BUILDABLE SOLUTIONS FOR

# High-Rise Residential Development

BCA Buildability Series

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# INTRODUCTION

Prefabrication is one of the key means of increasing buildability. As the industry strategises itself to build with less labour and shorter construction time, prefabrication of concrete structures has become a viable alternative to the traditional way of construction. Over the last few years, some industry players have effectively adopted the use of precast concrete components to their advantage by combining it with cast in-situ concrete elements. Different mix of precast and cast in-situ elements are used to meet different design requirements for better quality and cost effectiveness. Such combination enables their projects to achieve higher level of productivity than is possible with solely cast in-situ construction. By using precast concrete components predominantly, on-site operations are considerably reduced, providing a safer working environment.

However, it is important to have a good appreciation of its difference in management from the conventional construction. The benefits of using prefabrication would not be fully realised by merely adapting the traditional way of design and construction process. The keys to successful implementation lie in the planning and understanding of the close relationships between design, construction, detailing, execution and manufacturing of precast concrete components. In other words, it is vital to have a good cooperation between the architect, the engineer, the builder and the precaster.

## Scope of Our Study

Our study focuses on the salient issues involved in the use of precast concrete components; with specific mention of in-situ flat plate or precast floor slab with precast façade system as buildable solutions for high-rise residential development.

Drawing from the experiences of private practitioners, we had collated and outlined the planning and design process as well as practical considerations that one should be familiar with when dealing with precast concrete components. Good examples of local high-rise building projects were also documented for reference.

The guidelines presented are meant to provide a greater awareness and understanding on the use of precast concrete components. They should not, however, be deemed as restrictions to either design creativity or to potential alternatives raised.

# 1 Building Framework

## Floor Slab with Precast Façade System

# Building Framework

## Floor slab with Precast Façade System

For high-rise residential development, repetitive and simple construction techniques are important to achieve an economical and speedy construction. In developing the overall concept plan, project team members have to work together to consider carefully how the project can be built, the elements to be prefabricated and the building framework to be adopted.

The choice of the building framework can be undertaken by assessing the project objectives and how they can be best met. As the building framework used for the project would set out the planning requirements and construction methods, there are a number of factors that one has to consider before making a decision. Different building systems have their advantages and disadvantages, it is therefore not possible to prescribe any system as being better than others. Generally, a hybrid of different concepts could be used to achieve the best project outcome. In local context, the prevailing form of construction is a combination of precast concrete components with cast in-situ elements. However, the extent whereby precast concrete components are used may vary from project to project.

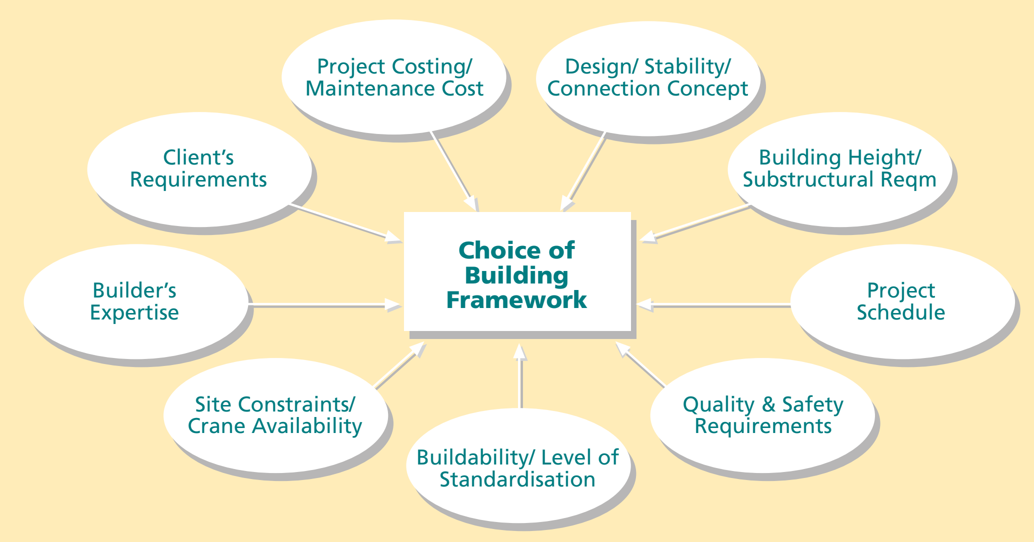



**Fig. 1.1** – Factors influencing the choice of building framework

In general, the building solution using floor slab with precast load-bearing façade is found to be a buildable yet simple framework for high-rise residential development. The floor slab system used may be in-situ concrete flat plate, precast full slab or half slab in combination with supporting precast facades. This system offers much flexibility in accommodating to the changes in internal layout, more generous headroom and considerable benefits in achieving better quality wall finishes. With proper joint details, most of the construction works can be done internally thus creating a safer working environment.

## 1.1 DESIGN CONCEPT

The main load-bearing system consists of floor slab supported by precast load-bearing walls and façades at the perimeter of the building. Essentially, the design concept is to maximise the use of architectural members such as façade walls and partition walls as structural members to improve the floor layout and its structural efficiency. Precast façades used for the building envelope can be designed to form part of the structural system in supporting vertical loads from the floors. This design approach minimises the need for other structural elements, thereby providing an economic solution. Alternatively, these facades can be designed as non load-bearing panels

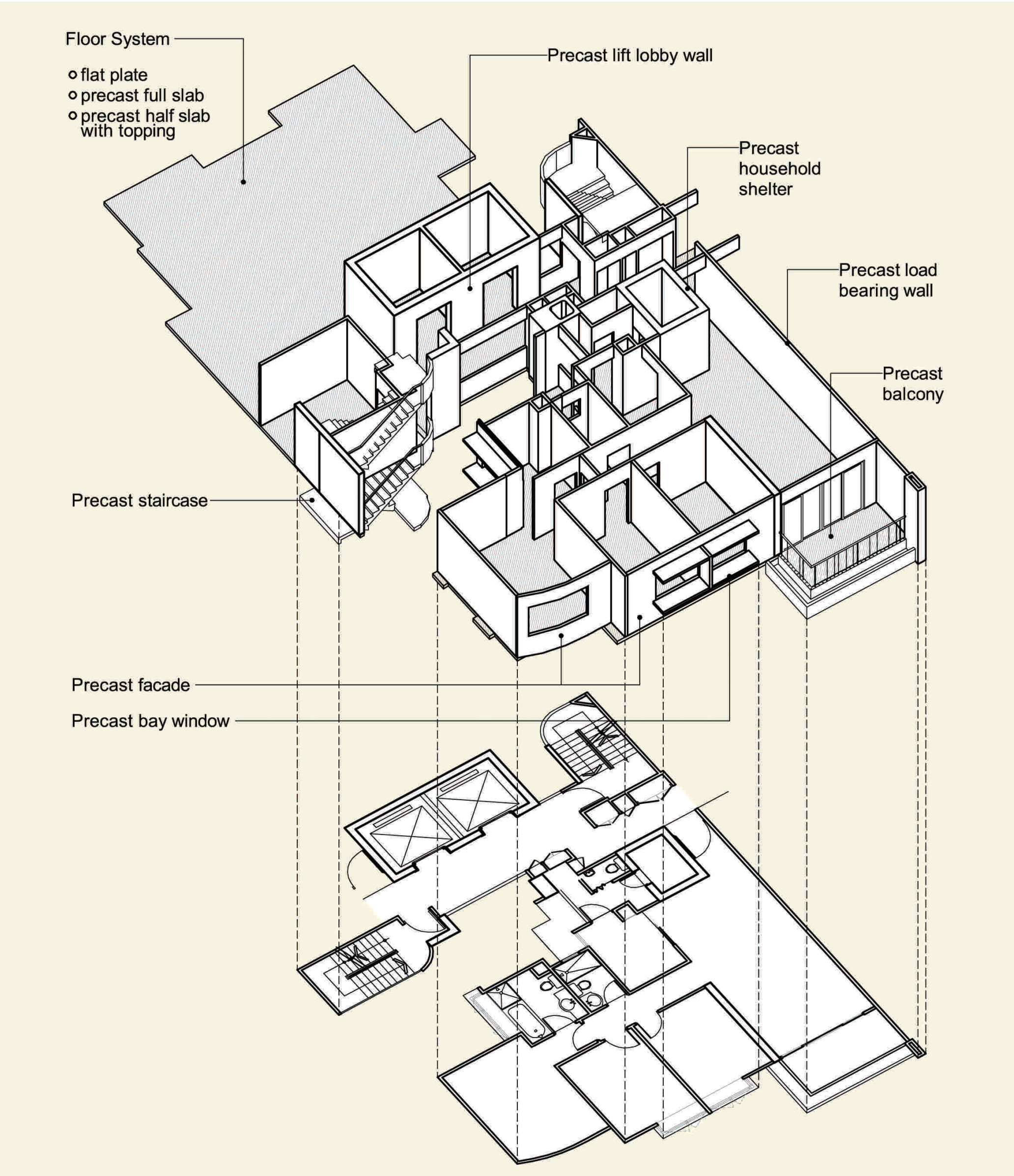



**Fig. 1.2** – **Example of a typical apartment unit using floor slab with precast loadbearing wall and façade system**

like window wall units which resist or transfer negligible load from other structural elements. In short, the use of precast façades offers a practical and economical way in providing the desired architectural expression as well as functional advantages such as structural capabilities, good acoustic insulation and fire resistance.

Depending on the building layout, span direction and stability requirement, other precast structural elements such as columns, beams and shear walls can be used to complement in supporting part of the floor loading and lateral forces. Other precast concrete components such as balcony slabs, staircases, refuse chutes, planter boxes and air con ledges can also be integrated as part of the overall building system.

## 1.2 STABILITY OF BUILDING

The overall stability of the building can be provided by core walls, which are already present for basic functional purposes such as staircase wall, lift core wall and household shelters. Locally, these cores are usually constructed using in–situ reinforced concrete.

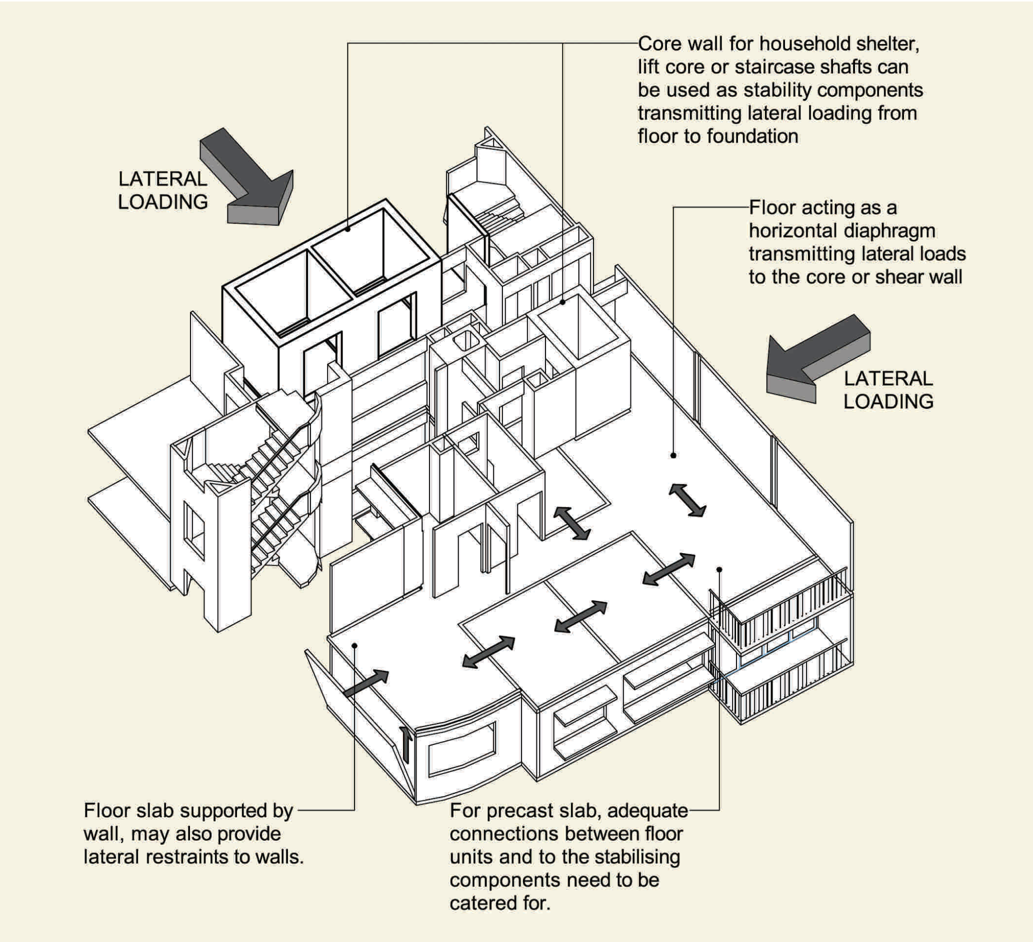



**Fig. 1.3 – Stability of building provided by core walls and floor elements**

Prefabrication of these cores is however, possible and feasible in the form of three-dimensioned elements (L shaped, U shaped or Box shaped). Proper connections can be designed to achieve structural continuity required for lateral stability of the building structure.

As the building frame using flat plate or precast slab as the floor system is generally less rigid, it is important to locate the core wall and other stabilising components in strategic positions to achieve the required stiffness for lateral stability. Where necessary, shear walls that have large in-plane stiffness can be used to complement the building stability against horizontal loading by counterbalancing the torsional effects induced by any eccentric position of the core walls.

To transfer the horizontal or lateral loads from the facades to the core or shear walls, the in-plane stiffness of the floors are used as a diaphragm. For the use of precast full slab system, it is important to have adequate connections between the floor units as well as with the stabilising components. Grouted or concrete in-fill joints in combination with the connecting tie bars are commonly used for this purpose. As for the precast half slab system, the diaphragm action of the entire floor can be achieved through the reinforcement placed within the cast in-situ reinforced concrete topping.

## 1.3 FLOOR SYSTEM

Cast in-situ flat plate and precast slab are efficient floor systems suitable for high-rise residential development. These floor systems enable homeowners to have a beamless structure with predominantly flat ceiling. They do not pose much restriction to the position of horizontal services and internal wall, thus enhancing design flexibility. Both systems can cater for spans of 6 m to 7 m with typical reinforced concrete section. Post tensioning strands can be incorporated in the floor section to cater for greater spans up to 11m. Apart from cost, the choice of the floor system will depend largely on the following factors :

- **Regularity of Room Sizes**

  Regularity of room sizes is not a major issue when in-situ flat plate system is adopted. As for precast floor slab system, such regularity will give a higher level of standardisation, which in turn reduces the cost of doing precasting works.

- **Builder’s Expertise**

  Given a choice, most builders would adhere to the systems that they are familiar with. Reusable materials and equipment from previous projects can also be deployed to minimise cost.

- **Site Constraints**

  If the site is in close proximity to the neighbouring residential housings, the use of precast slab will be preferred as it minimises environmental nuisances such as pollution, noise, debris and dust as in the conventional in-situ construction.

- **Crane Capacity and Usage**

  Precast solutions necessitate the use of cranes for installation. Hence, the capacity and availability of the crane will determine the suitability of system to be adopted. On the average, it takes about 20 minutes to one hour to install one panel. Therefore, there is a trade-off between the availability of crane time versus quantum of precast activities. To minimise site handling and crane usage, the logical solution is to maximise panel size and weight so as to reduce the number of panels required. However, there is a need to consider the cost implications in deploying greater crane capacity for the lifting of larger precast panels.

**Table 1.1 – Floor System**

| SLAB TYPE | ADVANTAGES | DISADVANTAGES |
|---|---|---|
| **In-Situ Flat Plate** | • Flat soffit<br>• No beam required<br>• Simplified and efficient formwork system can be deployed<br>• No special provision for diaphragm action required<br>• Services can be incorporated readily | • Formwork and propping required<br>• Difficult to strip forms within rooms |
| **Precast Full Slab** | • Flat soffit with good finish<br>• No formwork required<br>• Minimum wet trade<br>• Fast erection | • Connections may be more complicated<br>• Greater attention needed for waterproofing and diaphragm action<br>• Building services in slab require earlier planning and co-ordination |
| **Precast Half Slab with Topping** | • Flat soffit with good finish<br>• Minimum formwork<br>• In-situ topping provides good waterproofing and horizontal diaphragm action<br>• Connections details simplified<br>• Services can be readily incorporated in topping | • More propping required<br>• Limited space for building services<br>• Precast slabs cannot be stack cast |

### 1.3.1 In-Situ Flat Plate

In-situ flat plate system essentially is a reinforced concrete slab supported directly by reinforced columns or walls without intermediate beams spanning between the columns or walls.

**SLAB THICKNESS :** The minimum slab thickness for the flat plate can be determined using appropriate design methods. Locally, the slab thickness typically ranges from 150mm to 250mm depending on the span, regularity of the supports or geometry, location of the openings, load concentration and acoustic requirement. Punching shear around columns will be a critical consideration in flat plate design. Provision of additional localised reinforcement or proprietary shear reinforcement may be used to reduce the average slab thickness.

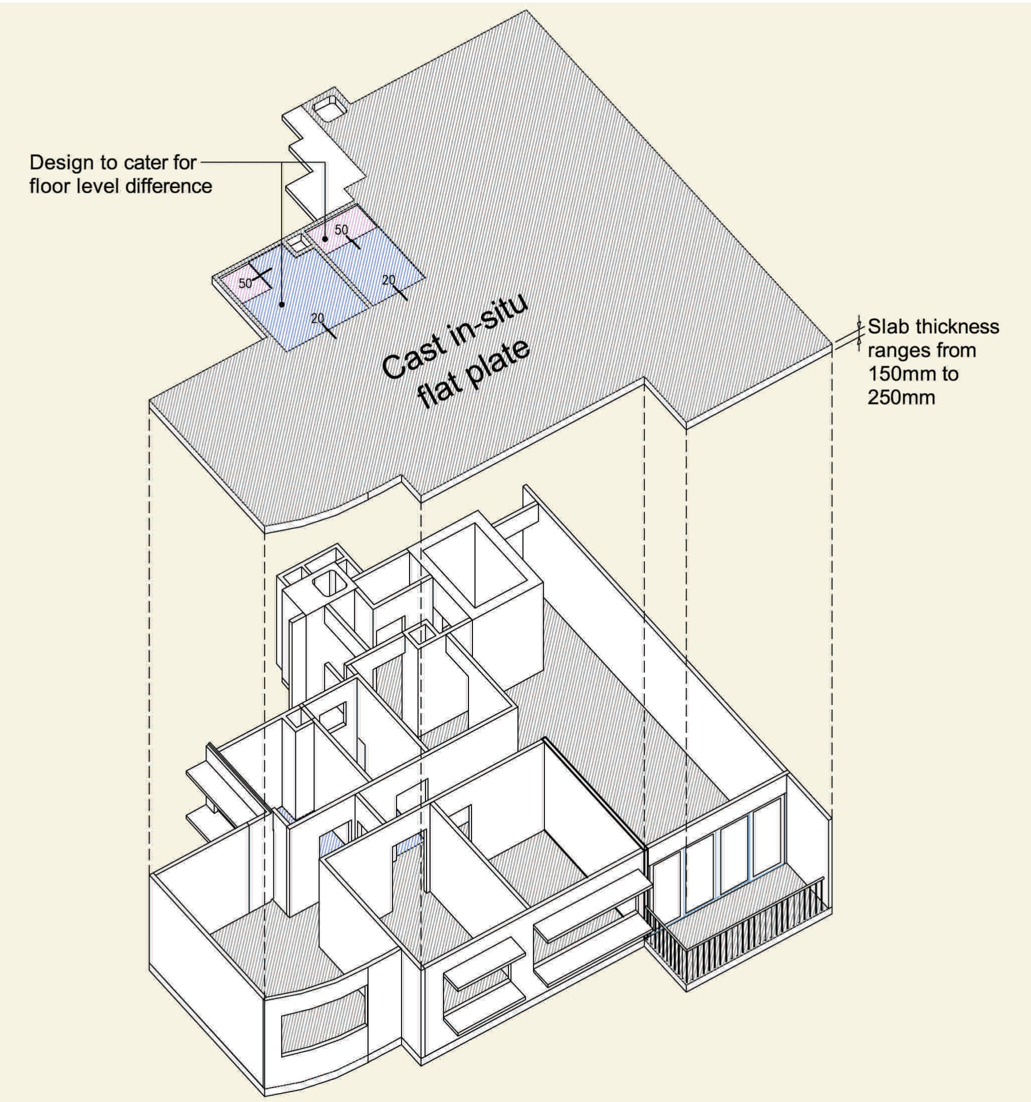



**Fig. 1.4 – Use of in-situ flat plate as floor system**

**FLOOR LEVEL DIFFERENCE :** When the floor level difference is small, it may well be desirable to provide level slab soffit if the span of the slab is not excessive. The slab thickness may vary at localised areas. The entire underside of the floor can be kept flat as much as possible throughout the building floor plate. For greater spans, hidden beams or slab folds at drops in the top level can be incorporated for economic reasons. Alternatively, it may be more economical and practical to provide a kerb for wet areas so that there is no need to thicken the slab to cater for the drop level (see Fig. 1.5).

**FLOOR OPENINGS :** Floor openings for mechanical, electrical and plumbing services are common, in particular for kitchen and bathrooms areas. As such openings would reduce its load capacity, it is therefore important to consider these openings in the analysis and design of the flat plate. Hidden beams can be incorporated around sizeable openings to strengthen the floor plate. Where possible, openings should be located away from structural walls and columns.

