in such a way that they are having usable information for precast production, handling and erection. Furthermore, the precast detailed drawings must provide all information to the architect and engineer to enable them to check the geometry and the relation to the rest of the building. The precast engineering team shall assign a unique identifying tag (called element number or piece ticket) to each precast component. A set of erection drawings consisting of building plans, elevations and sections shall be prepared indicating the exact location and geometry of each precast component and its connections. The precast detailed drawings are prepared by expert draftsmen in 2D CAD or with the help of 3D Modelling software to produce the final 2D drawings. This entire process is called precast detailing and it is an essential and important part as errors in these drawings can cause difficulties at site, which can increase the cost when precast pieces must be refabricated.

Generally, the following precast shop drawings shall be prepared:

1. Precast erection plans and elevations
2. Precast erection details
3. Embed plans and anchor layouts
4. Precast element form details
5. Precast element reinforcement details
6. Bar bending schedules
7. Hardware details

Precast Erection Drawings and Details: These drawings show how the precast concrete members are erected and they are prepared using the contract documents. The erection drawings contain all precast concrete member piece marks, fully dimensioned size and shape of each member, location of each member with respect to the building lines or column lines and finished floors, and details and locations of all connections. Joints and openings between precast members and any other portions should also be identified.

Erection layout plans show the precast members at each floor looking down and they are useful for indicating precast concrete beams, slab, columns and walls. Sections and details must be marked on the plans. Erection elevations are views that look directly at the structure and are usually taken from the outside looking in (Figure 4). Erection details are blow up sections, which show all the information to make a connection between precast concrete elements or to other structures. Embed plans and anchor bolt plans are used to show the location of embeds and anchors placed in the foundation or structure for connecting the precast elements. The hardware drawings will show the details of inserts and embeds required to be placed inside the precast member when it is manufactured.

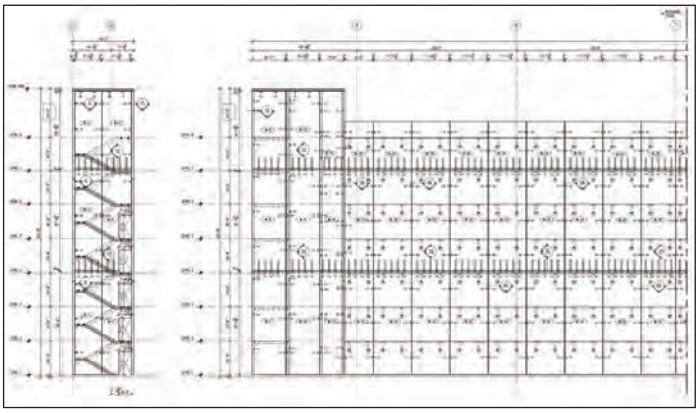

Fig. 4: Precast Erection Elevation of a Building

Precast Element and Reinforcement Details (production drawings): The precast production drawings are used in the precast plant to manufacture the precast concrete members. These drawings must show each precast member including all the specifications, details, dimensions, inserts, reinforcement details, finishing etc.

The precast element form detailed drawings (piece drawings) show the precast piece in the position from which the precast plant personnel will view it or cast it (casting view). Various views like top, bottom and side views must be added on the drawing (Figure 5). Separate sections and blow up details should be used to clarify any complicated areas. Inserts that are required for connections and lifting must be shown and provisions for MEP services must be detailed and specified. Concrete surface finishing must be specified and marked with symbols on the drawing.

The reinforcement drawings will show the reinforcement required inside the precast element (Figure 6). These drawings should show all

