

REVOLUTIONIZING CONSTRUCTION: THE EFFICIENCY OF PRECAST CONCRETE INSTALLATION

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Abstract

The utilization of precast concrete components traces its roots back to the time of the Roman Empire, where early forms of concrete were employed in the construction of tunnels, aqueducts, and culverts. This innovative construction approach, involving the placement of limestone, sands, and water into molds, marked the inception of precast concrete construction and prefabrication technology. The essence of this technique lies in the preparation of components off-site, reducing construction time significantly. Unlike cast-in-site construction, where waiting for concrete to reach full strength is imperative, precast concrete components are pre-manufactured, allowing for a streamlined and efficient construction process. Furthermore, the installation of precast structures requires minimal on-site construction workers.

1. Introduction

Precast concrete components have been in use since the Roman Empire. Ancient people would place mixers of limestone, sands and water into molds and wait for them to be dried and harden. The hardened materials would then be transported to build tunnels and aqueducts and culverts. The mixture was an early form of concrete and this inaugurated precast concrete construction process and prefabrication technology. It greatly decreases the construction time. Since the components are pre-manufactured, there is no need to wait for the concrete to reach full strength as in cast-in-site construction. There is minimal construction workers needed in precast structural installation

2. Classification of Precast Systems

According to the United Nations Development Plan and the United Nations Industrial Development Organization (UNDP/UNIDO) Project ^[2]. There are various structural systems that make use of Precast concrete elements. The type of precast system type varies from country to country. The basic prefabricated structural systems can be identified as: Large panel systems, Frame systems, Slab-column systems with walls and Mixed systems.

2.1 Large Panel Systems

Large Panel systems is used in multi-story structures composed of large concrete panels which are connected in the horizontal and vertical directions so that the wall panels enclose spaces for the rooms of the building. The panels form the structural system. The large panel system can be divided into cross wall, long wall and two-way

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system, depending on which wall panels are load bearing. Fig. 1 shows a long wall system, in which the load-bearing walls are placed along the longitudinal axis of the building.

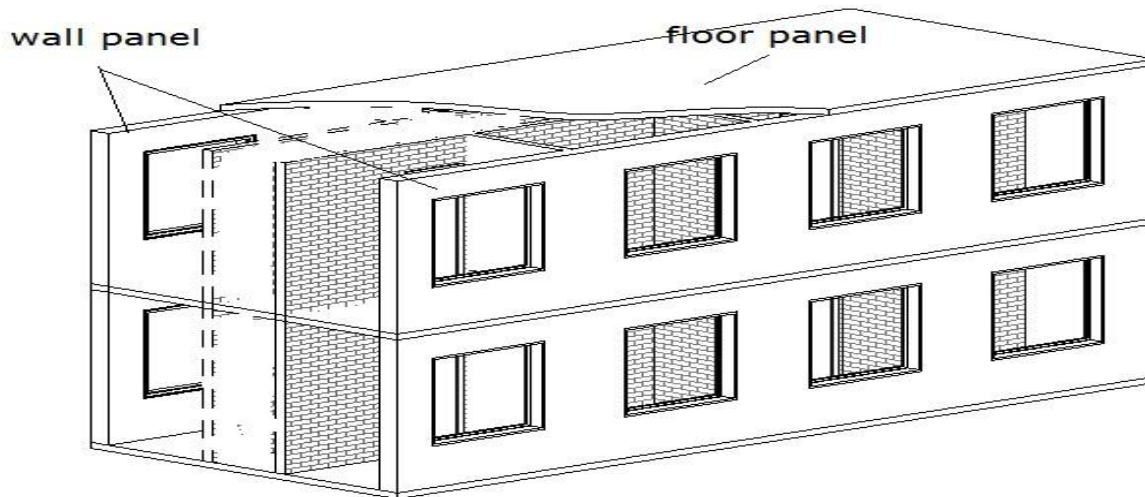


Fig.1 Long Wall Large Panel System, Redrawn from UNDP/UNIDO Project [2]

2.2 Frame system

In Frame systems, the beams are generally precast in lengths so as to occupy the clear spans between the columns. The columns are either cast in situ or precast on site. The connections between prefabricated members can be designed to provide the frame with rigid joints when subjected to seismic forces and live loads. The connection between the prefabricated beams and columns can also be designed to be hinged. The hinged connection is normally achieved by seating the beams on column corbels and by holding the beam ends in place by welded steel shoes, or by the use of vertical dowels or bolts, so that shear can be transferred between the beam and column but not bending moment^[2,3]. A hinge connection type is seen in Fig 2.