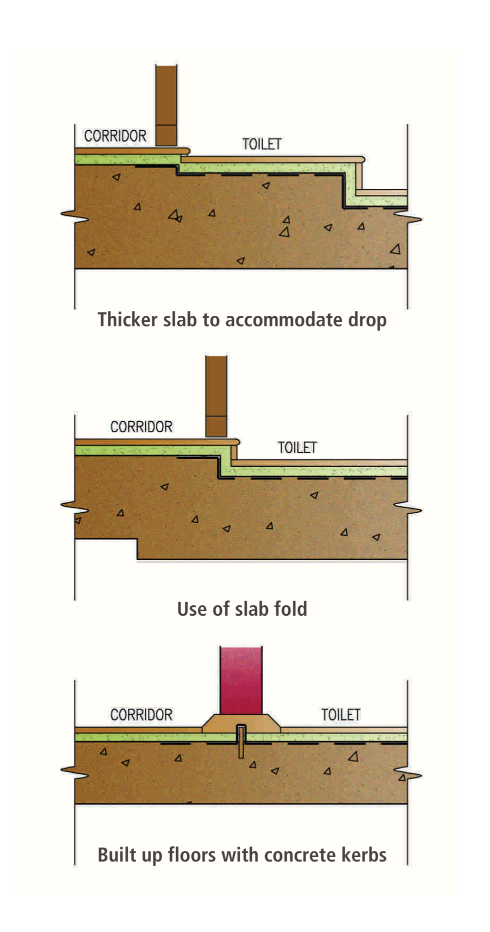



Fig. 1.5 – Provisions for floor level difference

**SERVICEABILITY REQUIREMENT :** As the flat plate used for residential development is likely to be less than 250 mm, it is important to consider the deflections under intended loads as well as construction loads. The deflection should be within acceptable limits, taking into consideration the relative stiffness of other building elements such as non-structural walls and floor finishes.

**CANTILEVER STRUCTURE :** Flat plate can be designed to be cantilevered supported on precast walls or columns. Depending on the cantilevered span, the precast walls or columns may require to be tie back for stability reason. Alternatively, the entire cantilevered slab area can be prefabricated together with supporting beams. Such details can be seen in certain design such as precast balcony (see Fig. 1.6) and ledges for planter or air conditioning unit.

**ACOUSTIC AND THERMAL INSULATION :** In most cases, the flat plate will have thicker slab as compared to that of the beam-slab system, this will help to provide better acoustic and thermal insulation.

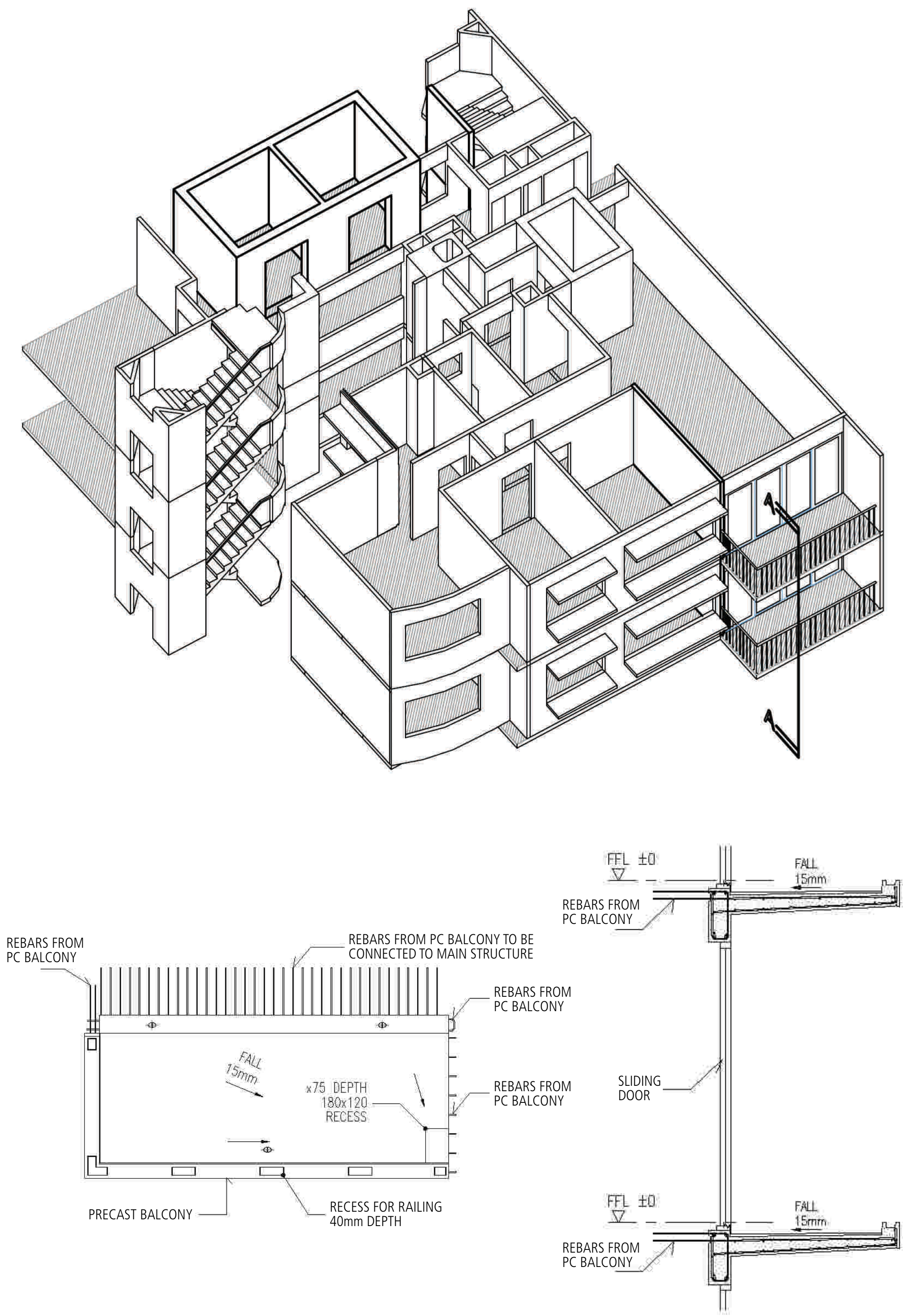



**Fig. 1.6 – Precast balcony details**

## 1.3.2 Precast Slab

There are two main types of precast slab, which are suitable for residential development, namely precast full slab and precast half slab with concrete topping. These floor systems can be customised to room sizes subjected to the limit of the available crane capacity and site access. They are designed to span in one or two directions and are supported by either beams, cast in-situ pour strips or bearing walls. Precast half slab which is also commonly termed as precast plank, is essentially the lower part of a composite slab construction. It is designed to serve as a permanent formwork for the in-situ reinforced structural topping. Its rough top surface enables shear transfer with structural topping and the reinforcements along the edges of slab panels serve to transmit shear to the supporting structures.

**LAYOUT OF FRAMING :** As precast floor slabs are required to be directly supported at the end of the span, the framing layout will have to incorporate certain grids of vertical load transfer elements such as walls, beams or stiffened cast in-situ pour strips. Partition walls that are not likely to be demolished by homeowners can also be designed as load-bearing walls (LB) to support the slabs. Early design co-ordination and modularisation will be necessary to determine the wall positions. Floor slabs used should be modularised or standardised for economy of scale. Designated floor panels can be designed and precast with hidden beams or slab folds to cater for floor levels difference at localised areas. However, it may be more economical to provide kerb for such areas as highlighted in section 1.3.1.

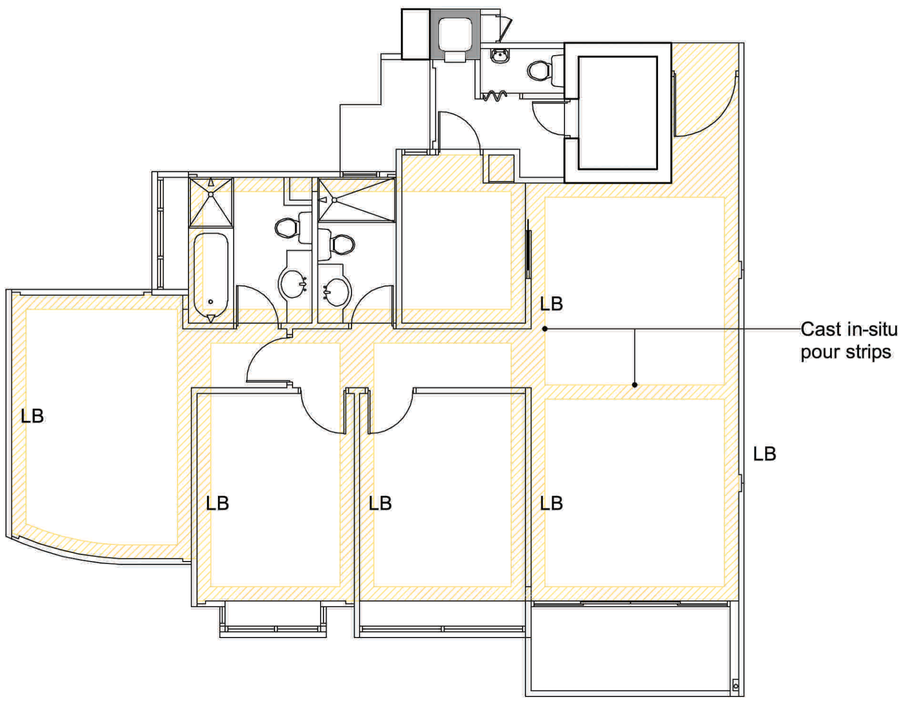



**Fig. 1.7 – Layout using precast slab supported by load-bearing walls**

**REPETITION OF PRECAST UNITS :** When modularisation of dimensions and standardisation of element sizes are adopted, variety of precast units can be minimised. For example, majority of bedrooms, bathrooms, kitchens and yard areas for different unit types can be standardised or modularised. Design of non-standard units can be done with minor modification to the standardised units.

**OPTIMAL DIMENSION :** For precast slab, consideration should be given to maximum lifting capacity of installation crane, transportation modes and their limitations. Nevertheless, room-size panels are preferred so as to minimise jointing and enhance productivity. If the complete room- size panel with width larger than 3.5 m is desired, on-site precasting may be a better option.

**Fig. 1.8 – Example of precast slabs connected by stiffened cast in-situ pour strip**

**SLAB THICKNESS :** The minimum slab thickness for the precast slab can be determined using appropriate design methods. The typical precast full slab thickness ranges from 150mm to 250 mm, depending on the span, regularity of the supports or geometry, location of the openings, load concentration and acoustic requirement. As for precast half slab, the usual thickness is about 75 mm to 125 mm with in-situ topping ranging from 75 mm to 100 mm depending on design requirement.

**FLOOR OPENINGS :** For precast slab, openings can be designed and provided during the manufacturing process. If the opening is large, trimmer bars/angles or cast in-situ beams can be incorporated to strengthen the floor slab system.

## 1.4 WALL SYSTEM

**TYPES AND USES OF PRECAST FAÇADES :** Precast facades can be designed to serve as load-bearing walls/shear walls or non load-bearing wall panels as summarised below:

**Precast Façades**

They can be in the form of solid wall panels, window wall panels and spandrel panels.

**Load-bearing Wall or Shear Walls**

- As part of the structural system in supporting vertical loads from the floors
- They can be designed as shear walls to resist and transfer lateral loads to building foundations
- Analysis should include in-plane shear stresses, panel stability and diaphragm connections
- Proper connections between the precast façade elements should be designed for any shear and tensile stresses under vertical, horizontal and wind load conditions

**Non Load-bearing Wall Panels**

- As part of column enclosure to reduce requirement for temporary formwork
- They can be designed as normal beams or vierendeel beams (for large panels) taking their own weight and wind loading
- They are supported by load-bearing walls, columns or stiffeners through loop bars, mechanical or other connections

**REPETITION AND STANDARDISATION :** Planning for appropriate repetition and standardisation in the design and detailing of the façades/walls will reduce the construction time and cost of precasting. Non-typical panels can be designed and

1 – Air Con Ledge
2 – Window Unit
3 – Bay Window
4 – Façade with Planter Box
5 – Window Unit

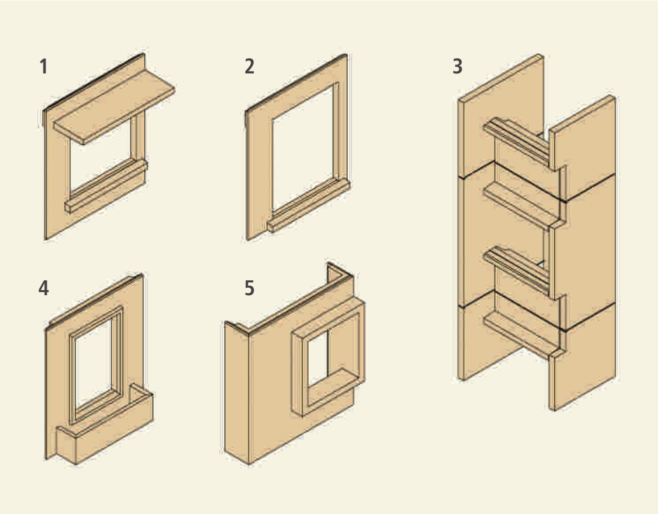



**Fig. 1.9 – Examples of precast façades in different forms**

modified from the typical basic mould to maximise the mould usage. To facilitate precast production, the design should be guided by a modular set of grids with consistent and standardised dimensions so as to achieve better productivity and higher degree of standardisation. More details on modular grids and planning can be obtained from the handbook 'Modular Coordination' published by BCA.

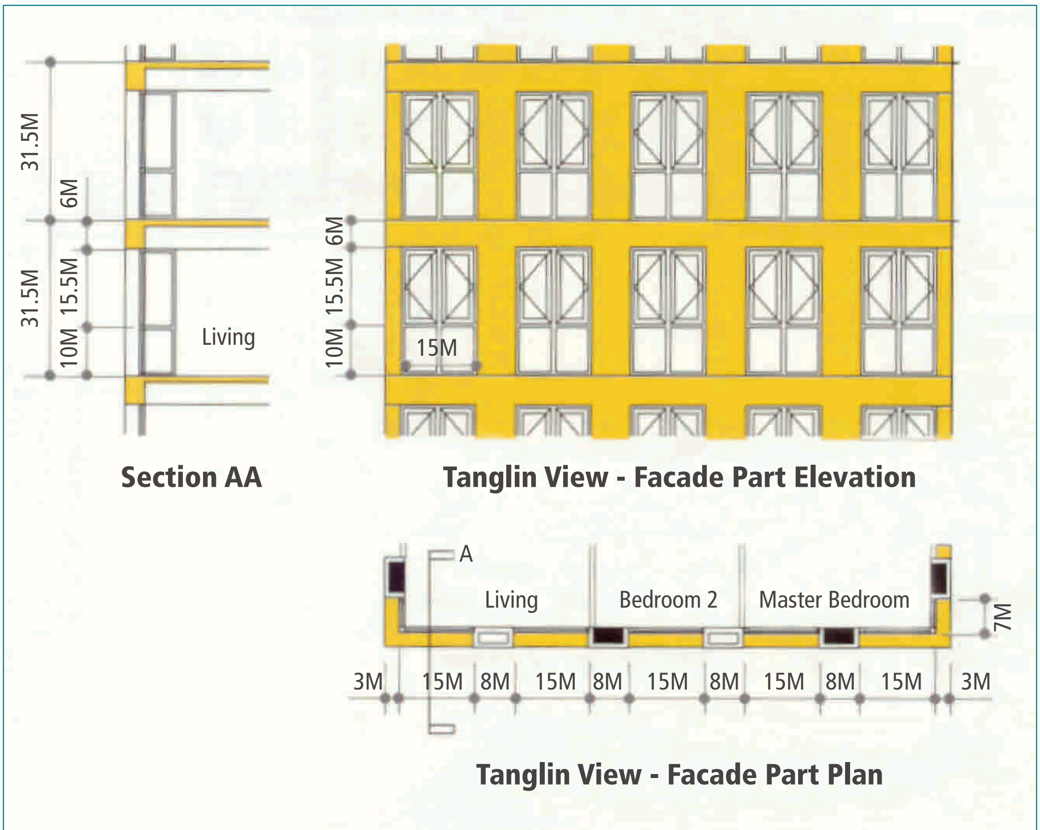



**Fig. 1.10 – Modular grid system used for building façade**

**DIMENSIONS AND OVERALL WALL PANEL SIZE :** It is important to consider the lift weight of the façade and wall panel in selecting the panel size. The heaviest wall panel will determine the crane capacity required for erection and hence the cost involved. As a guide, the panel weight should be limited to 4 to 6 tonnes and not more than 10 tonnes. For economy of precasting works, façades and wall panels should be divided into the largest possible units that can be transported and be lifted up on site. The usual panel sizes are "storey-height by bay width". In local context, the common sizes of panels are approximately 3m by 3m (~ 9 $m^2$). The maximum dimension of panel is about 3.6 m by 12m. For load-bearing facade and wall, the wall thickness ranges from 150 mm to 185mm depending on structural, performance and serviceability requirements. For non load-bearing façade, the wall thickness generally is about 100 or 125 mm.

**Fig. 1.11** – Hoisting of precast panels is essential for erection

## SHAPE AND SURFACE FINISHES :

Rectangular panels are the most efficient to design, construct and lift, but other shapes, slopes and in-planes curves can also be used for variation and aesthetic reasons. It is possible to adopt horizontal casting for in-plane curve with 6m radius and above without much added cost. However, for smaller radius curvatures, vertical casting may be required. Generally, it will be more expensive as the mould cost is higher for such casting.

**Fig. 1.12** – Vertical casting may be required for curved panels

In general, the shape of the precast panels can be differentiated as closed or open-shaped unit. Closed-shaped unit where the opening is within the panel is more rigid and easy to handle. However, the panel segment at the side of the opening should not be too narrow to avoid cracking during lifting operation. Open-shaped unit where part of its opening is not supported, is more filmsy and requires temporary stiffeners or strongbacks for safe handling and erection. Nevertheless, with due consideration for tolerances and interfacing details, open-shaped unit can be readily adopted for more variety. In any case, panel shape and configurations which may be unstable when erected for example too top heavy, or laterally unbalanced, should be avoided where possible.

**Fig. 1.13 – Different panel profile can be shaped using appropriate forms for casting**

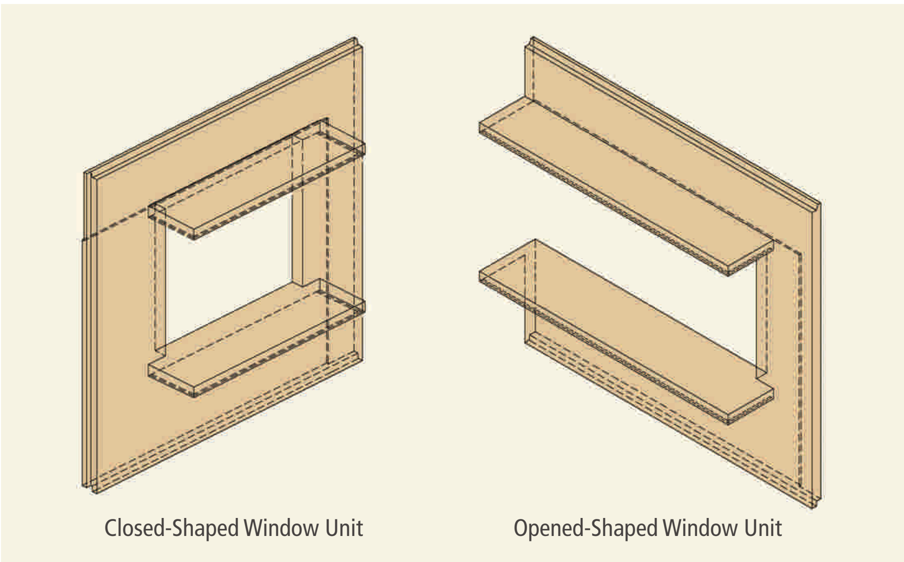



**Fig. 1.14 – Example of closed and opened-shaped units**

Edges and corners of the panels should be designed with reasonable radius or chamfer rather than sharp corners where high precision and alignment are difficult to achieve during site handling and erection.

The profile and configuration of the panels as well as the joint details express the architectural intent of the building. The horizontal or vertical joint lines can be emphasised with profiles or grooves in the panel for aesthetic reasons. For façades, panel divisions should be consistent with the groove lines provision where possible. Generally, horizontal groove on every floor level is provided. Vertical grooves on flat panels should be modularly spaced out.

As for surface finishes, there is a tendency to adopt simple, paint finish for high-rise residential buildings. One may also explore different surface textures for variation in design expression. Details could be found in the handbook 'Architecture in Precast Concrete' published by BCA.

**Fig. 1.15 – Horizontal and vertical grooves line together with joint details can be part of the architectural feature**

**TREATMENT FOR WINDOW OPENINGS :** Drips details should be provided at the top and the side of the window projections to discourage ingress of water. These details are to be incorporated during the casting of the window units. To avoid chip-off, the drip should not be located too close to the edge of the precast unit.

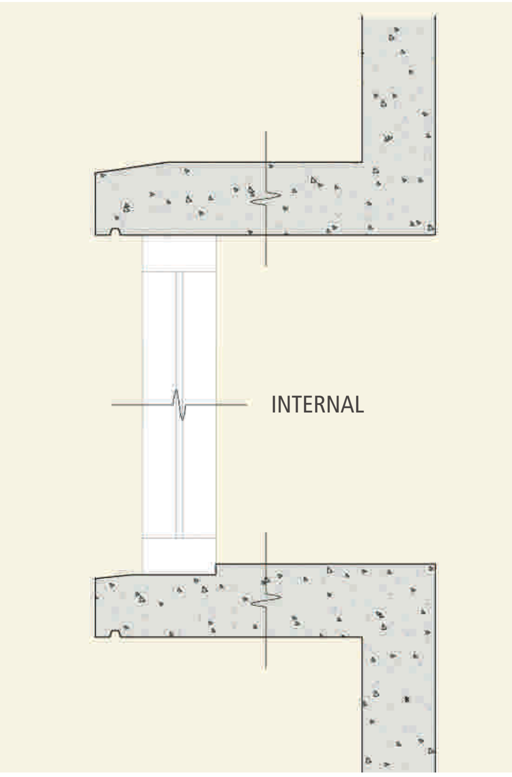



**Fig. 1.16 –** Section showing drip details

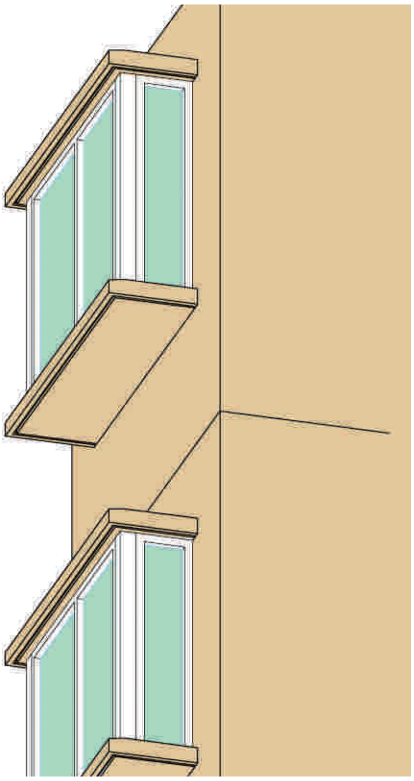


**Fig. 1.17 –** Drip grooves on bay window façade to control weathering

**CAST-IN WINDOW SYSTEM :** Windows are generally constructed using metallic framing system and are secured within the opening of façade walls. The gaps between the window frames and façade walls are susceptible to water ingress unless due attention is given to the interface details. One way to achieve water-tightness is by installing the outer window frames or even the finished windows during the prefabrication for façade wall panels. Using this system, the window frames can be well integrated with the façade wall panels and hence eliminates the need for site grouting and sealant application. The quality of waterproofing as a whole should improve with better control over workmanship in the precast yard.