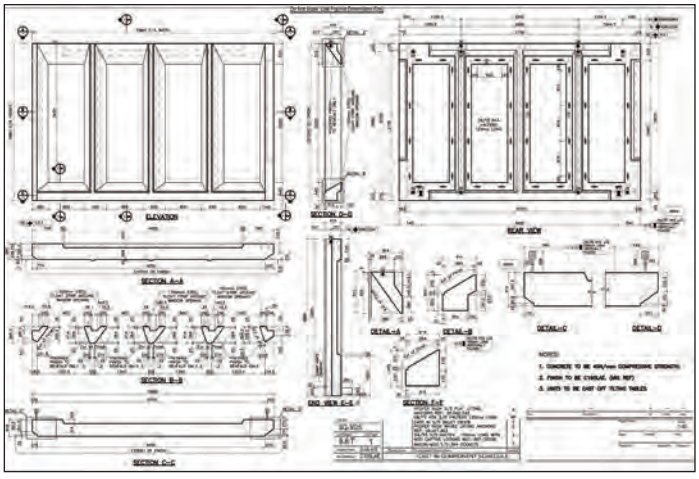

Fig. 5: Precast Element Drawing

the necessary information so that they can prepare a reinforcement cage, which will fit into the form. Size and location of reinforcing bars (rebars) and welded wire mesh must be shown in plans, elevations and sections. Blow up details shall be prepared for clarification of areas with reinforcement congestion. Bar bending schedules can be added on the reinforcement drawings, which will show the bar mark, bar shape code, size and type of rebar, total number of bars, bar length, bar bending dimensions and total weight.

3D Modeling of Precast Structures and BIM

Instead of using 2D CAD software to prepare the technical drawings it might be beneficial to utilize more advanced software to prepare accurate 3D digital models of the project from which drawings and other information can be generated and documented. A process called building information modelling (BIM) can be followed where all information is stored in 3D computer models. A BIM model can consist of all the virtual equivalents of the actual building components used to construct a building. These components have all the characteristics of their real counterparts. These intelligent components are the digital prototype of the physical building elements that allow us to simulate the building and understand its behaviour in a digital environment way before the actual construction starts. Each consultant and subcontractor can model their building components in separate 3D models, which can be integrated into a single model that includes all information (Figures 7 and 8). From the digital 3D model, the precast drawings like plans, sections and elevations can be generated as well as all the production drawings of each precast component can be prepared.

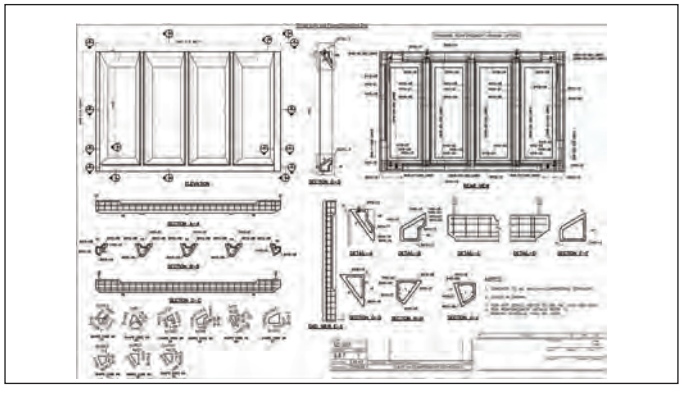

Fig. 6: Precast Reinforcement Drawing

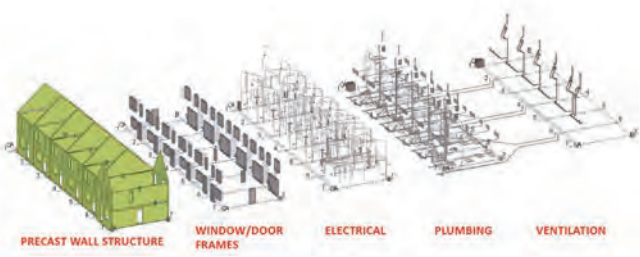

Fig. 7: Precast Structure 3D Model with Separate MEP Services

Fig. 8: Precast Structure 3D Model with Integrated MEP Services

Precast Design Standards

India

IS 11447	Construction with large panel prefabricates
IS 15916	Building design and erection using prefabricated concrete
IS 15917	Building design and erection using mixed/composite construction

International

FIB 27	Seismic design of precast concrete building structures
FIB 43	Structural connections for precast concrete buildings
PCI	PCI Design Handbook USA – precast and prestressed concrete
CAE	Guidelines for the use of structural precast concrete in buildings (New Zealand)

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