2.3 Slab-column system with walls

The slab-column systems with walls have their special feature because of the method of construction. There are two ways: The first is lift-slab system involving cast in situ reinforced concrete slabs and precast reinforced concrete columns; the second is a system consisting of prefabricated reinforced concrete slabs and columns which are prestressed together after erection to form a continuous structure.

2.4 Mixed system

Mixed systems are structural systems which do not fit specifically into purely large panel systems, frame systems or slab-column systems with walls. One particular system, for example, consists of casting in place structural walls and prefabricated floor slabs. A system like this can be referred to as a mixed system^[3].

The structural system for a particular building can consist of one or a combination of the basic systems mentioned above. Alternatively, the system can be composed either of prefabricated elements only/or of prefabricated elements in combination with cast in situ concrete.

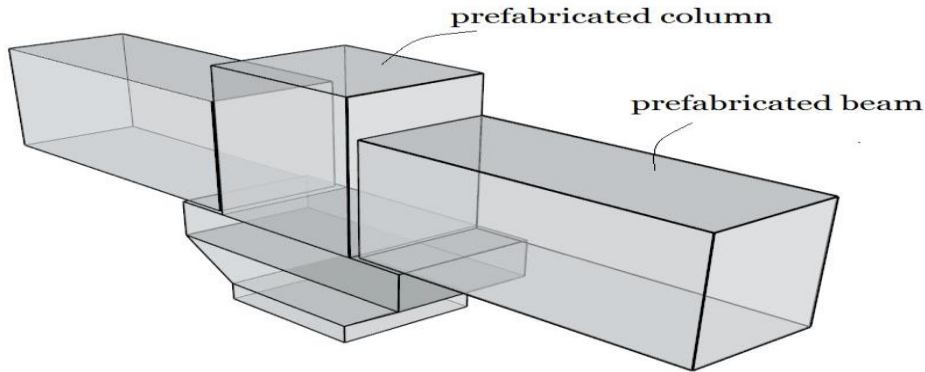


Fig 2. Example of Hinged Beam-Column Connection

3. Installation

Because of their weight, precast elements are moved with machinery and hoisted in position by cranes. Proper site planning has to be conducted in order to navigate around the site and lift the precast elements. Lin et al ^[5] proposed a new innovative strategy for evaluating site accessibility during the pre-construction site layout planning. Their research presented a trial case which used a sandbox environment to evaluate the accessibility of a construction site. Because tractor-trailers are usually used to move precast elements, the simulation particularly focused on two-section vehicles. The results showed that realistic visualizations and simulations provide solid references for construction planners. Potential accessibility problems and unsafe situations were identified in the sandbox environment and ways of avoiding them can be determined early in the design and planning stages.

After setting out and surveying of the site, the lifting and hoisting of the precast components is the next step. The size of the precast elements, in addition to the surroundings and lifting capacity of the lifting equipment plays a big role in terms of safety during the installation of the components. A. de la Fuente, et al ^[6] presented a real case study of a 46m long Precast, Prestressed Concrete Girder with lateral instability problems. Their results concluded that numerical simulations, performed with Analysis of Evolutive Sections program, AES, may be used for simplified evaluations of the risk of lateral instability.

Hong ^[7] discussed several precast connection types. To connect vertical precast elements, sleeve, bolt, welded or dowel connections can be used. To connect horizontal elements, cast-in- site connection is used. Joining of vertical and horizontal precast elements can be done using any of the above methods, including a pinned connection. The pinned connection, between a beam and a column, is set up by resting the beam on the column corbel as shown in Fig. 3.

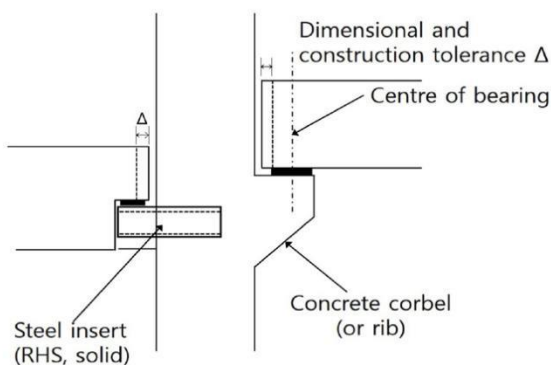


Fig. 3 Hong [7] details of pinned connection; beam resting on column corbel.