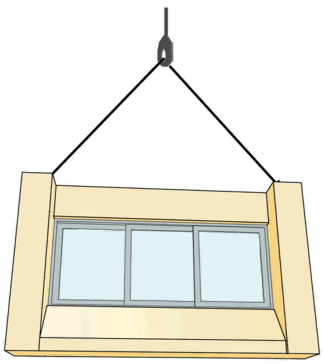


**Fig. 1.18 –** Cast in-window façade wall panel

Fig. 1.19 – Building can be enclosed immediately upon installation of cast-in window façade panels

Besides, the use of cast-in window façade panels will also enable the building to be enclosed immediately upon installation, allowing internal works to proceed earlier. However, proper protection of the windows during the subsequent construction activities will have to be considered. More details on cast-in window can be obtained from Good Industry Practices – Aluminium Window published by BCA.

**TOLERANCES :** Tolerance considerations for panels, installation and interfacing are required so that the panels can be fit together on site without having to be modified. Tolerances should be specified only for those dimensional characteristics that are important to the correct assembly, performance and appearances of the building. If the tolerances are exceeded, the panel may be accepted if any one of the following criteria is met:

**Criteria 1:** Exceeding the tolerances does not affect the structural integrity or architectural performance of the panel.

**Criteria 2:** The panel can be put together within tolerance by structurally or architecturally acceptable means.

**Criteria 3:** The whole erected assembly can be modified economically to meet all structural and architectural requirements.

**Fig. 1.20 – Tolerances/ gaps between the precast column/ beam and the window unit are required**

Besides checking on the manufacturing and erection tolerances, it is important to take account of the interfacing tolerances. Interfacing tolerances are those required for joining of different materials in contact with or in close proximity to panel, and for accommodating the relative movement expected between such materials during the life of the building. Typical examples are window openings, joints, flashing, interior finishes, M&E services openings and recesses.

**JOINTS AND WATERPROOFING DETAILS :** In local context, except for spandrel panels, precast façade units are usually designed as one-storey high and connected at every floor level. Joint details are mainly required horizontally between the floor and the wall panels and vertically between the wall panels. As the precast façades form the external envelope of the building, the waterproofing details of these joints must be adequately provided to pre-empt water ingress.

Examples of horizontal joints adopted locally are as shown in Fig 1.21 & 1.22. The upturn feature incorporated is intended to prevent water seepage. The physical barrier of the sealant and backer rod forms another line of defence. There are also added features such as the application of waterproofing system and joint filler like non-shrink grout to attain a better performance.

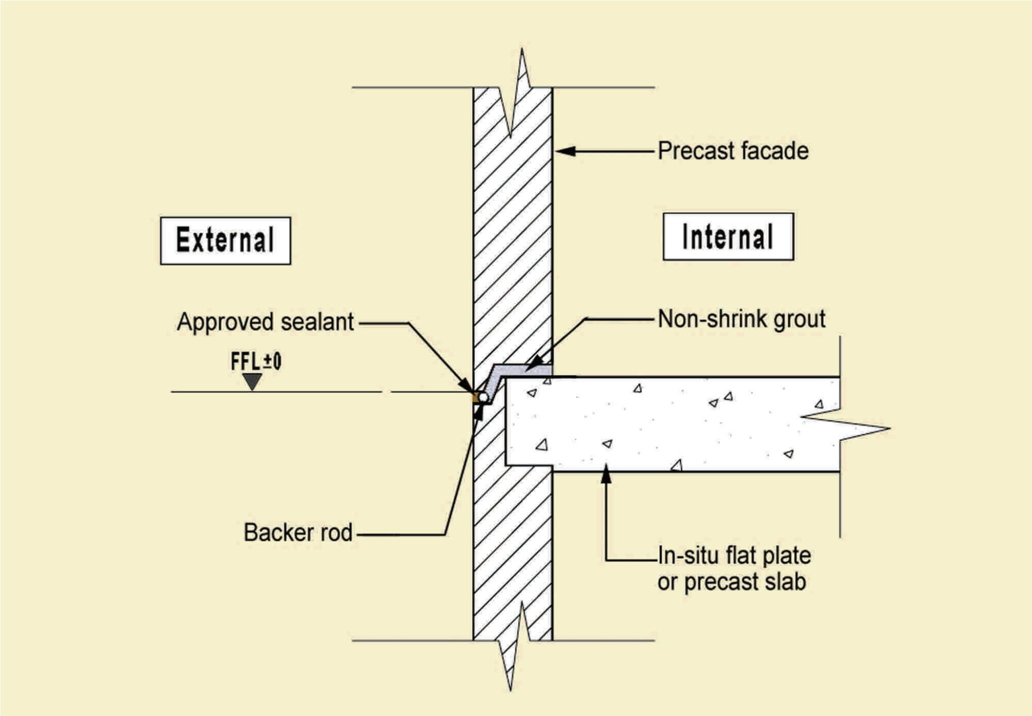



**Fig. 1.21 –** Horizontal joints between precast façade and floor elements

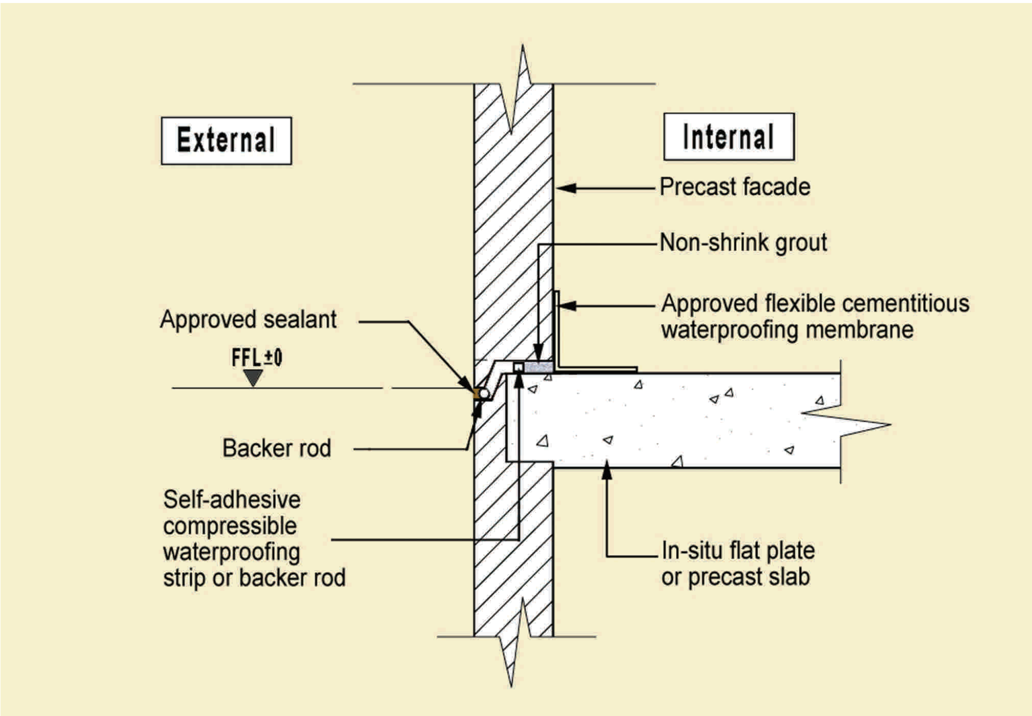



**Fig. 1.22 –** Horizontal joints between non-load bearing precast façade and floor elements

As for the vertical joints, they are mainly designed to be cast in-situ with similar sealant and backer rod details for water-tightness. Reinforcement bars are used and lapped at the internal face of the wall to be cast on site as illustrated in Fig. 1.23. The precast panel face in contact with cast in situ joint is roughened for better bonding.

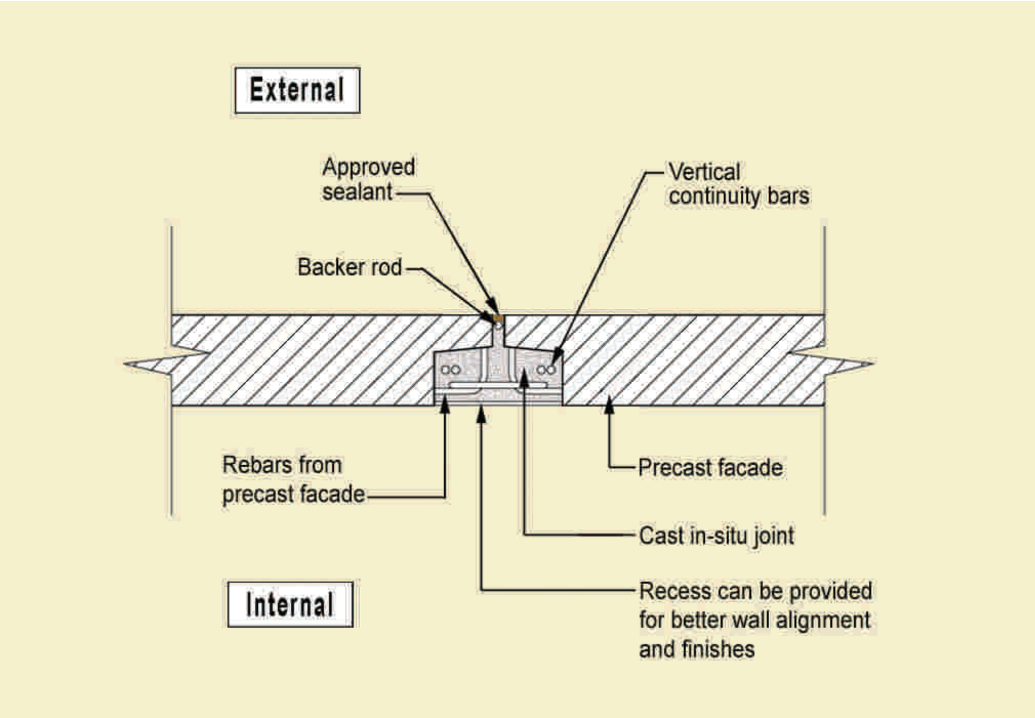



**Fig. 1.23 – Vertical joints between precast façade panels**

**Fig. 1.24 – Casting of in-situ vertical joints**

## 1.5 OTHER PRECAST CONCRETE COMPONENTS

Besides the typical precast floor and wall systems, there are other precast concrete components that can be used in combination for better and more economical design and construction.

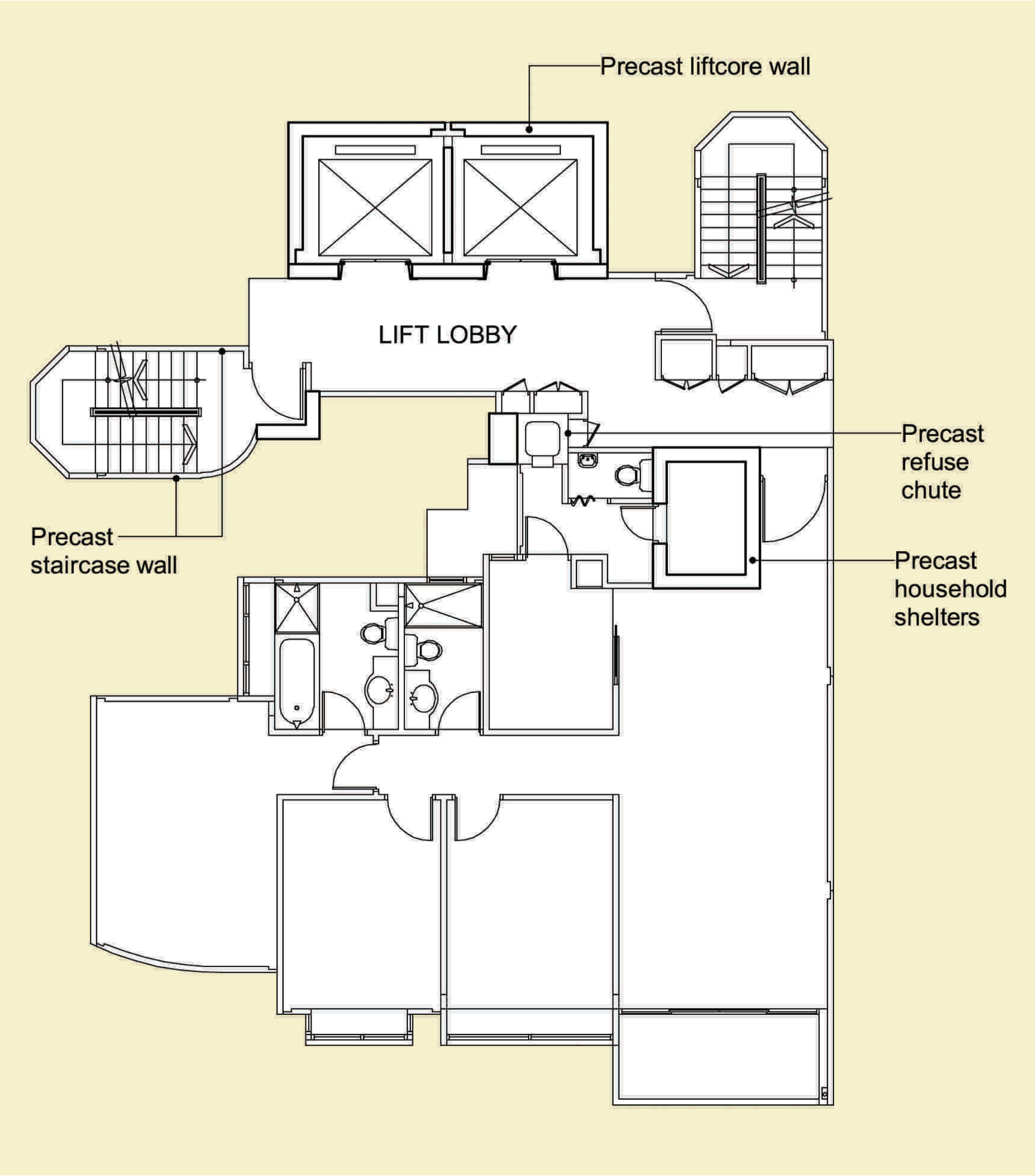



**Fig. 1.25 – Other precast concrete components which can be used in combination**

**PRECAST LIFT LOBBY WALL :**
The choice for precasting the lift lobby wall is generally related to the consistent quality finish that could be attained. Very often, the portion of wall above the lift door opening is strengthened with additional reinforcement so as to maintain the same wall thickness. Precasting this wall panel with mould laid horizontally overcomes the difficulty in vertical casting around openings; it improves the construction process as quality finish panel around the door opening and other smaller openings can be assured through horizontal casting.

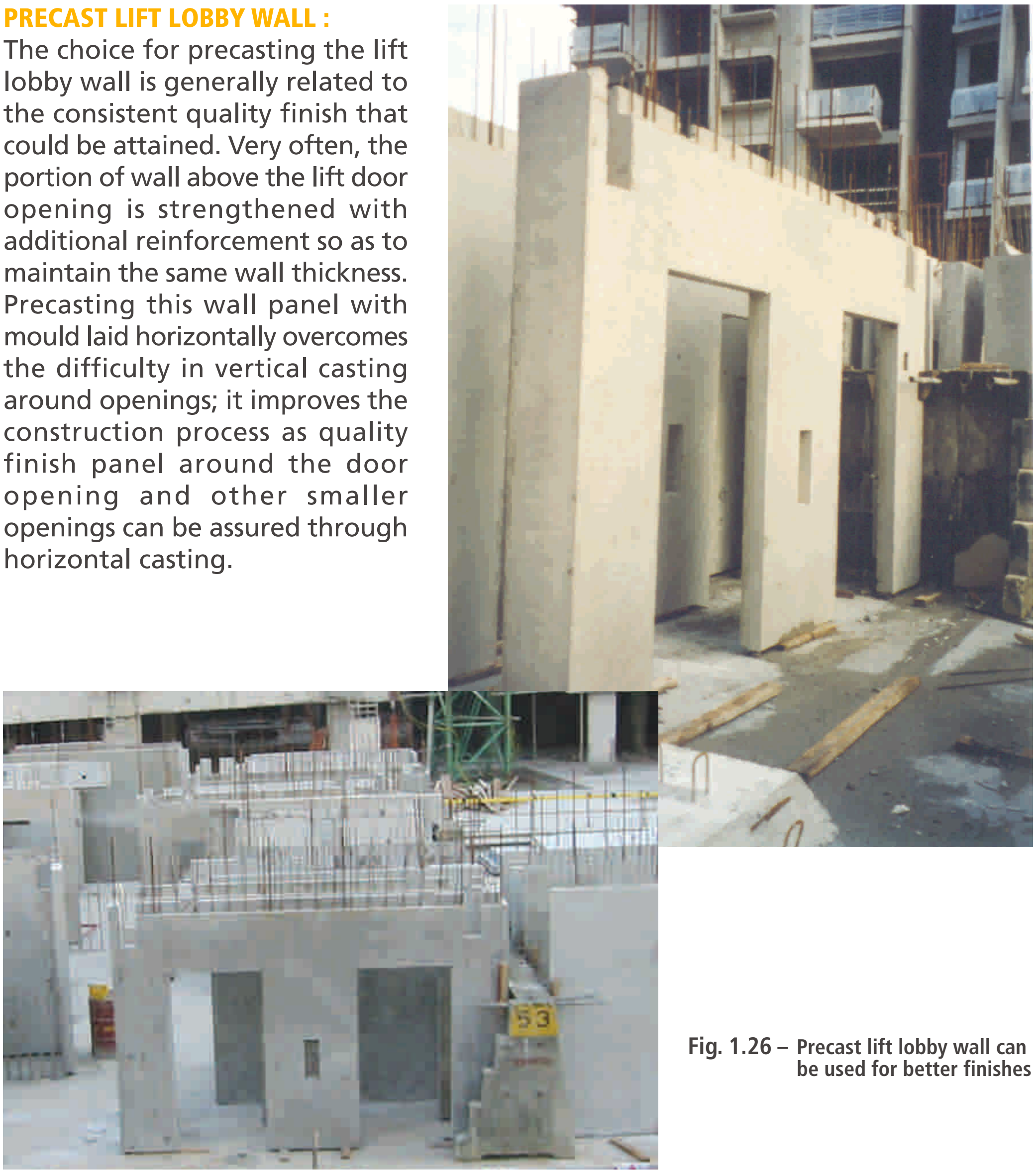
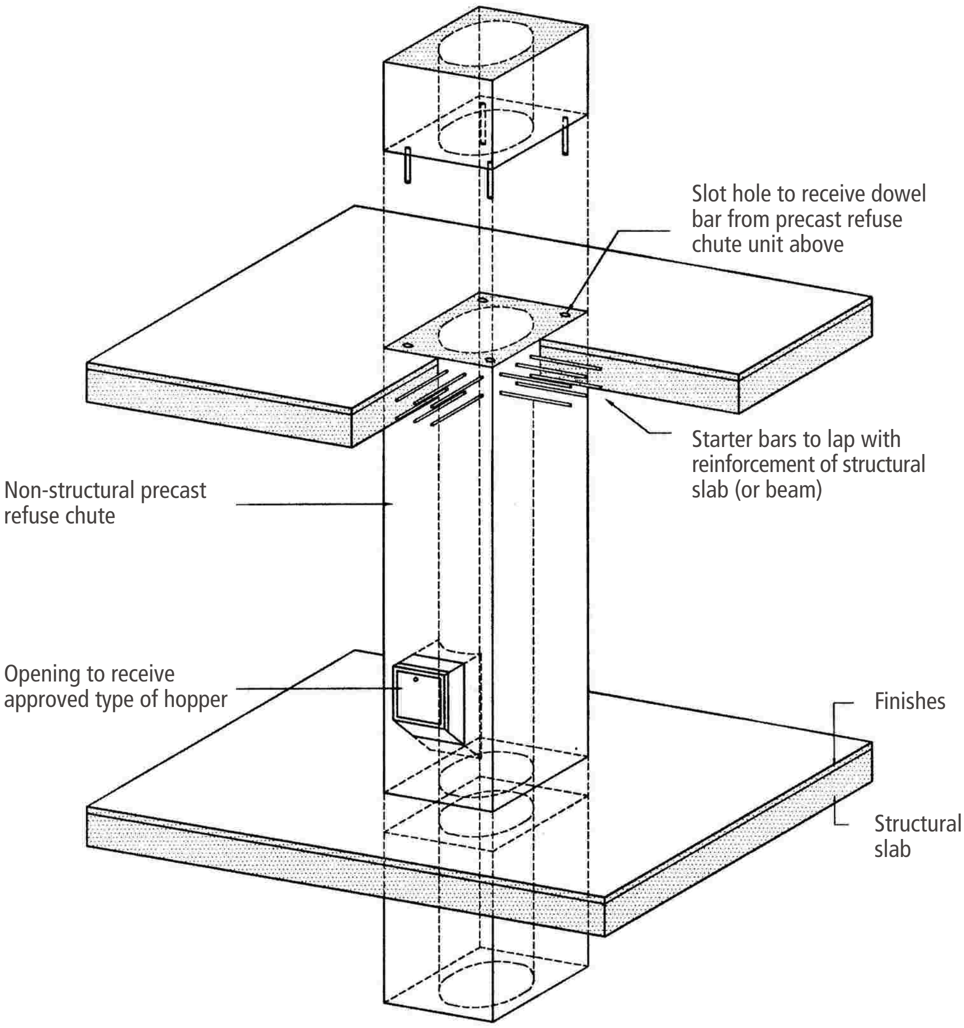



Fig. 1.26 – Precast lift lobby wall can be used for better finishes

**PRECAST LIFT CORE OR STAIRCASE CORE WALL :** These walls are commonly used to provide stability to the building and are mostly cast in-situ. However, there is an increasing trend to precast these wall elements owing to the advantages of having shorter construction time and better wall finishes. The cores or the shear walls can be subdivided into repetitive elements taking into account the limits of transportation and cranage capacity. As these walls must be sufficiently rigid to keep the horizontal displacement at the top of the building within acceptable limits, it is important to install vertical reinforcement in the precast units and inter-connect the units by means of vertical ties.