4. Project Analysis

4.1 Project Background

The project located in Hangzhou, China. It is an 8storey reinforced concrete structure. Each story is occupied by four families as shown in Fig 4. It is a precast large panel two-way system with beams and shear walls. It is a mixed system. The vertical bearing members are reinforced concrete wall and the horizontal bearing members are slabs and beams. The symmetrical structure has displayed symmetrical stiffness. This makes the structure have good integrity. It can resist gravity loads, wind loads, and to some extent, earthquake actions.

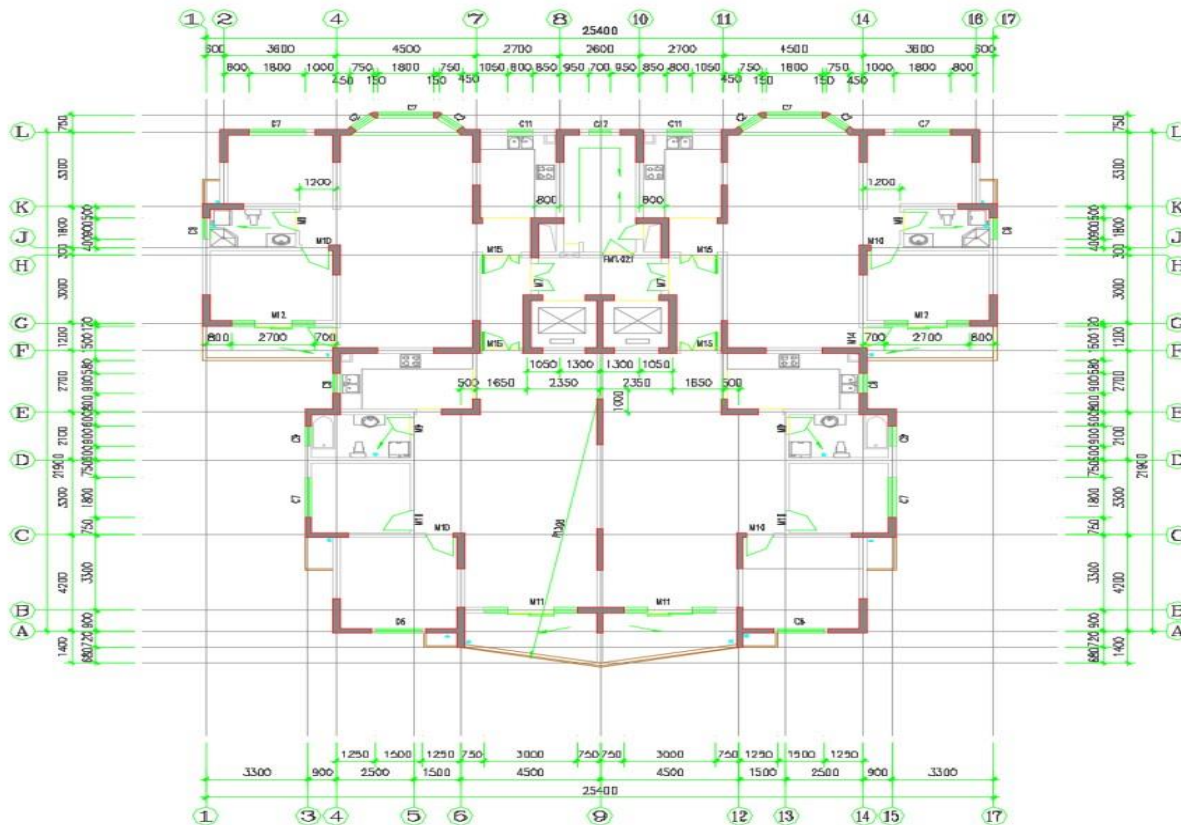


Fig 4. Floor plan for 8 story Residential Apartment

4.2 Construction Procedure

The precast elements in this apartment building are wall panels, beams, slabs (including balconies and air conditioning slabs) and stairs. Both the first floor, as well the middle of the building (from axis line 7-11) was cast-in-site. This was to help improve strength as well as seismic resistance of the building. The remaining 7 stories were comprised of precast elements with cast-in-site shear walls in the center. The installation of the elements is from left to right along the transverse axes.

After the setting and hardening of the foundation, the first floor is constructed. The installation of elements begins on the 2nd floor and moves from floor to floor till it reaches the final 8th floor. Because the floor by floor design is identical, the same order is used for each floor. The horizontal elements (beam and slabs) are installed first so that the vertical elements (wall panels) can transfer loads to the foundation. The installation process is as follows:
Beams □ Slabs □ Walls panels

4.3 Installation of Elements

Only 2 connection types are used in the entire building. These are the cast-in-site connection and the sleeve connection. The beams resting on the first floor are cast-in-site. The top of the beams have protruding steel rebars that will connect to the bottom of the precast wall panels via sleeve connection. The bottom of the beams has sleeves embedded in them. The perpendicular as well as head to head connections between the beams are moment-resistant rigid cast-in-site connection. The connections between the beam and the slab resting on the first floor are also rigid connections, as are the connections between the slabs of this floor.

4.4 Installation of Precast Slabs

The precast slabs are numbered according to the order shown in Fig 5 below.

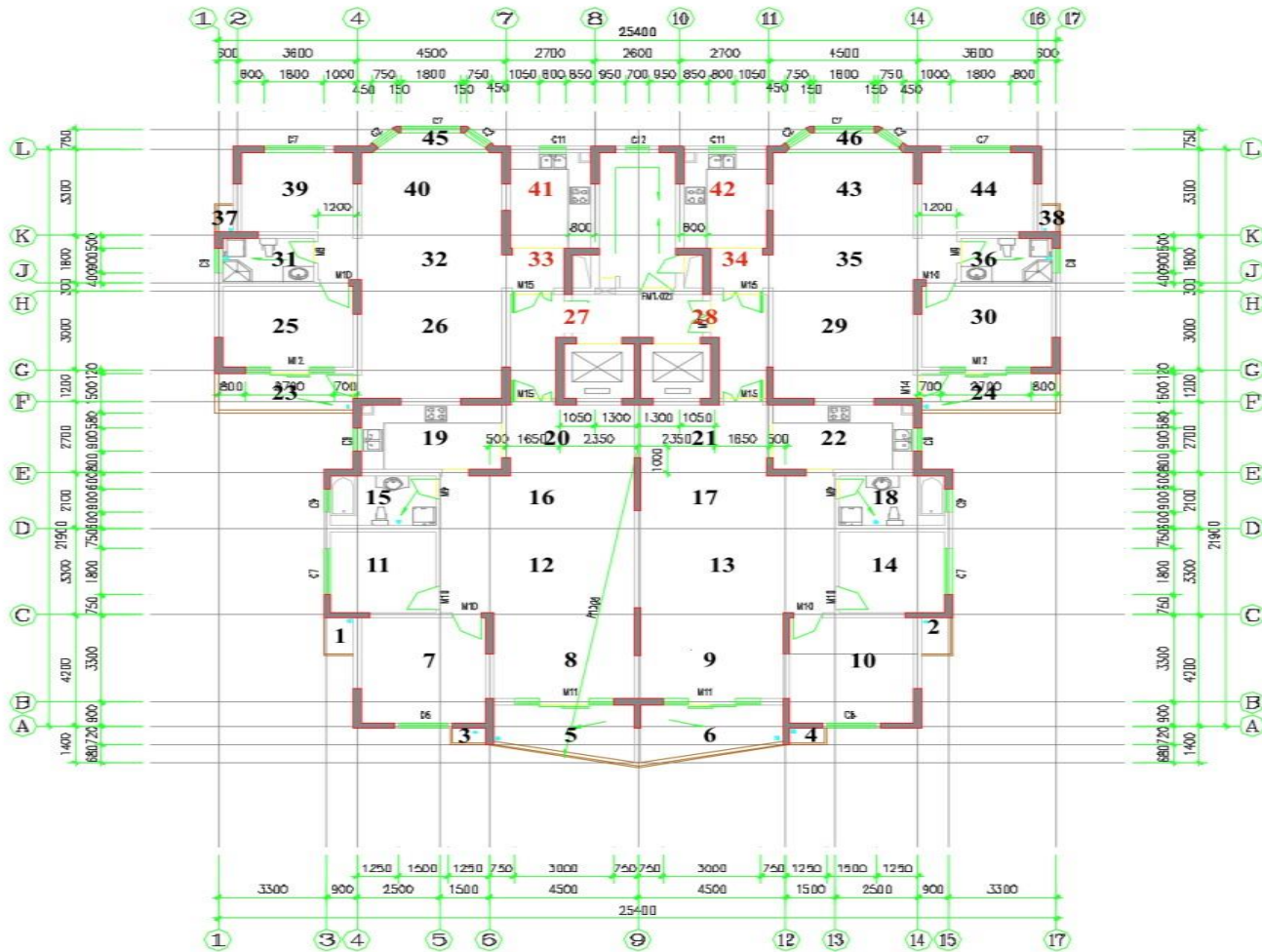


Fig. 5 Order of Installation of Precast Slab

The balcony slabs are installed first by the constructor's preference. These slabs are referred to as Precast Air-conditioned Slabs (PAS). The slabs are followed by the Precast Balcony Slabs (PBS) then the Precast Floor Slabs (PFS). The building is symmetrical so there are double pieces of the same slab. The slabs are numbered to help in the accurate installation of the elements onto the building. Table 1 shows the precast slabs used in the building. Because the building is symmetrical, only half of the slabs used are represented in the table. The core of the building is cast in site. This means that the slab numbers 27, 28, 33, 34, 41 and 42 are cast-in-site thus they are not mentioned in the table.