**PRECAST REFUSE CHUTE :** Refuse chute is usually designed as non load-bearing structure supported by perimeter beams and slabs above. Effective anchorage between the precast refuse chute and supporting structural members can be achieved using starter bars. The stability of the precast refuse chute can be further enhanced through tie bars anchored into structural wall or column.




**Note:**
(1) Provide temporary prop and bracing to ensure stability during construction
(2) Finishes to be laid after applying sealant & waterproofing membrane surrounding precast refuse chute

**Fig. 1.27 – Example of precast refuse chute**

**PRECAST HOUSEHOLD SHELTER (HS) :** Cast in-situ construction of household shelters can be quite laborious and time consuming owing to the close spacing of the reinforcement required. Immense effort has to be put in to co-ordinate the sequence of tying reinforcement and integrating the CD devices during construction to achieve a high quality of workmanship. Coupled with the fact that the construction of the household shelters is often at the critical path, it becomes viable to consider using precast household shelters. This will facilitate the site progress of concurrent works, which in turn, lead to shorter construction cycle time.

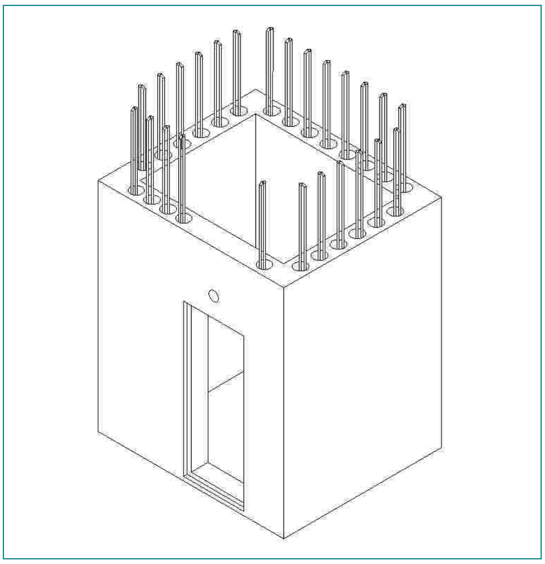


**Fig. 1.28 – A fully precast household shelter unit (Patented)**

A fully precast household shelter has been developed to make its construction easier and more productive. It is in the form of three-dimensional volumetric unit. The walls of the precast HS unit are with vertical voids as shown in Fig. 1.28 so that the unit will be lighter and easier to handle during transportation, hoisting and installation. These voids are then cast with concrete mix after inserting vertical continuity bars. Services such as electrical sockets, TV/radio could also be pre-installed in the precast HS units The fully precast household shelter unit is approximately 9.5 ton (for average internal size of $2.8m^2$).

The use of two L-shaped wall panels was subsequently developed as shown in Fig 1.30 to cater for projects where lower capacity cranes are deployed. In-situ concrete in-fill will then be required to join two sub-HS units together.

**Fig. 1.29 – Precast 'L-shaped' wall panels for shelter construction**

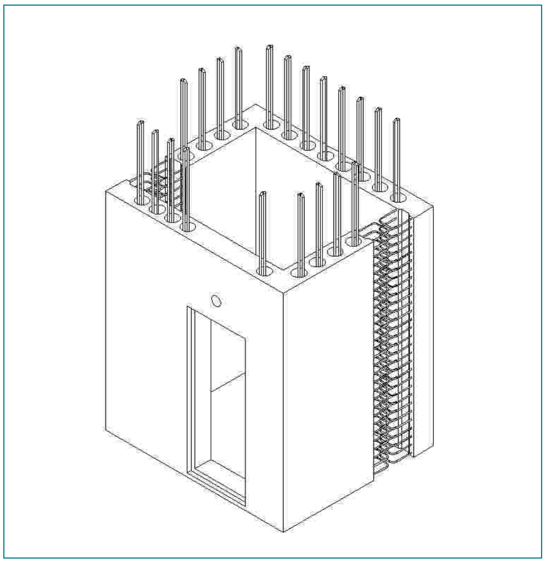


**Fig. 1.30 – Precast household shelter in 2 separate 'L-shaped' panels (Patented)**

**Fig. 1.31 – Installation of precast household shelter in 2 'L-shaped' panels**

The recommended dimensions which will satisfy the minimum size requirements stipulated in household shelter technical requirements are as shown in Table 1.2.

### Table 1.2 – Recommended Precast Household Shelter

| GFA Range | Minimum Internal Floor Area of Household Shelter ($m^2$) | [1]For Storey Height > 2800mm but £ 4000mm<br>[2]Thickness of wall 250mm, 275mm or 300mm | |
|---|---|---|---|
| | | [3]Square ($m^2$) | [3]Rectangle ($m^2$) |
| GFA £ 45 $m^2$ | 1.6 | 1.3 x 1.3 ( = 1.69 ) | NA |
| 45 < GFA £ 75 $m^2$ | 2.2 | 1.5 x 1.5 ( = 2.25 ) | 1.8 x 1.25 ( = 2.25 ) |
| 75 < GFA £ 140 $m^2$ | 2.8 | 1.7 x 1.7 ( = 2.89 ) | 2.0 x 1.4 ( = 2.8 ) |
| GFA > 140 $m^2$ | 3.4 | 1.85 x 1.85 ( = 3.42 ) | 2.0 x 1.7 ( = 3.4 ) or<br>2.3 x 1.5 ( = 3.45 ) |

[1] Minimum slab thickness 175mm, height of precast household shelter to vary
[2] Thickness of wall is standardised to 250mm, 275mm or 300mm depending on setback and HS clear height
[3] Internal dimensions

**PRECAST STAIRCASE STOREY SHELTER (STAIRCASE SS) :** The same concept of prefabricating the household shelter can be readily adopted for the construction of the staircase storey shelter. However, as the staircase SS is much bigger than household shelter, there is a need to have more precast components integrated to form the staircase SS.

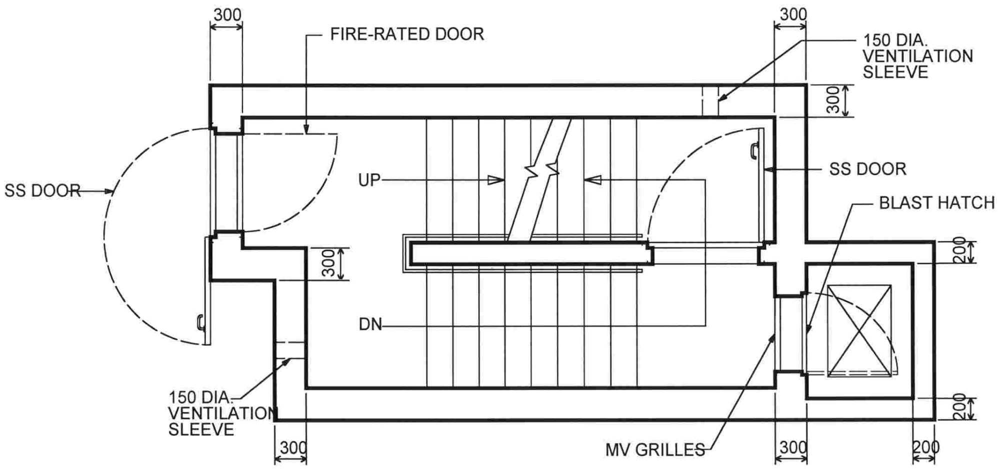



**Fig. 1.32 – Typical layout plan of a staircase storey shelter**

In coming up with the preliminary design, it is important to consider the sequence, manner of assembly and overall dimensions and weights of components. Installation of precast staircase SS should preferably be planned and carried out in one continuous process in tandem with other construction activities.

One may consider the use of precast staircase and wall panels in combination with cast in-situ joints to form the unit. Alternatively, a combination of three-dimensioned precast units may also be custom-made to minimise the number of joints. Essentially, the precast components are to be sub-divided into manageable repetitive elements, which can be easily transported and installed on site. For higher productivity, other salient features of the staircase SS such as the shelter door frame, ventilation sleeves MV duct openings for blast hatch and fixtures such as TV/radio points can be incorporated during the casting of precast components.

As the staircase storey shelter is to withstand blast loading, the walls must be sufficiently rigid and connected by means of vertical reinforcements and ties. Unlike the conventional precast staircase, which can be simply supported by landings or beams, the precast staircase in this instance would need to be fully supported and connected with the wall panels to achieve structural continuity. The joints between precast components should be robust and airtight to satisfy the staircase SS requirement.

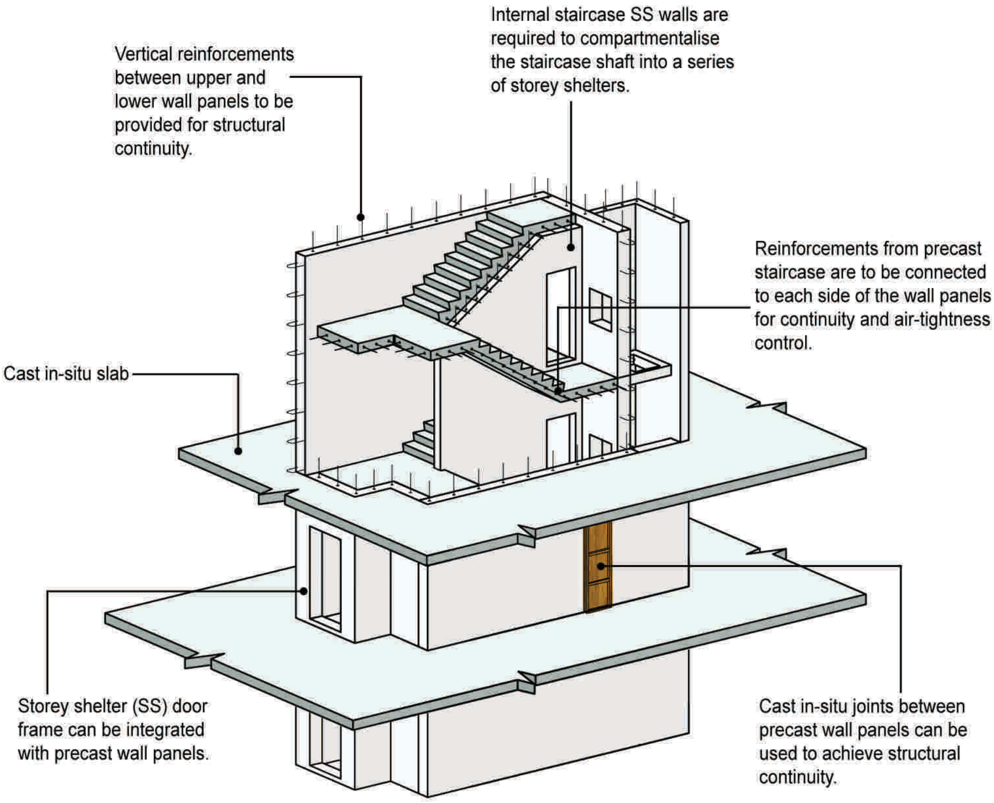



**Fig. 1.33 – Key considerations in the design of precast staircase storey shelter**

***NOTE :*** *The above figure is meant for illustration purpose only. To enhance the buildability and quality of staircase storey shelters, BCA has been working actively with precasters in developing buildable solutions for industry use. The precast design scheme by M/S Excel Precast Pte Ltd has recently been accepted by BCA. Currently, BCA is working with M/S Hong Leong Asia Pte Ltd and M/S Precast Technology Pte Ltd in coming with more alternative buildable solutions for the construction of staircase storey shelters. Please refer to precasters for more details on their design schemes.*

# 2 Joints & Connections
## Between Building Components

# Joints & Connections

## Between Building Components

As the overall stability of a precast or semi-precast structure depends largely on its connections, it is important to consider the effectiveness of these connections in transferring the forces between individual building elements and to the stabilising cores and foundation. Special provisions of structural ties should be provided and detailed for structural integrity.

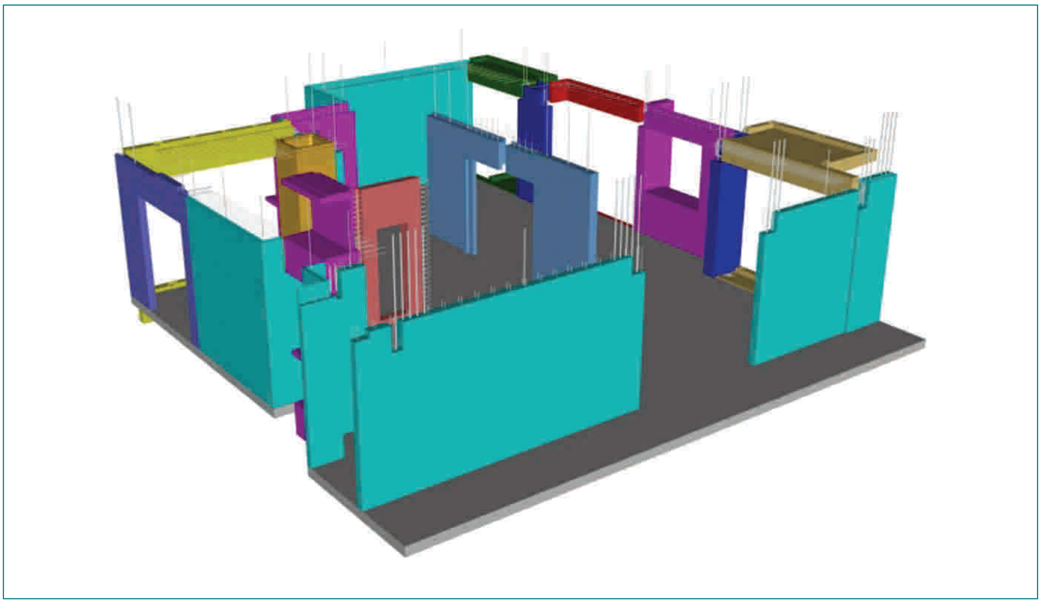


**Fig. 2.1 – An assemblage of precast elements that need to be connected at joints to form building framework**

The detailing of connections should satisfy the requirements with respect to the manufacture, transport and erection of the precast units. It should be designed for simple assembly and details compatible with the overall requirements for the building so as to achieve a shorter construction time.

Locally, cast in-situ joints including grouted pipe sleeves are more commonly used in private residential projects. In general, connection details for floor slab with precast façade/ wall system are relatively simple as compared with precast frame and skeleton system. Essentially, one need to consider the connections between the floor slab, façade and wall element, between the individual floor elements and wall elements.

This section will highlight some of the common features in such connections used in private residential projects as a guide. They should not be considered as "standard", as proper connections and details fulfilling all relevant performance requirements would need to be designed based on project specific basis.

## 2.1 CONNECTIONS AT VERTICAL JOINTS BETWEEN PRECAST FAÇADES/ WALL PANELS

The connections at the vertical joints between precast façades/ wall panels are often achieved by means of cast in-situ joints. The connecting links can be provided by using means of distributed loops anchored directly within the panels. For load bearing façade or wall elements, the vertical continuity bars should be provided and designed so as to transmit shear forces for overall stability.

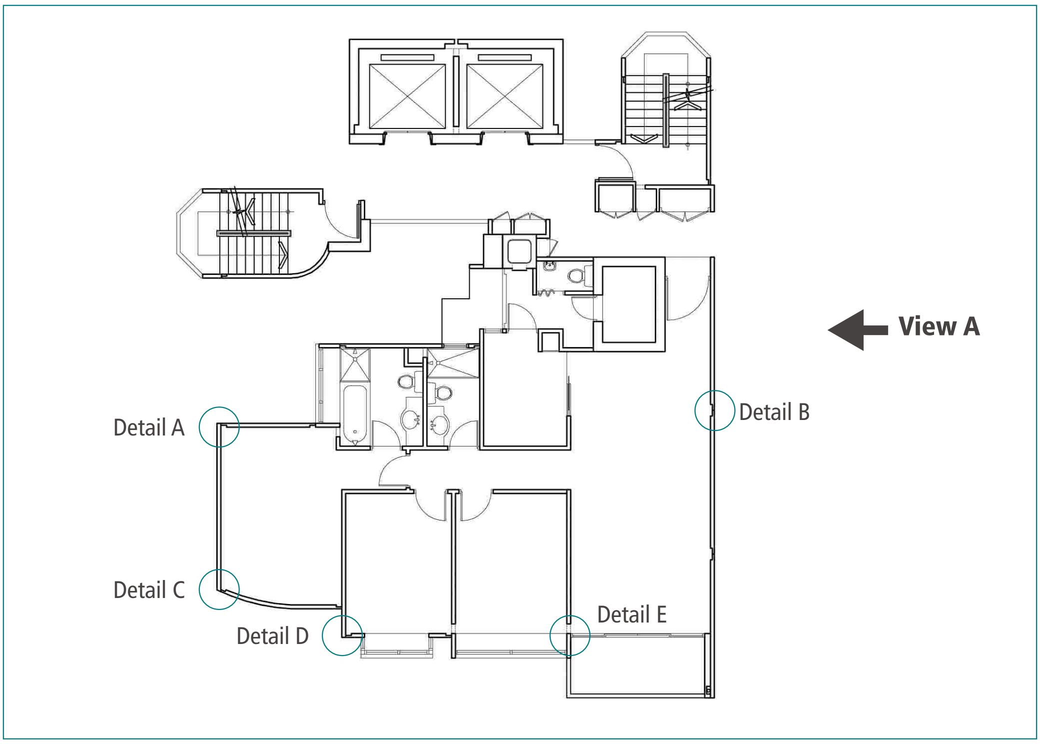



**Fig. 2.2 – Example of a typical unit using precast façades/ wall panels**

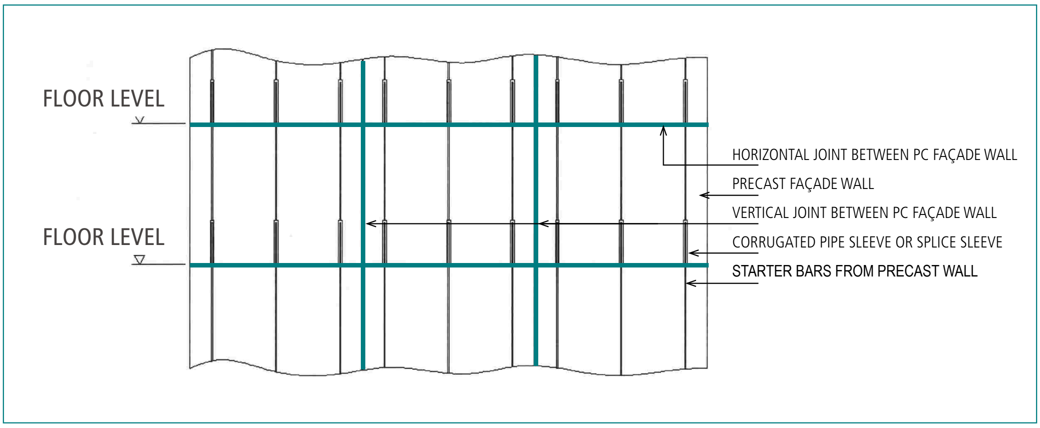
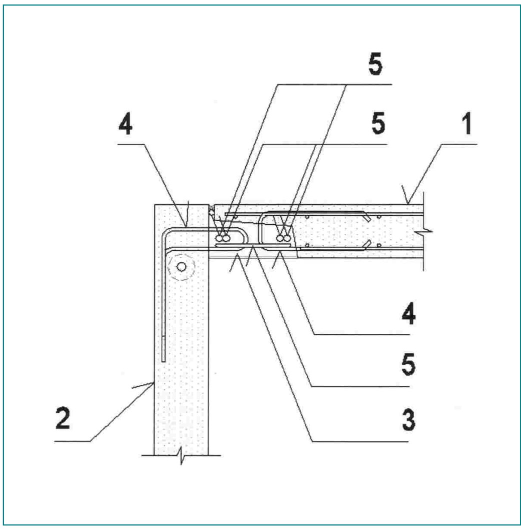