The supports are placed under the precast slabs during the installation. This is done to ensure site safety as well as connection integrity. The crane is only unhooked after the supports are put underneath the floor slab. The slabs

are connected using cast-in-site connections. This connection is used to connect the slabs with the rest of the building.

The concrete is poured into the wood-form of the cast-in-site slab portion of the precast slab. After the slab gains its strength, the other components are added on it. The precast slabs connect with the precast wall via cast-in-site connection.

Table 1 Precast Slabs

Name	Number of Component on Plan	Length (mm)	Width (mm)	Height (mm)	Weight (t)
PAS 1590-1	1	1500	900	130	0.54
PAS 1272-1	3	1250	720	130	0.36
PBS 4523-1	5	4500	2300 (Longest side)	130	3.53
PFS 4542-1	7	4500	4200	130	7.56
PFS 4533-1	8	4500	3300	130	5.94
PFS 3433-1	11	3400	3300	130	4.49
PFS 6033-1	12	6000	3300	130	7.92
PFS 3421-1	15	3400	2100	130	2.86
PFS 6021-1	16	6000	2100	130	5.04
PFS 4727-1	19	4750	2700	130	9.5
PFS 3727-1	20	3750	2700	130	4.05
PBS 4216-1	23	4200	1620	130	2.72
PFS 4233-1	25	4200	3300	130	5.54
PFS 4530-1	26	4500	3000	130	5.4
PFS 4218-1	31	4200	1800	130	3.02
PFS 4518-1	32	4500	1800	130	3.24
PAS 1260-1	37	1200	600	130	0.29
PFS	39	3600	3300	130	4.75

3633-1					
PFS 4533-1	40	4500	3300	130	5.94
PFS 3327-1	41	3300	2700	130	3.56
PBS 3675-1	45	3600	750	130	0.81

4.5 Installation of the Precast Wall Panels

The precast wall panels are installed after the precast slabs. The connection between the wall panels and the beam is a sleeve connection. The side-by-side connection of the wall panels to each other is a cast-in site connection, as shown in Fig 7. Brace supports are fixed to the wall and the wall is checked for verticality before the crane is unhooked.

The braces should be placed more than 67% of the wall panel height, measuring from the bottom. Under no circumstances should the braces be placed at the mid-line of the wall panel to avoid —kick out‖ effect or a panel failure due to the bending at the brace points. While the supports are still connected, the wood form is put and concrete it poured in it. The supports must be left to harden for at least 2 days.