**Fig. 2.3 – View A showing horizontal and vertical wall joints and splicing layout**

## 2.1.1 Connection Details between Load-Bearing Façades



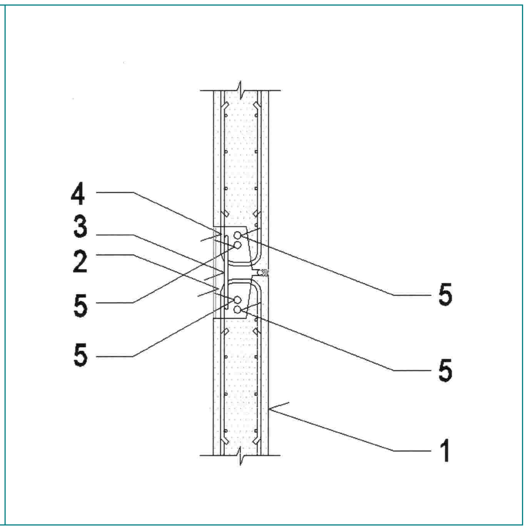




**Fig. 2.4 – Detail A**

1. PC wall
2. PC façade wall
3. In-situ concrete joint
4. Rebars from PC wall
5. Vertical continuity bars

**Fig. 2.5 – Detail B**

1. PC wall
2. In-situ concrete joint
3. Rebar placed on site
4. Rebars from PC wall
5. Vertical continuity bars

## 2.1.2 Connection Details between Window Unit with Supporting Wall

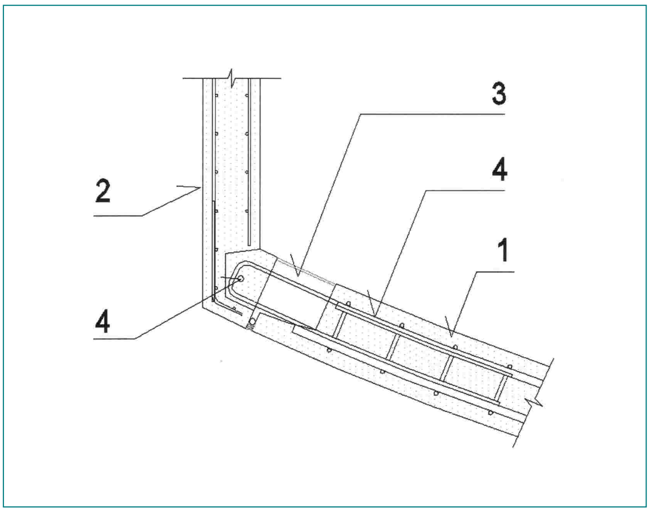



**Fig. 2.6 – Detail C**

1. PC window wall with beam
2. PC wall
3. In-situ concrete joint
4. Rebars from PC wall

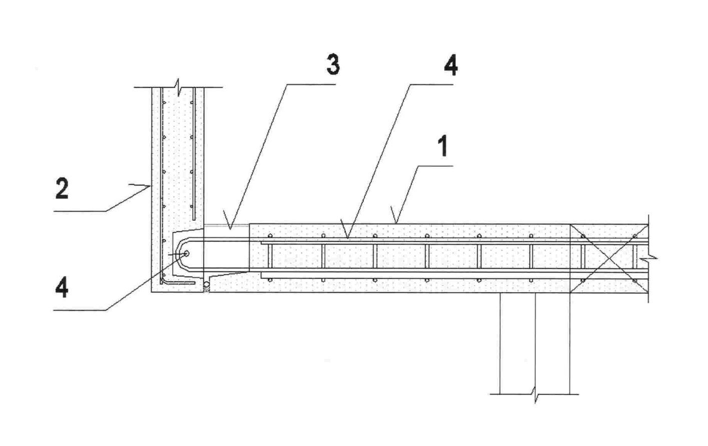



Fig. 2.7 – Detail D

1. PC beam for bay window
2. PC wall
3. In-situ concrete joint
4. Rebars from PC wall

## 2.1.3 Connection Details between Internal Load-Bearing Wall Elements

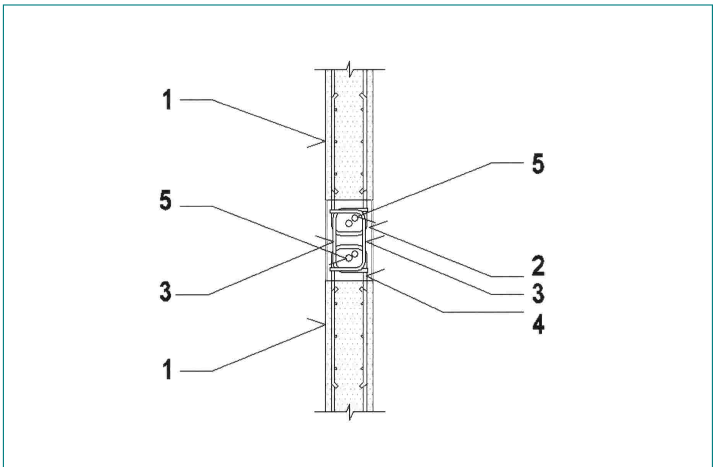



Fig. 2.8 – Detail E

1. PC wall
2. In-situ concrete joint
3. Rebars placed on site
4. Rebars from PC wall
5. Vertical continuity bars

## 2.2 CONNECTIONS BETWEEN PRECAST FAÇADES/ WALL PANELS AND FLOOR SLAB

The connections at the horizontal joints between precast façades/ wall panels are often connected by means of dowel connection, particularly for load bearing wall. Core holes within the wall panel are formed using proprietary splice sleeve or corrugated pipe sleeves. These holes together with the vertical continuity bars are filled with grout after wall installation. As for the connection between the precast façade/ wall with floor slab, the use of starter bars for bridging and continuity is commonly adopted as illustrated in the following figures.

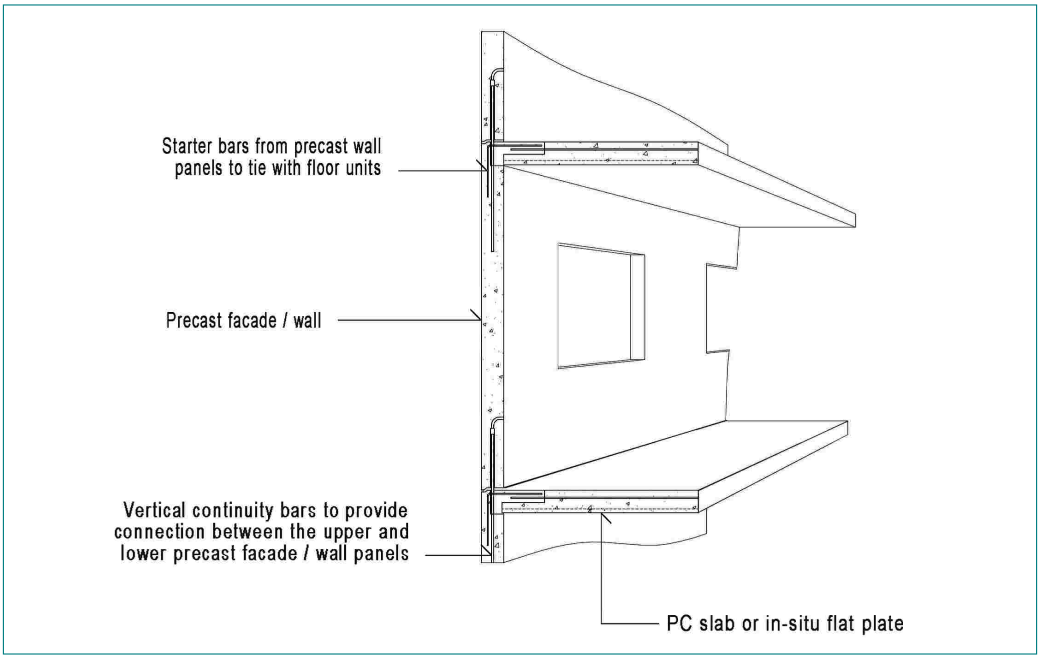



**Fig. 2.9 – Design principle for connection between precast façade wall with floor slab**

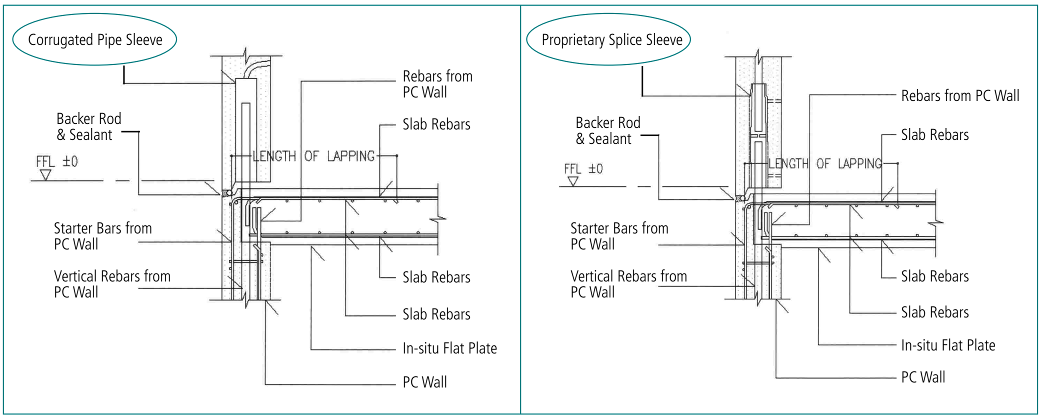



**Fig. 2.10 – Different splicing details for connection between the upper and lower precast wall units**

### 2.2.1 Wall to Floor Connections at Edge or Central Core

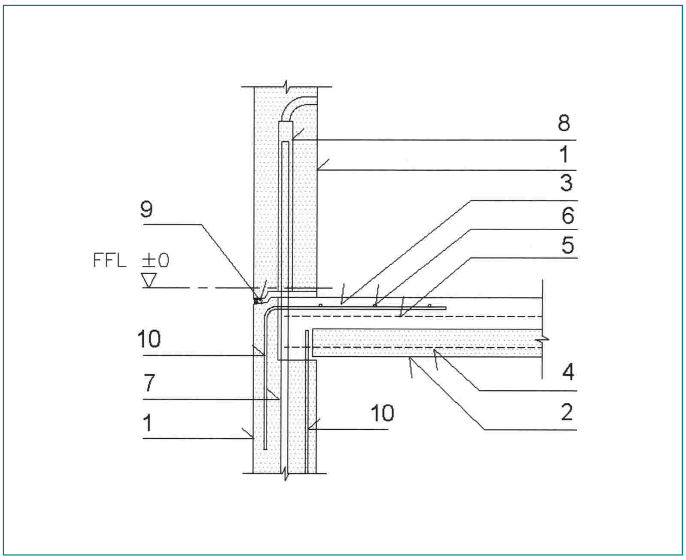



Fig. 2.11 – Connection between precast wall with precast half slab

1. PC wall
2. PC half slab
3. In-situ concrete topping
4. Rebars from PC slab
5. Slab rebars to be placed on site
6. Rebars from PC wall
7. Vertical continuity bars
8. Corrugated Pipe Sleeve
9. Backer rod & sealant
10. Starter bars from PC wall

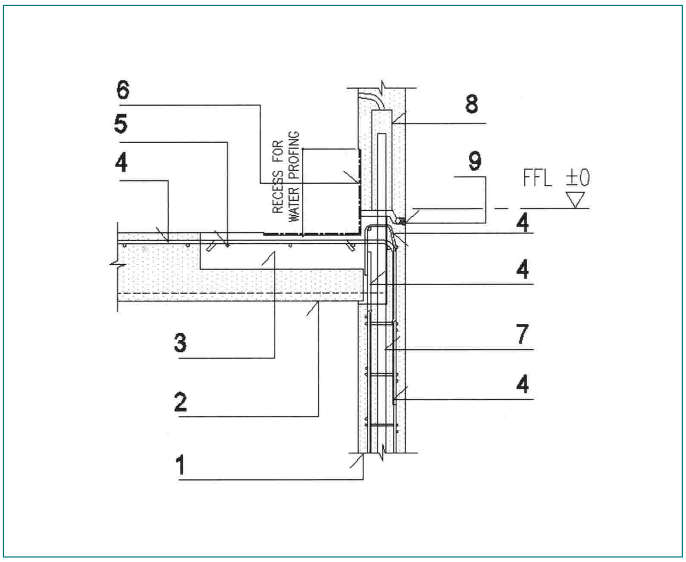



Fig. 2.12 – Connection between precast wall and precast full slab with waterproofing details

1. PC wall
2. PC full slab
3. In-situ concrete joint
4. Rebars from PC wall
5. Rebars to be placed on site
6. Waterproofing system
7. Vertical continuity bars
8. Corrugated pipe sleeve
9. Backer rod and sealant

## 2.2.2 Intermediate Load-Bearing Walls to Floor Connections

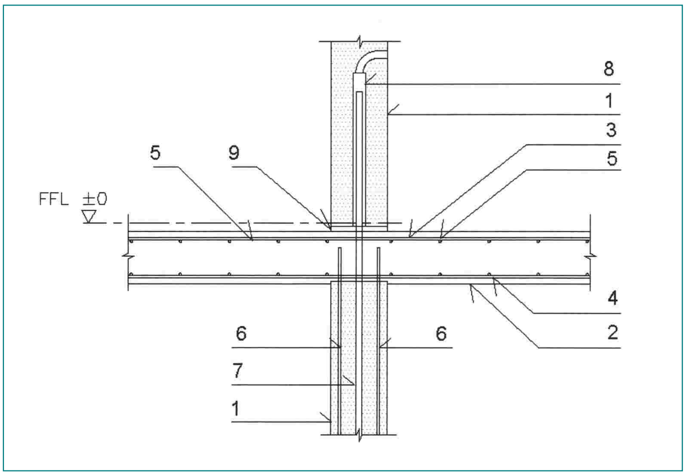



**Fig. 2.13 – Internal PC wall to flat plate**

1. PC wall
2. In-situ flat plate
3. Rebars to be placed on site
4. Rebars from In-situ flat plate
5. Rebars from In-situ flat plate
6. Rebars from PC wall
7. Vertical continuity bars from PC wall
8. Corrugated pipe sleeve
9. Grouting joint

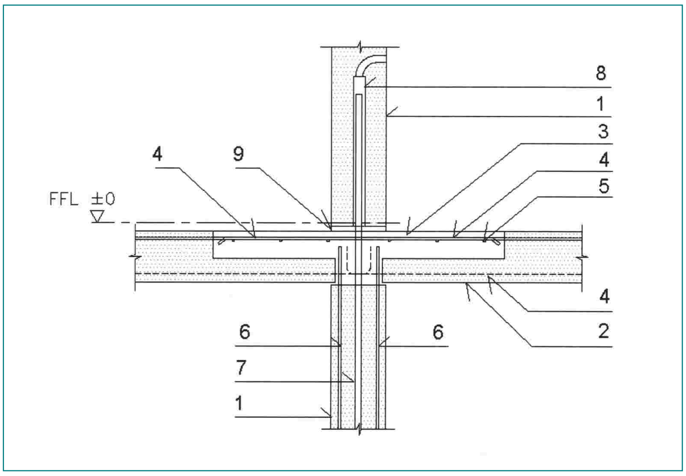



**Fig. 2.14 – Internal PC wall to PC full slab**

1. PC wall
2. PC full slab
3. In-situ concrete joint
4. Rebars from PC slab
5. Rebars to be placed on site
6. Rebars from PC wall
7. Vertical continuity bars from PC wall
8. Corrugated pipe sleeve
9. Grouting joint

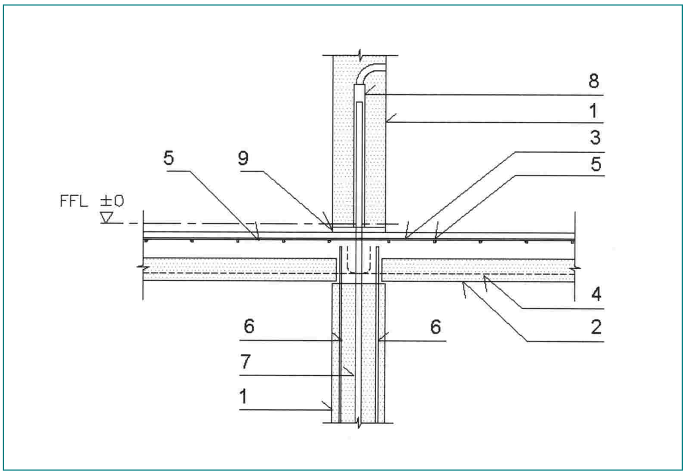
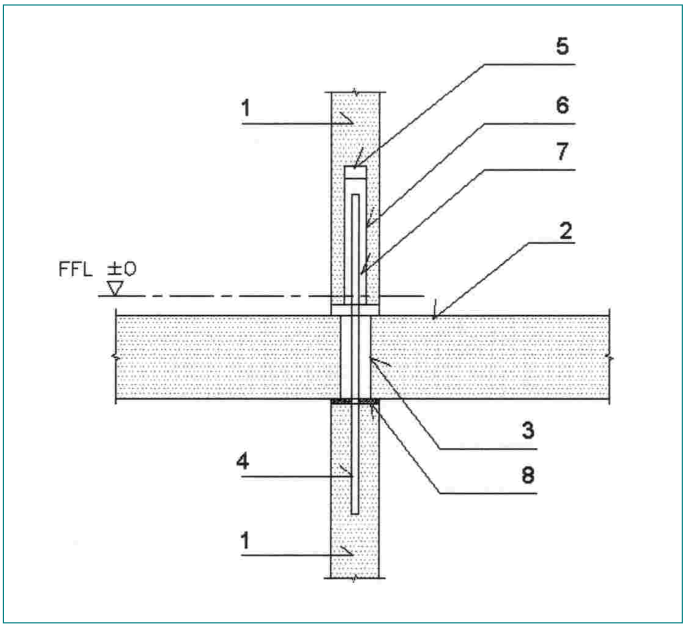



**Fig. 2.15 – Internal PC wall to PC half slab**

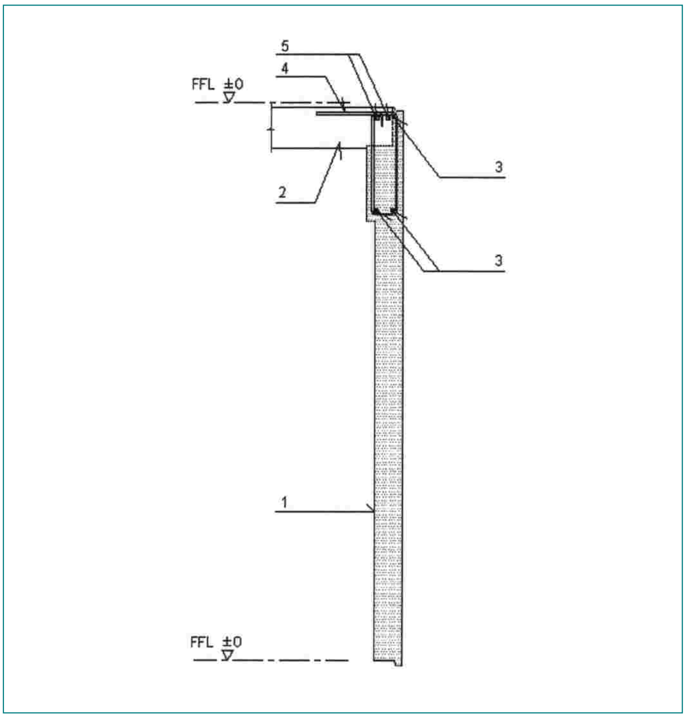
1. PC wall
2. PC half slab
3. In-situ concrete topping
4. Rebars from PC slab
5. Rebars to be placed on site
6. Rebars from PC wall
7. Vertical continuity bars from PC wall
8. Corrugated pipe sleeve
9. Grouting joint

### 2.2.3 Non Load-Bearing Wall to Floor Connections




1. PC partition wall
2. PC full slab
3. Corrugated pipe sleeve
4. Dowel bars from PC partition wall
5. Polyfoam
6. PVC pipe
7. Non-shrink grout
8. Compressive foam

**Fig. 2.16 – Internal partition PC wall to PC full slab**



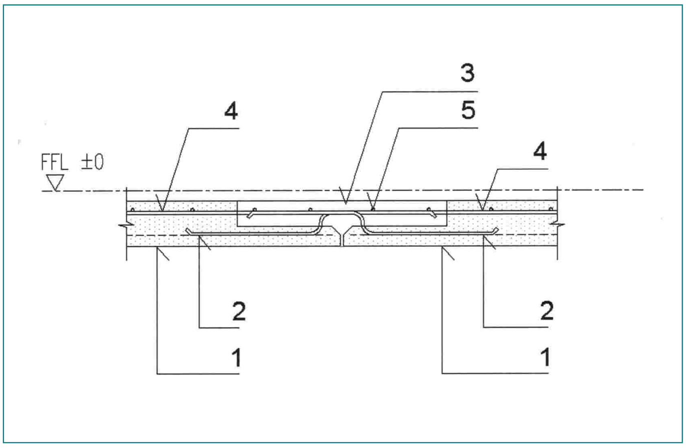

1. PC wall
2. In situ flat plate
3. Rebars from PC wall
4. Starter bars from PC wall
5. Rebars to be placed on site

**Fig. 2.17 – Downhang wall details**

## 2.3 CONNECTIONS BETWEEN PRECAST FLOOR ELEMENTS AND SUPPORTING STRUCTURES

The floors are required to resist horizontal forces in addition to vertical loads. To prevent movement between slabs, individual precast elements must be connected to form an integrated floor. This can be achieved using cast in-situ reinforced structural topping as in the case of composite precast half slab with topping system. For precast full slab, the use of grouted and concreted joints in combination with connecting tie bars will serve to achieve structural integrity and diaphragm action. The floor panels, in turn are supported by either beams, cast in-situ pour strips or bearing walls.

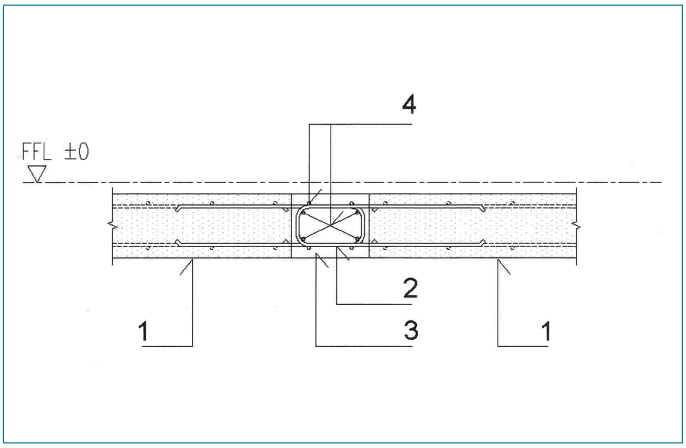
### 2.3.1 Connections between Precast Slab Panels and with Other Supporting Structures




1. PC full Slab
2. Bottom rebars from PC slab
3. In-situ joint
4. Top rebars from PC slab
5. Rebars placed on site

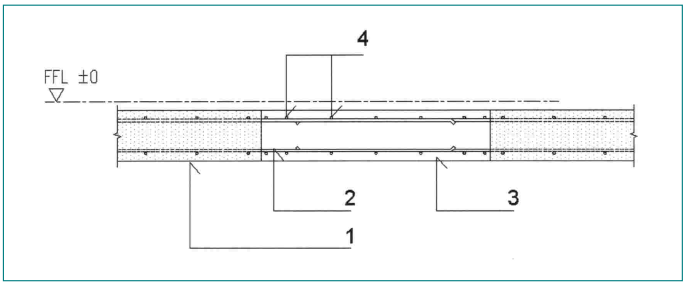
*NOTE : Recess at joint can be incorporated for better panel alignment and finishes. Appropriate fibre mesh can be placed to pre-empt cracks before proceeding to skim coat*

**Fig. 2.18 – Connection between precast full slab panels**



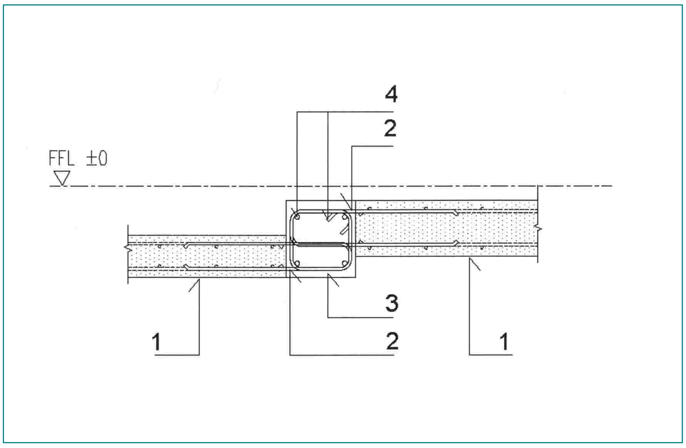

1. PC full slab
2 Rebars from PC slab
3. In-situ pour strip
4. Rebars placed on site

**Fig. 2.19 – Connection between precast full slab panels using cast in-situ pour strip**




1. PC full slab
2. Rebars from PC slab
3. In-situ pour strip
4. Rebars placed on site

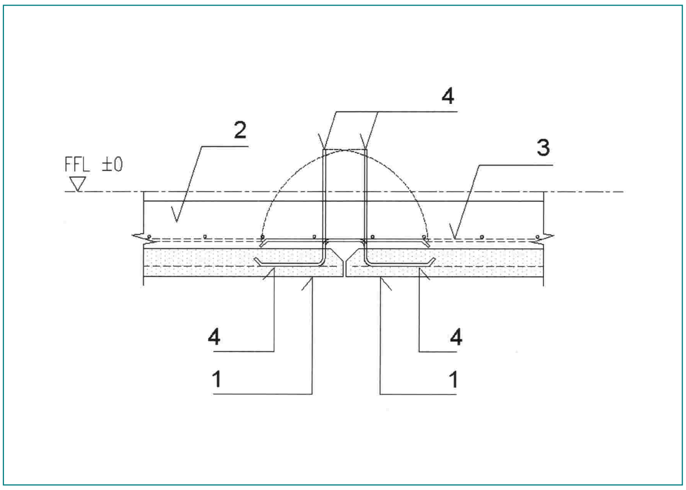
**Fig. 2.20 –** **Use of stiffened cast in-situ pour strip to connect precast full slabs**




1. PC full slab
2. Rebars from PC slab
3. In-situ pour strip
4. Rebars placed on site

*Note: Dimensions of pour strip depends on design requirements*

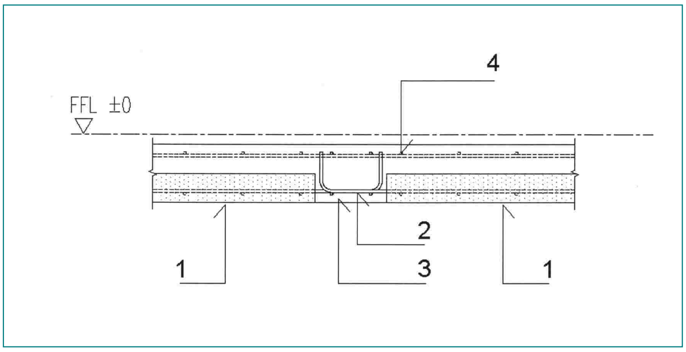
**Fig. 2.21 –** **Use of cast in-situ pour strip to cater for floor level difference**




1. PC half slab
2. In-situ structural topping
3. Rebars placed on site
4. Rebars from PC slab

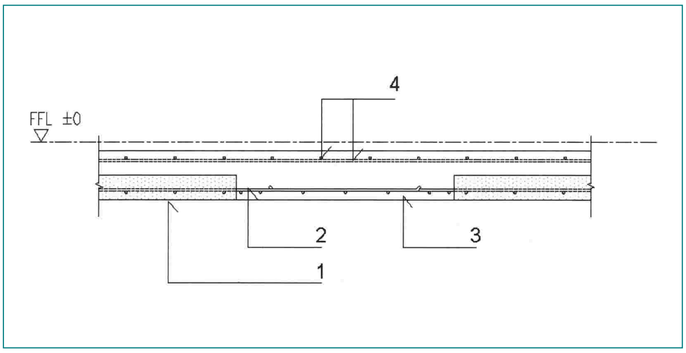
*See note in Fig 2.18*

**Fig. 2.22 –** **Connection between precast half slab in the secondary direction**



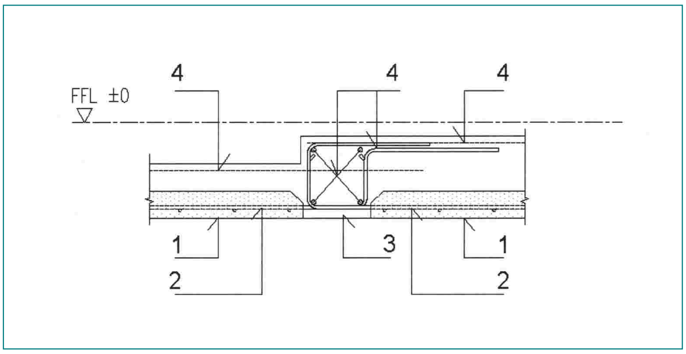

1. PC half slab
2. Rebars from PC slab
3. In-situ pour strip
4. Rebars to be placed on site

**Fig. 2.23 – Connection between PC half slab in the secondary direction using cast in-situ pour strip**



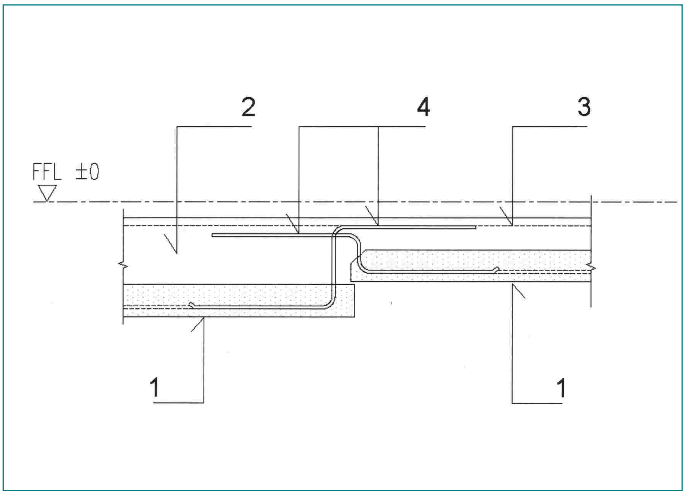

1. PC half slab
2. Rebars from PC slab
3. In-situ pour strip
4. Rebars to be placed on site

**Fig. 2.24 – Use of stiffened cast in-situ pour strip to connect PC half slab panels in the secondary direction**



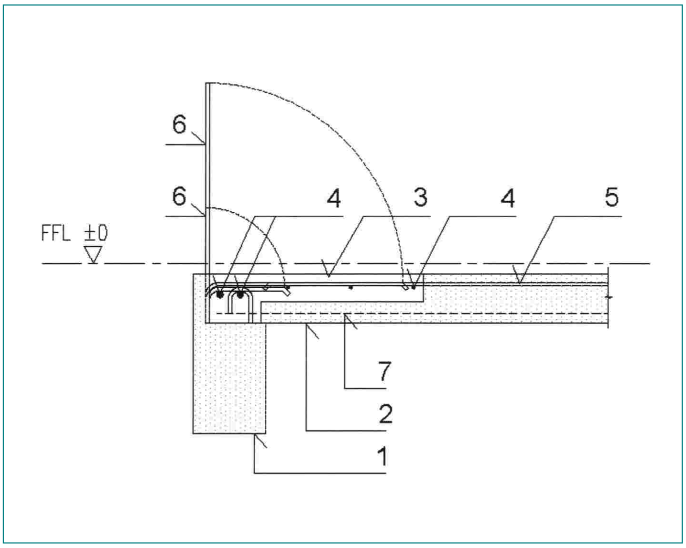

1. PC half slab
2. Rebars from PC slab
3. In-situ pour strip
4. Rebars to be placed on site

**Fig. 2.25 – Use of cast in-situ pour strip to cater for floor level difference**




1. PC half slab
2. In-situ structural topping
3. Rebars to be placed on site
4. Rebars from PC slab

**Fig. 2.26 – Details to cater to the change in slab thickness**




1. PC beam
2. PC full slab
3. In situ concrete infill
4. Rebars placed on site
5. Rebars from PC slab
6. Rebars from PC beam
7. Bottom layer wire mesh from PC slab

*Note: PC slab could "sit" directly on the PC beam during installation. The anchorage bars from the precast beam are to be bent and tied in place before casting the joint.*

**Fig. 2.27 – External PC beam supporting PC full slab**

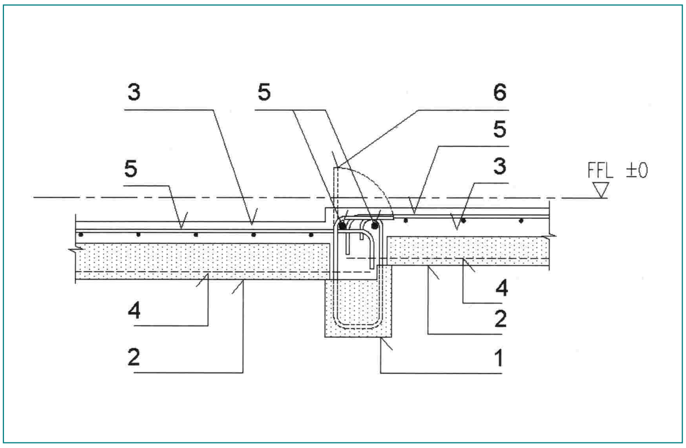



Fig. 2.28 – Internal PC beam supporting PC half slab

1. PC beam
2. PC half slab
3. In-situ concrete infill
4. Bottom layer wire mesh from PC slab
5. Beam & slab rebars to be placed on site
6. Rebars from PC beam

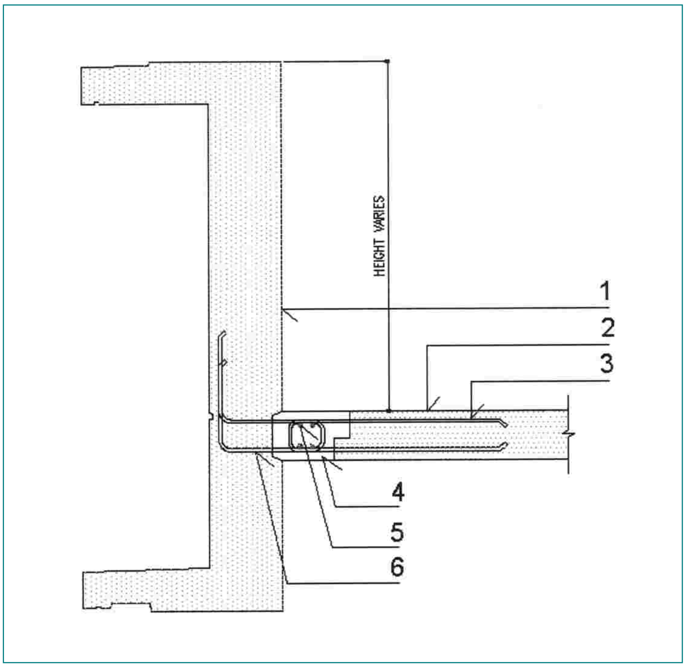
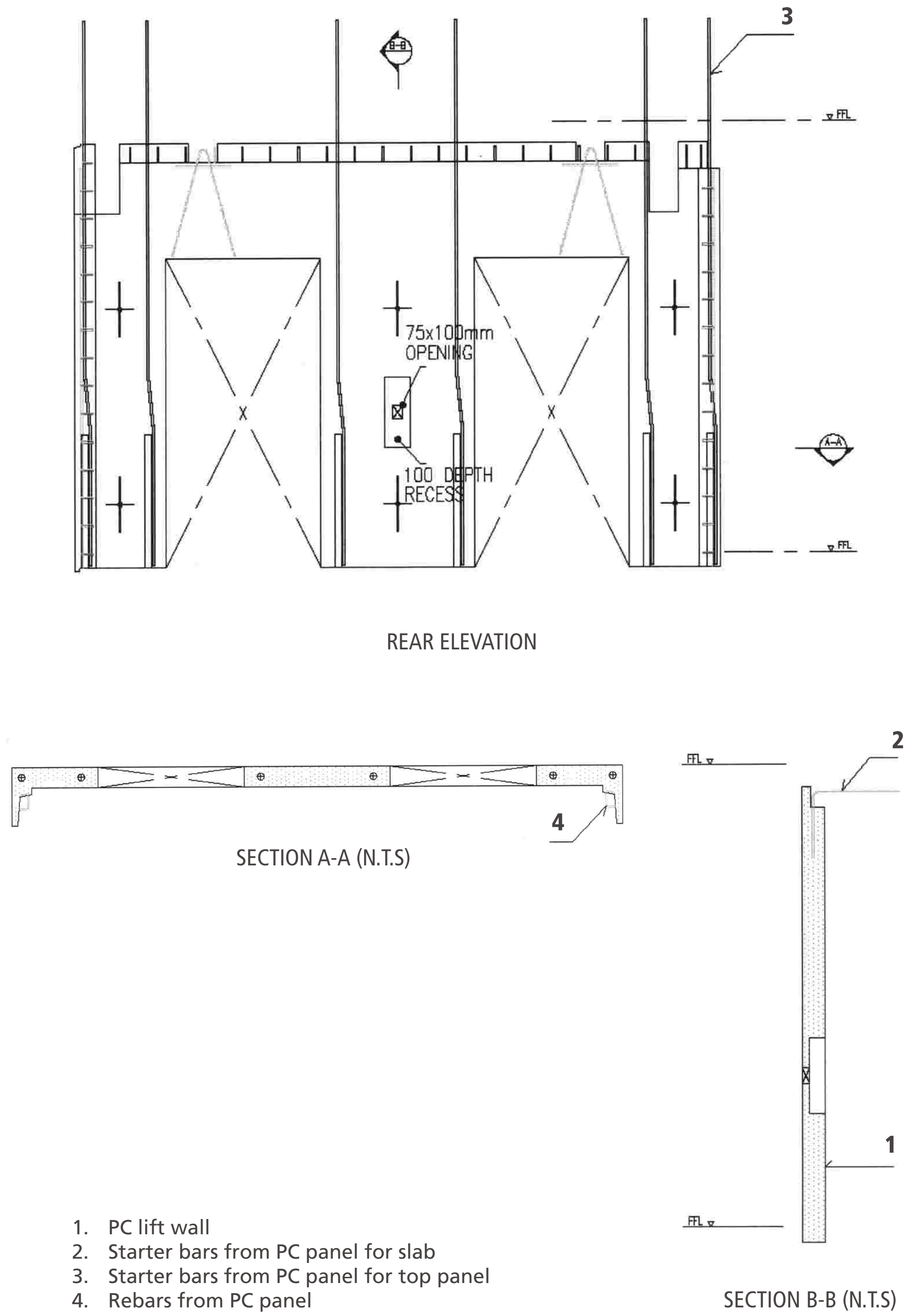



Fig. 2.29 – Bay window beam supporting PC full slab

1. PC beam
2. PC full slab
3. Rebars from PC slab
4. In-situ concrete infill
5. Rebars to be placed on site
6. Rebars from PC beam




1. PC lift wall
2. Starter bars from PC panel for slab
3. Starter bars from PC panel for top panel
4. Rebars from PC panel

**Fig. 2.30 – Example of PC lift wall details and connection with floor elements**

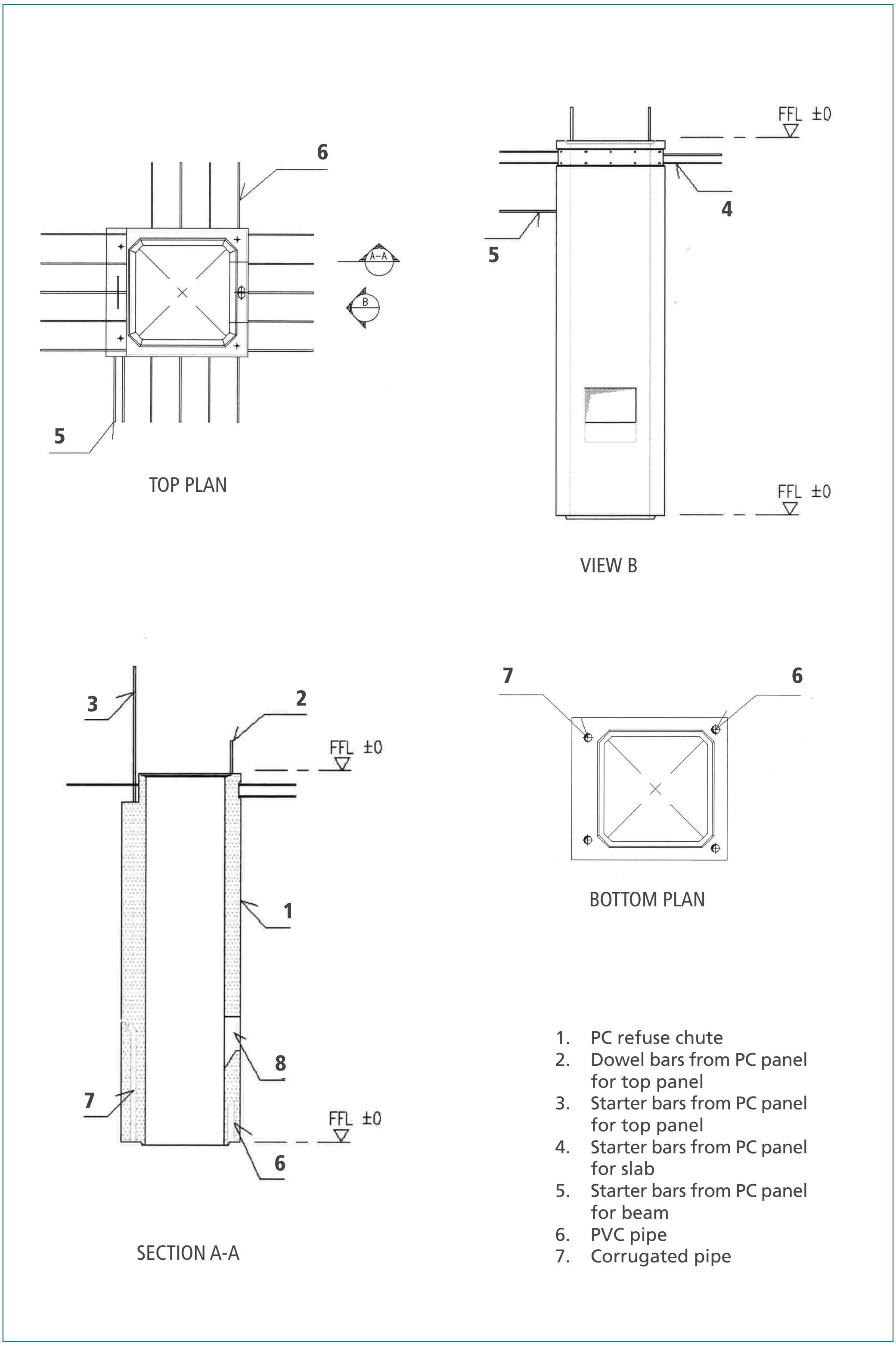



**Fig. 2.31** – **Example of PC refuse chute details and connection with floor elements**

# 3 Interfacing Mechanical & Electrical Services Works

# Interfacing Mechanical & Electrical Services Works

One of the important aspects of precast activities is to consider the interfacing trades such as mechanical and electrical (M & E) services. To enhance the aesthetic appearance of the interior, services are often concealed or embedded wherever possible. The idea of incorporating M & E services into precasting works is to minimise unnecessary hacking and cutting for recesses as can be seen in the in-situ brick or block construction. However, it would entail that the final study and location of the building services must be completed much earlier than usual.

## 3.1 APPROACH IN CO-ORDINATING M & E SERVICES WORKS

The incorporation of services at the planning and design stage of project development is critical to avoid unnecessary delays during installation and construction. Locations of the building services especially those that need to be embedded or concealed in the precast components, should be determined early to facilitate precast panel production. Once the locations of the services are determined, block-outs and recesses can be formed into panels as they are cast. Openings and conduits can be incorporated in the panels for the services to pass through. With a host of different building services, co-ordination works are essential to ensure that the provision of such services

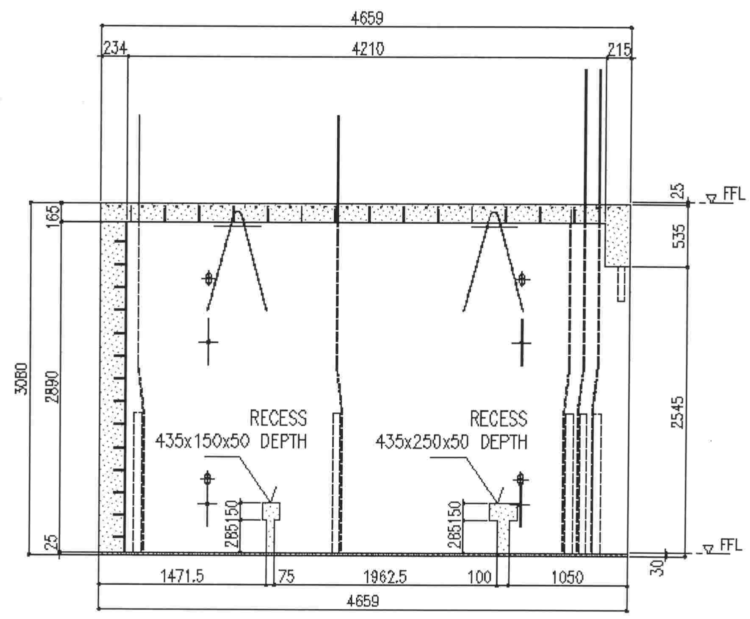



**Fig. 3.1 – Example of PC wall element drawing showing the recesses required**

can be contained within the limited zone without affecting the structural integrity of the precast wall and slab panels. The details of the services to be incorporated in each precast panel should be reflected in the precast element drawings for easy reference and construction.