Fig. 7 Cast-in-site Connection between two Wall Panela

The vertical members in each floor are comprised of precast solid walls, precast window-wall panels, precast door panels as well as the cast-in-site load bearing walls. Cast-in-site shear walls were placed along the center of the building to act as the core of the building. Fig.8 shows the installation order of the wall panels.

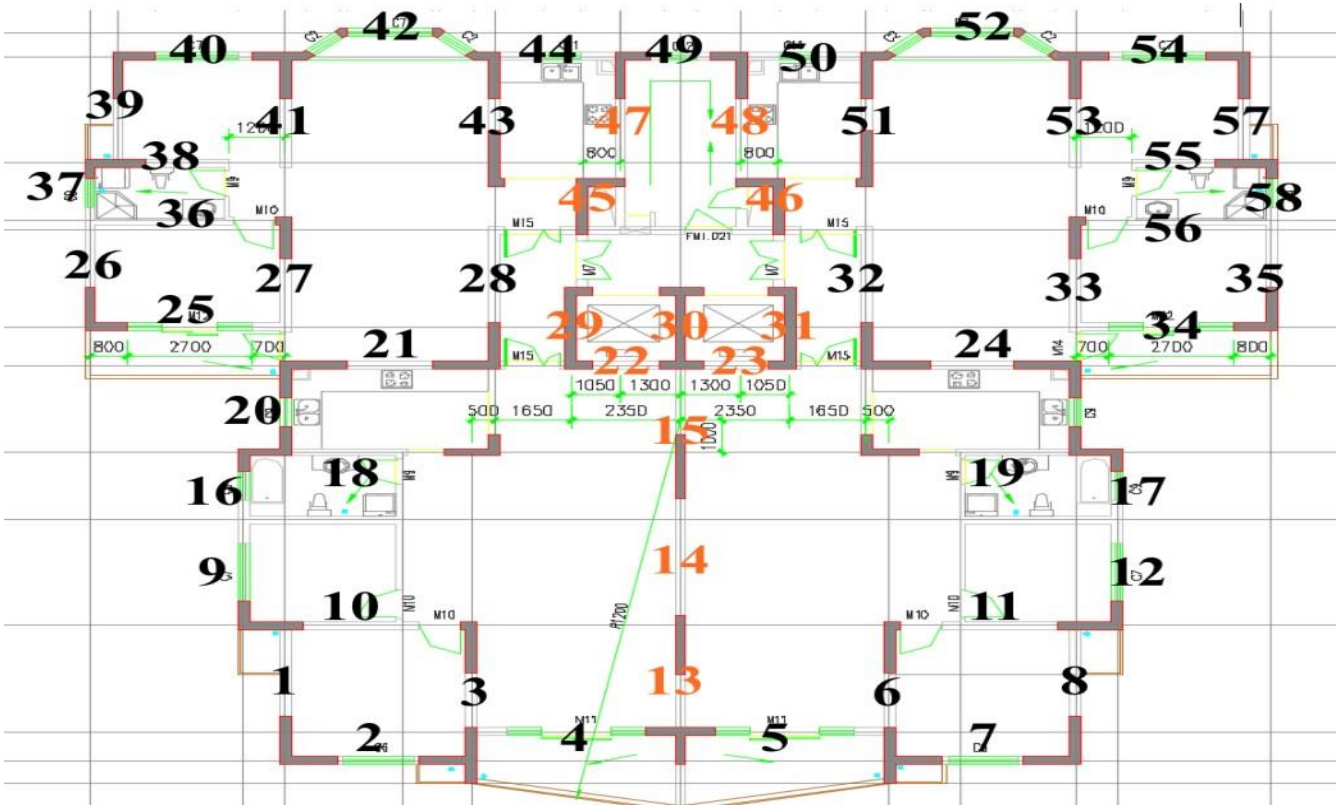


Fig. 9 Precast Walls Installation Plan

4.6 Installation of Precast Beams

The precast beams are lifted and placed on the walls with the help of taglines, which direct and keep the beams from swaying. The tag lines ensure that the beam doesn't swing and sway during the installation. The left and right ends of the beam have protruding steel bars for connection with other beams. This connection is a cast-in-site. The vertical connections between top end of the wall and the bottom end of the beams are sleeves. For beam length less than 6m, it has 2 supports. The arrangement of the beams is shown in Fig. 10. The center beams indicated in purple are cast-in-site.

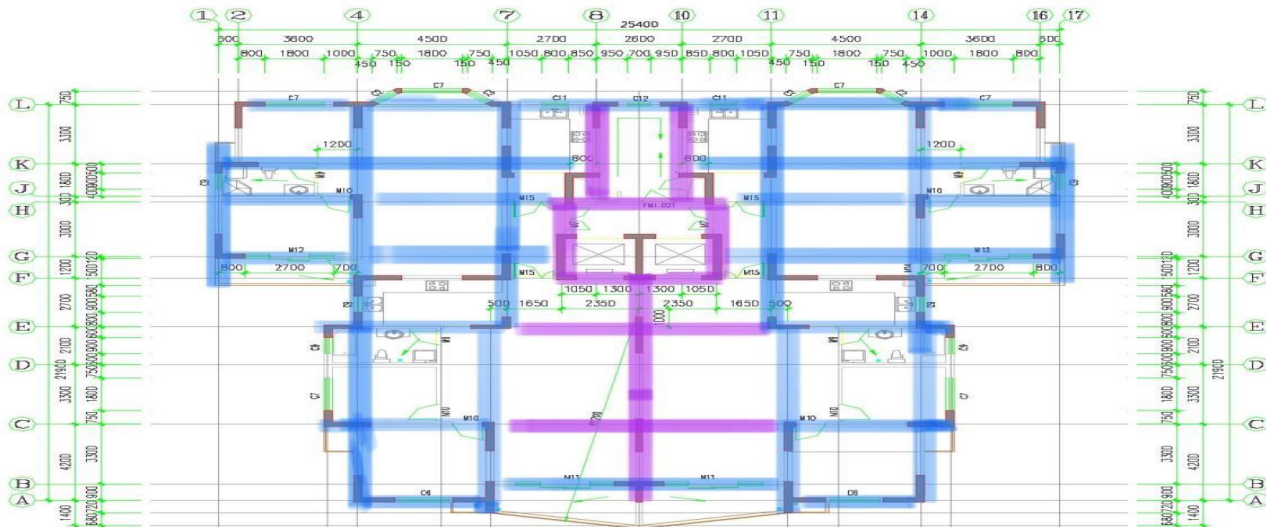
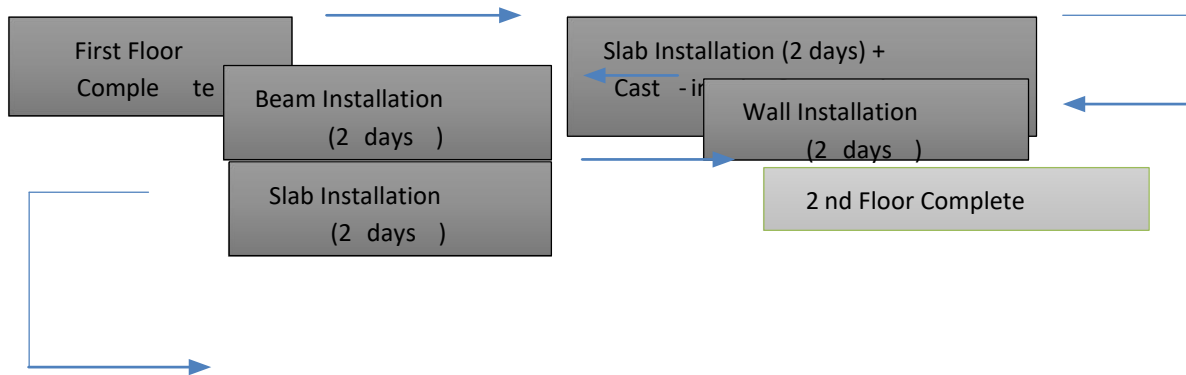


Fig 10. Arrangement of Precast Beams

5. Conclusion

- 1) Structural installation of precast elements is an advanced and effective way of construction. It utilizes basic building principles which greatly simplify the structural construction process. This paper explores the installation of precast elements for an 8story residential building.
- 2) The precast elements are connected to one another by means of grouted sleeves and cast-in-site. The bracing for the elements as well as the wood-form for the cast-in-site connections must remain un-tampered with for at least 24 hours.
- 3) The project analysis used the floor by floor installation procedure was as illustrated below.



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