For private residential development, the possible locations for services routing can be found in the spaces between floor and false ceiling, within floor structure, within floor screed and within wall structure. The use of vertical service cores and service ducts is common for concealment and distribution of services.

There are basically three groups of services that need to be taken into account when planning for precast panel production : Electrical, plumbing and sanitary services and air-conditioning services. Concealed electrical works for telecommunications, power and lighting can be easily catered for by casting conduits and necessary terminations needed during the precast panel production. Provisions for other

**Fig. 3.2 – Cast in conduits for electrical services within the wall panels**

building services such as sanitary, water supply and air conditioning could come in the form of recesses or grooves formed in the precast panel. These recesses or grooves would allow the service piping and ducts to be embedded at a later stage. They can be reinstated with structural grout to level with the wall finishes after installation of the services.

The approach to incorporate M & E services into precasting activities depends on whether the buildings or areas are designed to have false ceiling.

**AREAS THAT DO NOT HAVE FALSE CEILING:** The approach is to embed services within the floor slab or floor screed. These services are extended up and above the floor level for the connection with the M & E terminations or piping within wall panels. Appropriate cast-in termination items, or preferred recesses would be provided in precast wall panels. Provision of recesses in wall panels should preferably be done vertically so that the load carrying capacity of walls would not be reduced unnecessarily. The depths of these recesses usually range from 30mm to 50 mm depending on the services or thickness of termination items. Similarly, floor recesses at the interface connection are to be provided as appropriate.

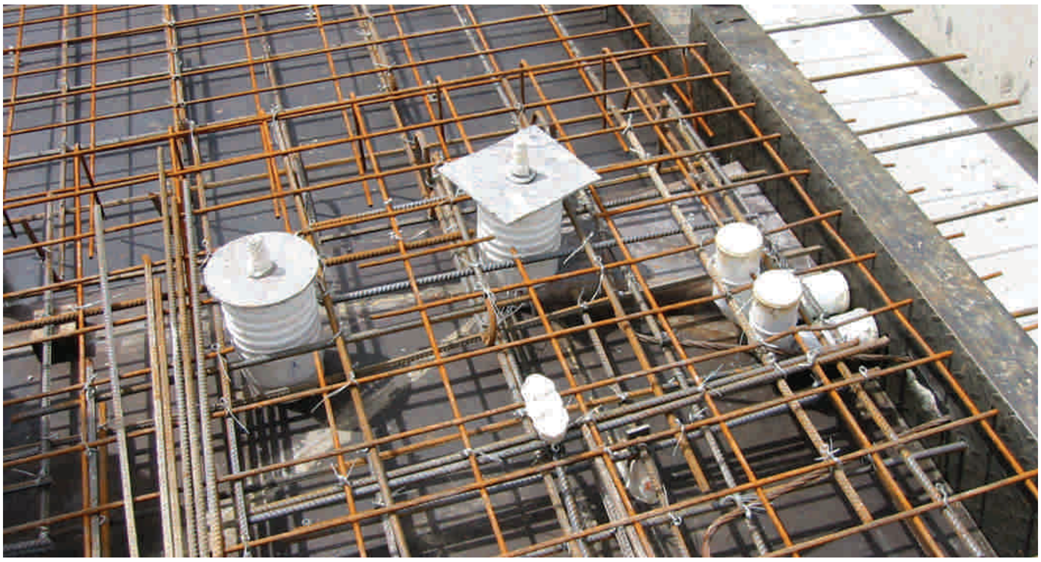


**Fig. 3.3 – Services can be embedded within the floor slab and extended up and above floor level for connection**

**AREAS WHICH HAVE FALSE CEILING:** The approach is to make use of the ceiling space to cater for M&E services routing. All terminations and connections can be concealed within the ceiling space. In this way, maintenance of services can be accessed within the ceiling area. Where services are connected to the precast wall, the required services affixed to the ceiling can be redirected and embedded into the precast wall panels. All routing works can be kept clear off the floor slab. This will benefit homeowners who want to upgrade or alter the existing services without having to remove floor finishes or risk hacking critical structural elements.

**Fig. 3.4 – With add-on ceilings, all services can be concealed within the ceiling space after installation**

## 3.2 ELECTRICAL SERVICES

For lighting and power routing, it has been a practice to have cast-in conduits from which the electrical wiring can be pulled through these embedded conduits. These conduits can be incorporated in the precast floor slab or cast–in situ topping as well as precast wall panels to eliminate the need to chase or embed the services at a later stage.

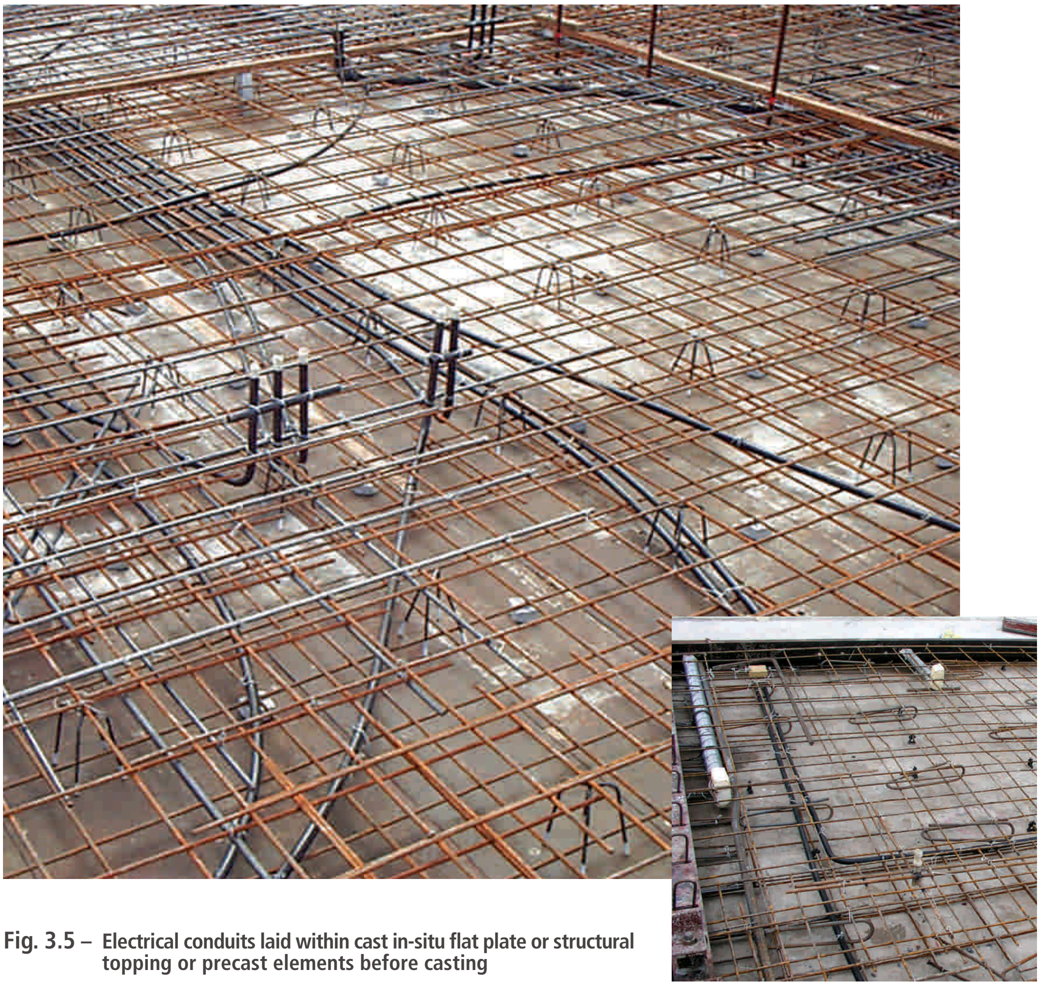
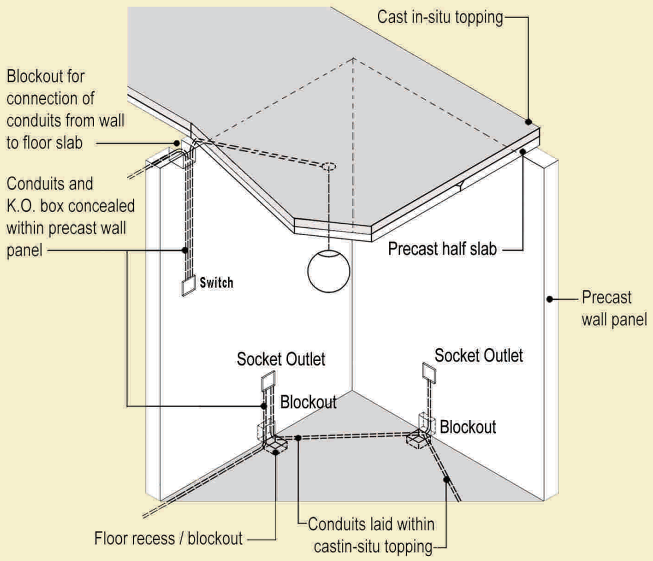
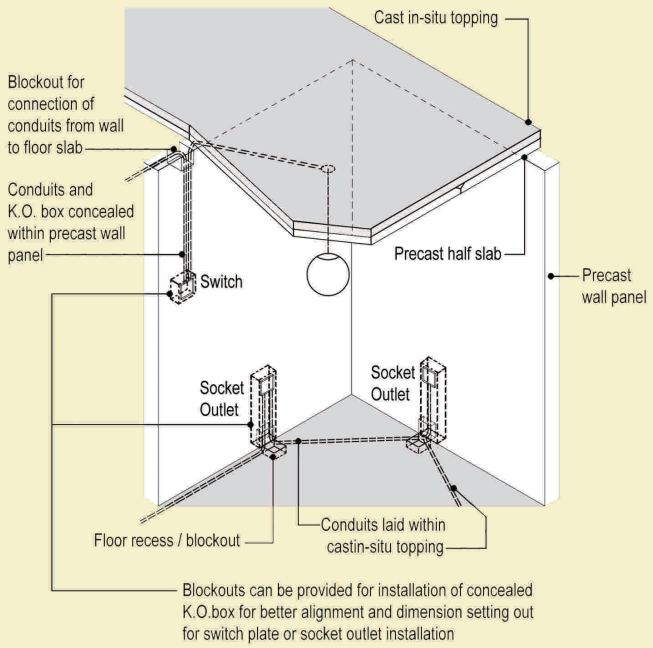


**Fig. 3.5 – Electrical conduits laid within cast in-situ flat plate or structural topping or precast elements before casting**

**CONDUITS JOINT BETWEEN WALL PANEL AND FLOOR SLAB:** There are essentially two approaches to connecting the conduits between the precast wall panels and slabs. The first approach is to rout the power and low level wiring from the floor slab up to the wall panel. This means the electrical routing is run within the unit's floor slab. The floor slab is normally cast prior to installation of wall panel on the unit concerned. Therefore, provision is required by means of recesses on the side of wall panel as well as on top of floor slab for connecting the conduit from the wall back to the floor conduit as illustrated in the Fig. 3.6.




**Blockouts provided at interface between wall and slab elements**




**Blockouts provided at wall-slab interface and K.O Box location**

**Fig. 3.6 – Connection of conduits between precast wall panels and slab using the first approach**

In the second approach, power and low level wiring system is routed to the floor slab above the unit or within the false ceiling space (see Fig. 3.7). In this case, the conduits are all run from the floor slab above the unit to be connected to the cast-in conduits at the top of wall panel. Following the installation of wall panel and floor slab, the connection of conduit from the wall to the floor slab can be done straight away. The blockout can be reinstated and cast together with the casting of floor slab or in-situ topping.

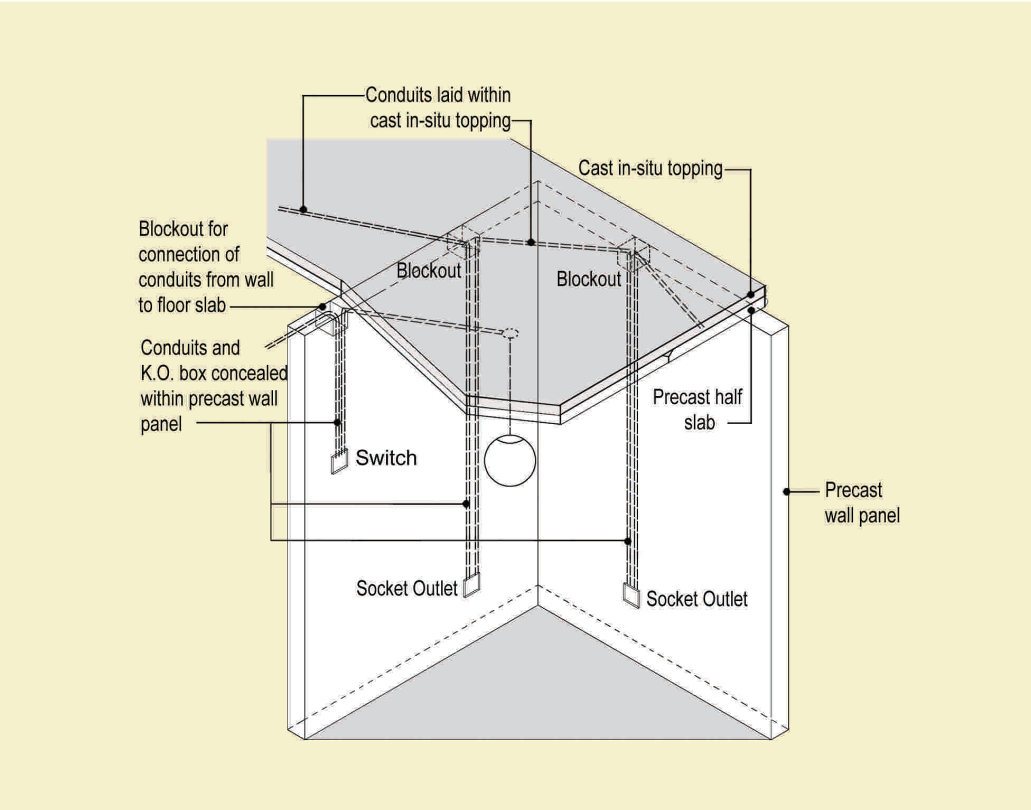



**Fig. 3.7 – Connection of conduits between wall plan and floor slab using second approach**

The main advantage of using the second approach is that there is only one recess required. It is located on top of the wall and the recess can be filled up together with casting of floor slab or in-situ topping. In other words, it saves the trouble of second operation to cover the recesses as deemed necessary in the first approach. Moreover, better and consistent wall finishes can be achieved using the second approach.

The first approach is still commonly used, as it requires less material cost for the electrical outlets located at low level. Precautions against chances of damaging the installed electrical wiring in the event of drilling works for fixing items to the wall tend to favour the first approach. This concern, however, can be addressed by planning the routing of vertical conduits along areas less likely to have wall drilling, such as the areas near to corners of wall.

**Table 3.1 – Technical Details for Electrical Services**

| | |
|---|---|
| **Ceiling Lighting Points**<br>• Provide connection rings at precast slab or plank<br>• Conduits and junction box to be included in precast slab during prefabrication or embedded and cast-in together with slab topping<br><br>**Switches and Wall Light Points**<br>• Conduits to be included in precast wall panels during prefabrication<br>• The necessary terminations can be cast-in together with the precast wall panels or to be installed at later stage in designated recess and groove formed on the wall panels<br><br>The above details are applicable for other electrical services such as power /SCV/ telephone.<br><br>*Note : Refer to TR 13 – Technical Reference for Performance Standard for embedding conduits in concrete where good practices in the laying, arrangement and overlapping of conduits for various electrical services within in-situ topping are highlighted.* | Points to note:<br>• To provide block-out of about 200mm by 200mm (on floor slab) at the junction in connection with the cast in conduits in precast wall panels (for connection using first approach)<br>• To provide block-out of about 200mm by 100mm (on wall panels) at the junction in connection with the cast-in conduits in floor slab<br>• All block-outs and grooves to be reinstated with structural grout after installation and connection |

## 3.3 PLUMBING AND SANITARY SERVICES

For maintenance purposes, plumbing and sanitary services should not be cast in. However, for aesthetic purposes, these services can be concealed by having recesses or grooves formed on the precast wall panels. These recesses can be reinstated using structural grout after the installation of the services.

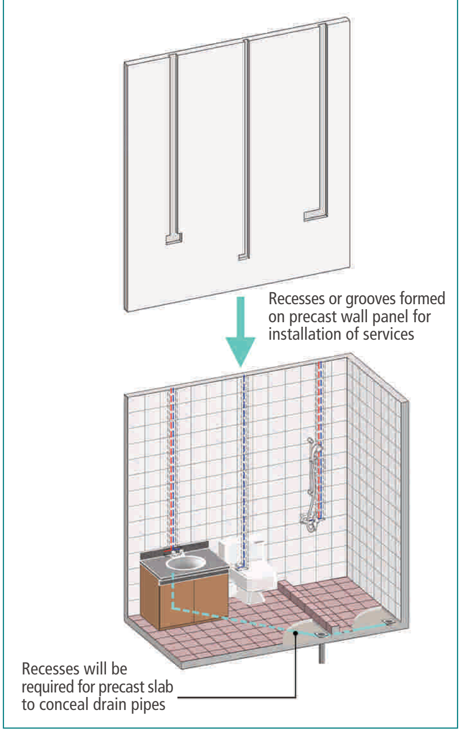



**Fig. 3.8 – Services can be concealed within the precast wall or slab panels using recesses**

**Table 3.2 – Technical Details for Plumbing and Sanitary Services**

| | |
|---|---|
| **Hot & Cold Water Pipes**<br>• Provide 40 mm depth recesses/ grooves in precast wall panels for the embedment of the hot/cold water pipes at a later stage.<br>• Depending on the water distribution run and room layout, horizontal water pipes may be required at certain areas. Designated recesses/grooves can be provided in precast full slab for the embedment of these pipes. For precast half slab and in-situ flat plate, these pipes can be concealed within the cast in-situ topping or slab.<br><br>**Basin/Sink Waste Pipes**<br>• Provide 50 mm depth recesses/ grooves in precast wall panels for the embedment of the basin/sink waste pipes at later stage.<br>• Provide designated recesses/grooves for the running of the horizontal waste pipes to the floor trap or floor waste for precast full slab system. For precast half slab or in-situ flat plate, these pipes can similarly be concealed within the cast-situ topping or slab. A minimum topping of 90 mm would generally be required to conceal these horizontal waste pipes. | Points to note:<br>• All recesses/grooves to be reinstated with structural grout after installation and connection. |

## 3.4 ACMV SERVICES

Basically, the provision for ACMV services in precasting works is similar to that for plumbing and sanitary services. The refrigerant pipes and insulated condensed drain pipes can be concealed within the wall panels using recesses or grooves formed. These pipes are then connected to the same embedded within the floor slab and topping to condenser units and floor trap.

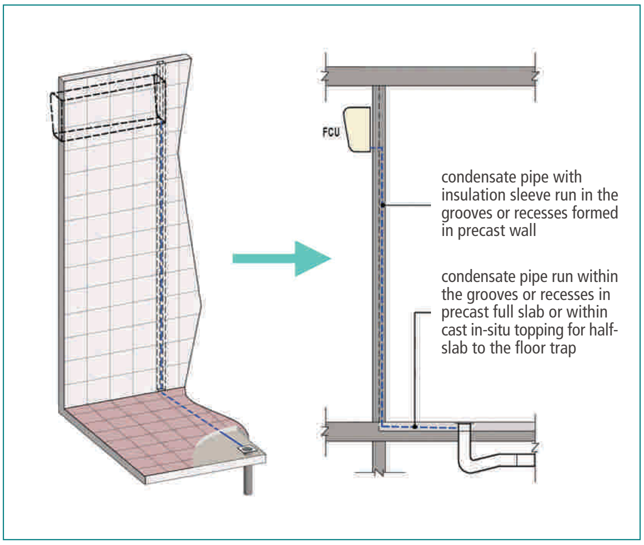



**Fig. 3.9 – Condensate pipes can be concealed within wall panels using recesses**

**Table 3.3 – Technical Details for ACMV Services**

| | |
|---|---|
| **Refrigerant Pipes**<br>• Provide appropriate openings on precast wall panels for running of refrigerant pipes from condenser units to respective fan coil units.<br><br>**Condensate Drain Pipes**<br>• Provide 40-50 mm depth recesses/grooves in precast wall panels for the embedment of insulated condensate drain pipes from the fan coil units<br>• Provide designated recesses/grooves for the running of the horizontal insulated condensate drain pipes to the floor trap. | Points to note:<br>• It is common to run the refrigerant pipes within false ceiling area for ease of installation and easy maintenance.<br>• The distance from condensate drain pipes dropper to floor trap should be kept minimum (within the range of 3 m to 4 m) so that the floor slab need not be thickened unnecessarily.<br>• All recesses/grooves to be reinstated with structural grout after installation and connection. |

4



# Managing Precast Concrete Components

# Managing Precast
## Concrete Components

Proper planning for the building design and construction processes plays a crucial role in ensuring successful implementation of any project. To fully capitalise on the benefits of using precast method, the project team must work together through the design and construction process to deliver solutions that equitably address each discipline's concerns.

The nature of precast concrete construction entails thorough preconstruction planning. As the various aspects and phases of the project are interrelated, its success will depend largely on how effective is the linkage between each construction phase during implementation. Construction sequences, production scheduling and resources are therefore important and need to be closely monitored to obviate costly delays in site progress

Each building system has its own set of design and construction issues. For precast concrete construction, one needs to consider and plan for temporary site facilities, precast production and erection among other construction activities.

### 4.1 PLAN FOR TEMPORARY SITE FACILITIES

**CRANE LAYOUT AND CAPACITY:** The speed of precast construction depends very much on the planning and execution of installation sequence. The crane plays a vital role in ensuring that the components are erected rapidly. Selection and positioning of numbers of crane depend on the size of project, site access (or constraints), block layout, cycle time, the numbers and tonnage of precast components. In general the crane capacity should be based on the combined weight of the heaviest panel and the rigging gear. The position of the crane in relative to the final panel location should also be considered. For example:

- How far must the crane reach to lift the panels?
- How far must the crane travel with the panels?
- How far must the crane reach to position the panels?

The crane's load chart and manufacturer's recommendations should be used before determining the correct crane size.

**SITE ACCESSIBILITY:** Good accessibility and sufficient space for manoeuvring crane and trailer within the site are important considerations for erection. Pre-planning of construction processes is required to allow for such access, particularly when two or more of the other construction activities are occurring at the same time.

Fig. 4.1 – Site access is important for the delivery and erection of precast components

**DELIVERY:** Efficiency in delivery is not just about maximizing payloads; it is important to consider the following pointers, particularly for precast concrete components:

- Arrival on time
- Correct components delivered according to schedule
- Components delivered without damage
- Panels loaded in a way that minimises handling on site

Fig. 4.2 – Wall panels transported by a low trailer

Consideration must be given to the height, width, length and weight limitations of the precast components in relation to transportation. For panels or components mounted on trailers, the overall height is limited to about 4200 mm in local context.

For panels that are delivered flat, careful consideration must be given to the method and equipment used on site to turn the panels to the final position. The panels must be designed for lifting stresses; otherwise the panels may be distorted and damaged during lifting.

**JOBSITE STORAGE:** Precast components that are cast off-site, generally do not require much site space for storage purpose. Whilst components that are cast on-site will require more site space for casting beds as well as storage space. Regardless of whether they are cast on-site or off-site, it is important to make provisions to store the precast components for subsequent installation. Storage area provided should be relatively level, firm and well drained to avoid differential ground settlement, which may damage the stored components.

**Fig. 4.3 – Ground level of storage area should be relatively level and firm**

Precast components should be stored based on the designed stacking method to pre-empt any damage and undue stresses. For horizontal precast elements such as precast slab, planks and beams, they can be stacked and supported separately using strips of woods or battens across the full width of designated bearing points. As for precast façade and wall panels, they are usually stored in vertical position supporting their own self-weight using rack with stabilising sleeper wall. In any case, precast components should be stored with careful consideration of the erection sequence so as to minimise double handling.

**Fig. 4.4 – Secure vertical panels on racks at appropriate spacing**

## 4.2 PLAN FOR PRECAST PRODUCTION

Owing to the more intricate architectural design in private residential development, precast elements, in particular building facades are adopted in a make-to-order fashion. Unlike the catalogued precast elements, which have been well designed, produced and stocked, the tailor-made precast elements produced are varied in shape, reinforcement and dimensions to meet specific project requirements. Generally, more time will be required for such production planning which involves development of precast element design and shop drawings as well as production processes.

**PRECAST ELEMENT DESIGN AND DRAWINGS:** Based on the project design, precast elements can be designed and developed with reasonable level of standardization and repetition. For economical design, the precast elements should be made as large as practicable and identical, to minimize the number of purpose-built moulds and to increase repetitive works.

For production purpose, shop drawings of individual precast components are prepared to detail all construction requirements. Changes to original design are not uncommon to improve buildability and to accommodate the production processes. Good co-ordination among project team members during this stage is therefore important. Any discrepancies should be resolved before confirming these drawings for production and construction. Essentially, shop drawings are the result of the integrated design process incorporating all design requirements for production and installation.

Good shop drawings should consist of the following information:

- Project location, reference number of components, and its location in the building plan, as well as references to the layout and elevation drawings
- Dimensions of components, centre of gravity, weight and concrete volume
- Locations of all reinforcing steel, cast-in inserts for connection, lifting and bracing.
- Locations of embedded items such as service conduits, blockouts and recesses as well as openings
- Edge details and architectural treatment where applicable

**PRODUCTION PROCESSES:** One of the foremost items in production processes is mould fabrication. To minimise cost, similar components can be grouped together to reduce the number of moulds required. Slight modifications using inserts or appropriate adjustments can be carried out to reduce the mould size for smaller pieces of the same general form to enable the reuse of moulds for several units. The other processes mainly involved procurement of raw materials for production of components, placement of reinforcements and accessories before casting. Resource management and scheduling are important and form part of these processes in ensuring precast components are produced on time for site erection.

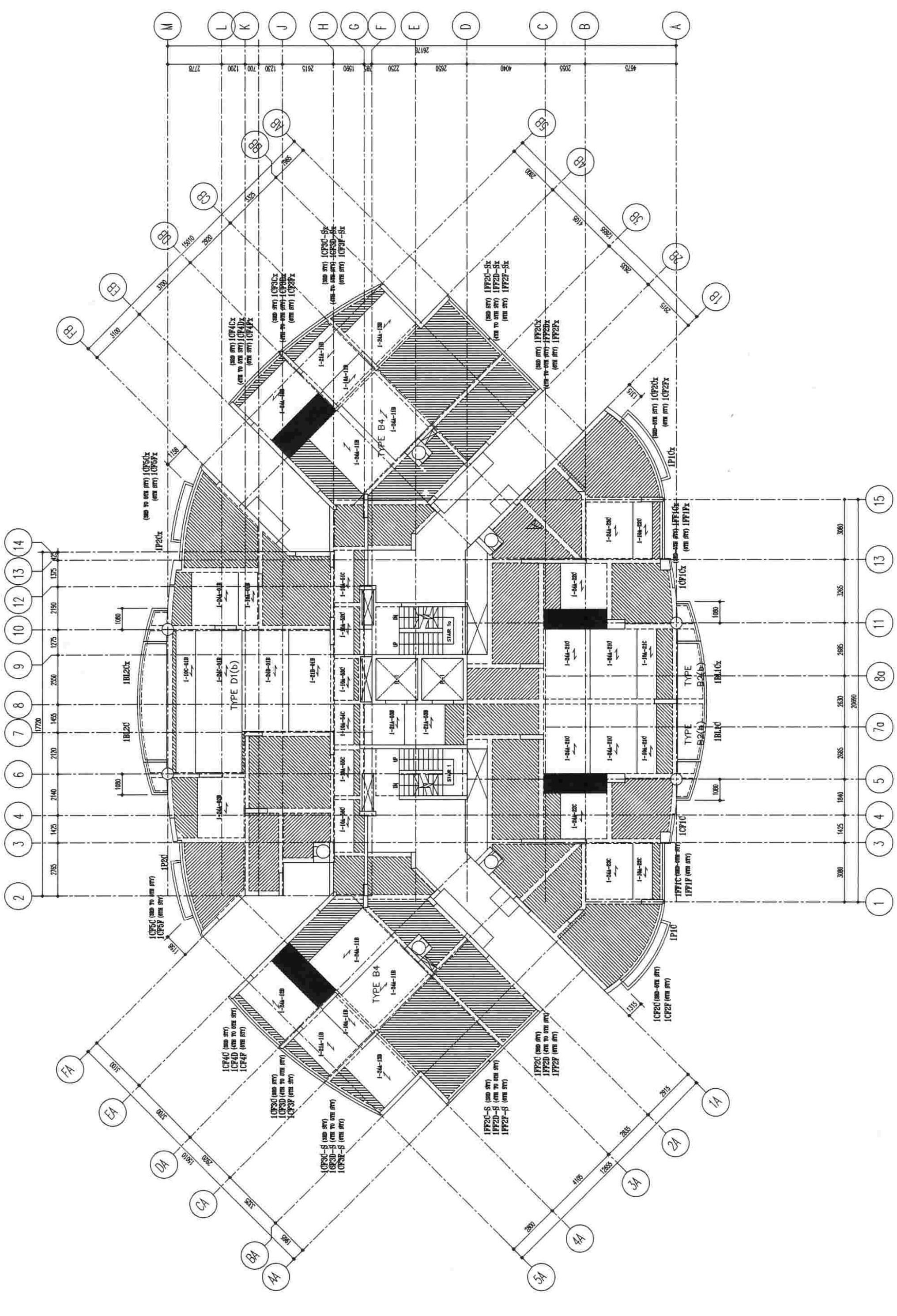


**Fig. 4.5 – Typical floor layout showing floor & façade details and references**

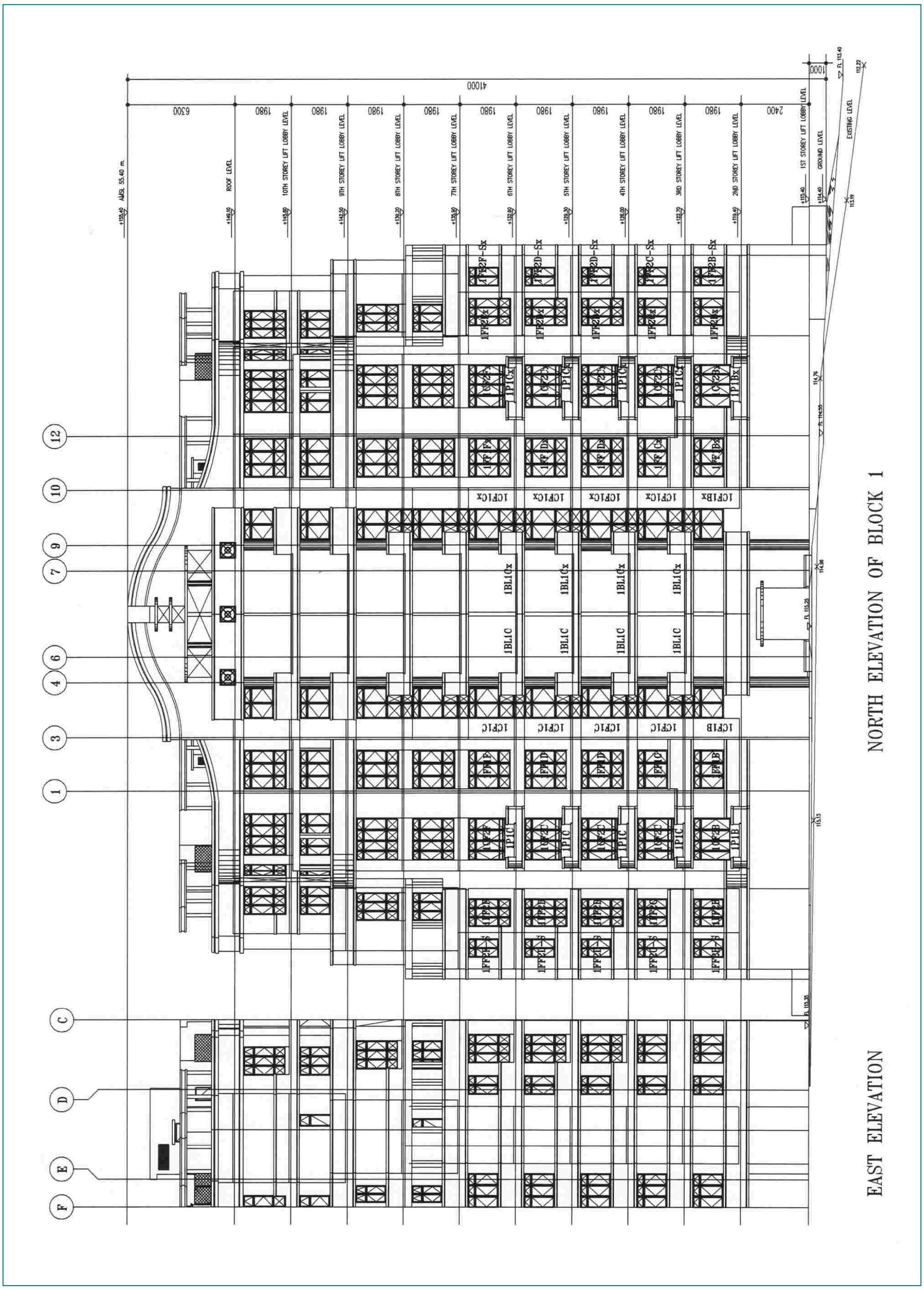



Fig. 4.6 – **Elevation details showing façade location**

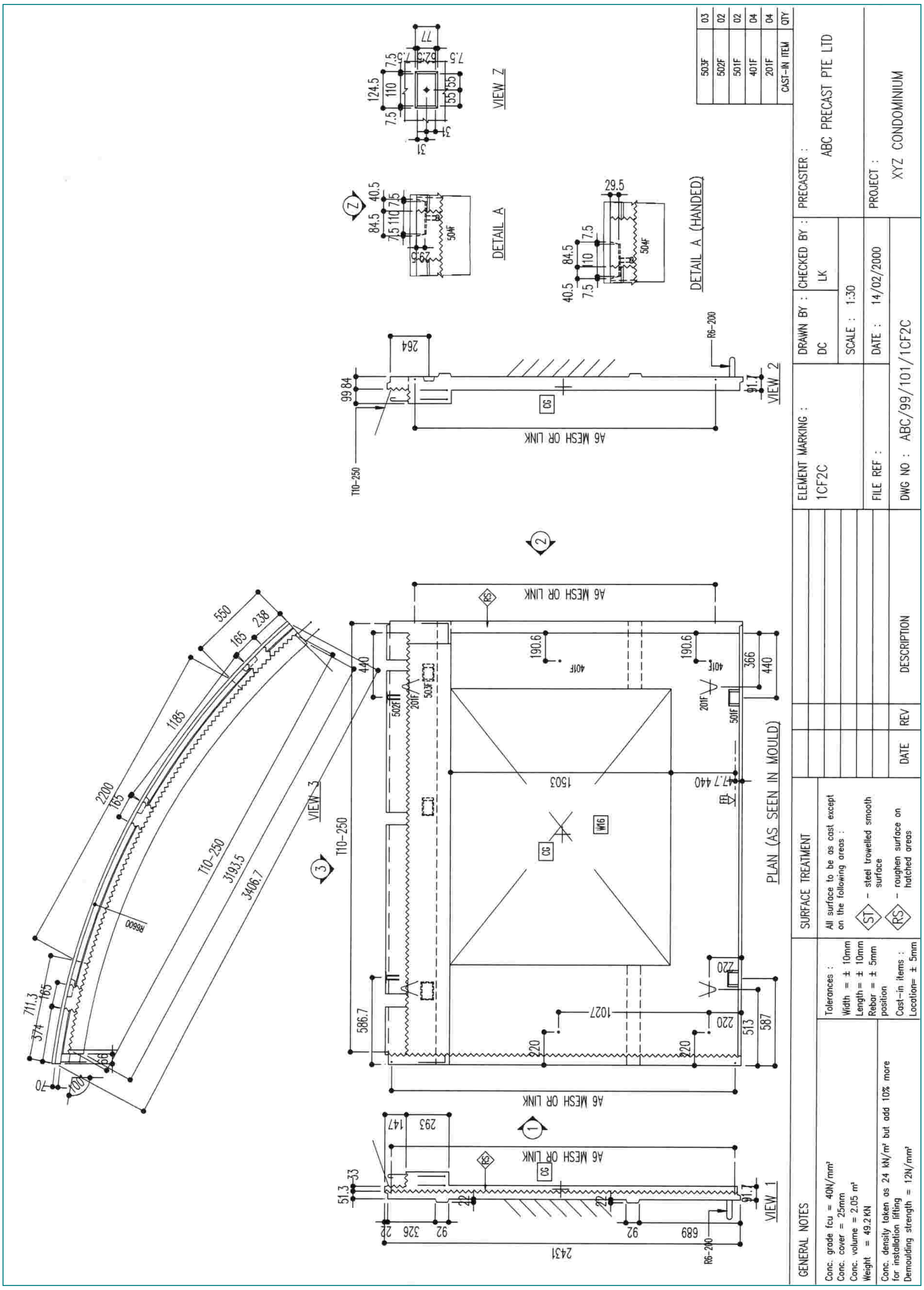



**Fig. 4.7 – Example of mould details of precast façade element**

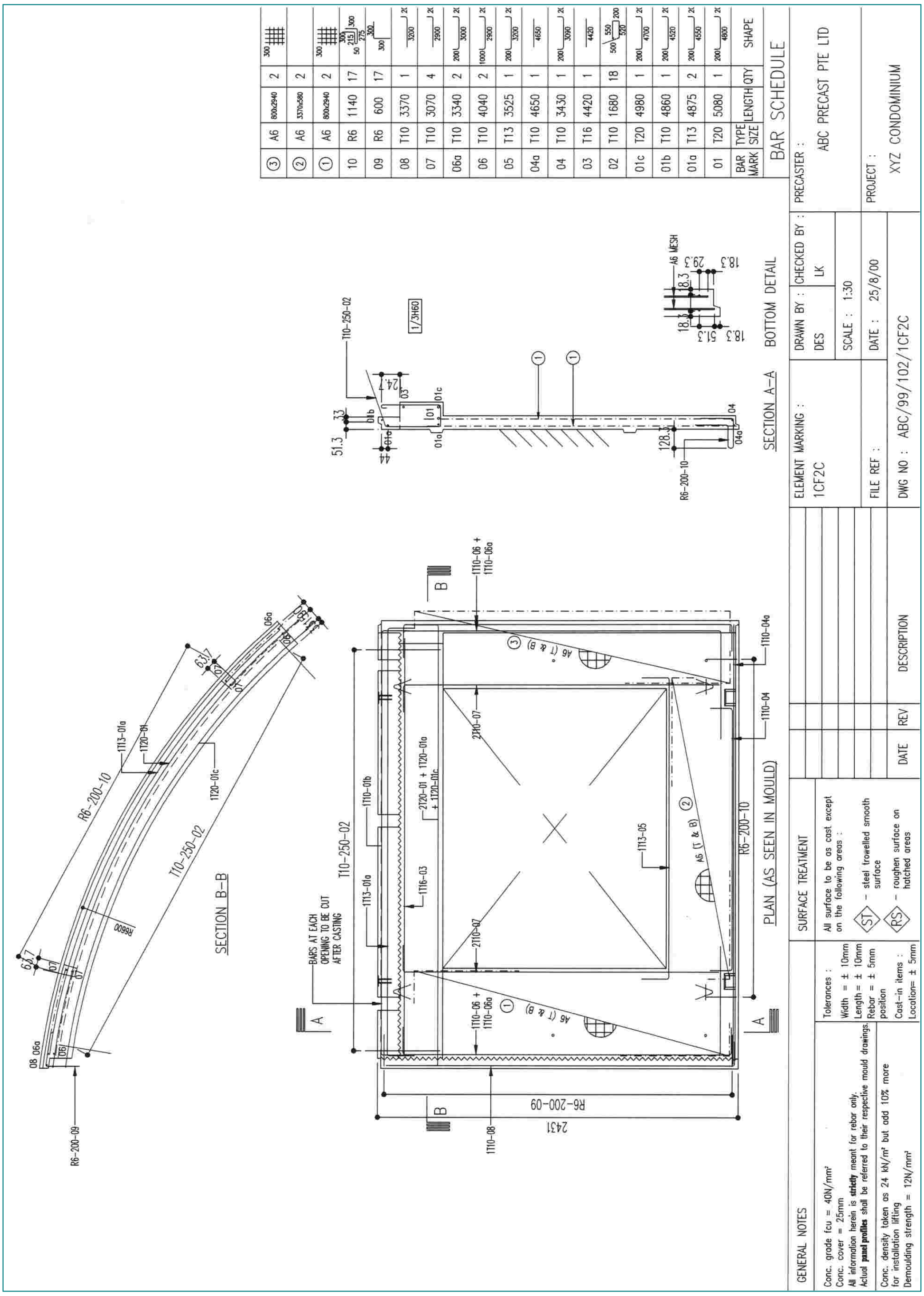



**Fig. 4.8 – Example of reinforcement details of precast façade element**

## 4.3 PRECAST PANEL INSTALLATION

In handling the precast panel installation, it is important to have the precaster, erector and builder working together to achieve the best performance and working method. Requirements for temporary propping, bracing and special lifting procedures have to be worked out in preparation for the actual installation.

Computer models can be used to simulate the erection sequence. During the actual installation, this should be checked against the computer modelling. If possible, a trial erection should be done at the site or precast plant to iron out any teething problems. Temporary supports required should be planned for and provided after installation to position the panels or components before jointing.

Generally, the preparation work and sequences of precast installation involved are as follows:

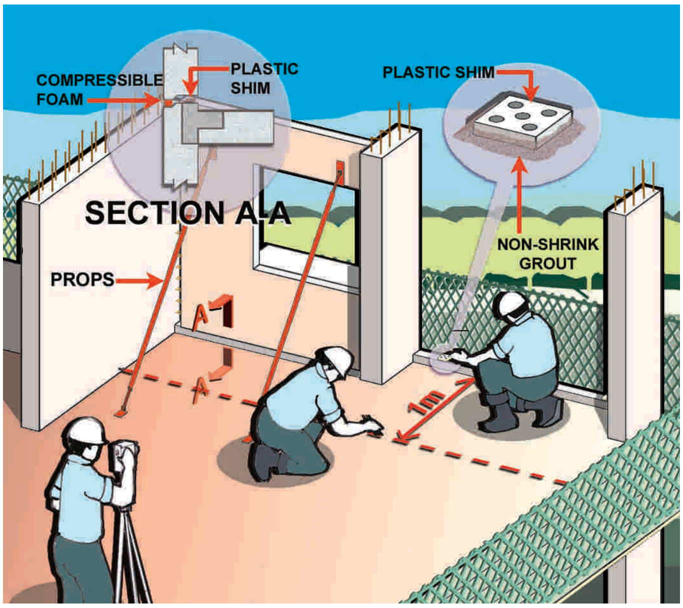
### Table 4.1 – General Preparation Works

- Prepare storage area for precast concrete panels.
- Arrange tools, equipment and all necessary accessories for erection use.
- Prepare erection and delivery schedule.
- For vertical load bearing components, check all starter bars location in cast-in-situ joint.
- Set up all reference lines on the slab surface.
- Take level height of the starter bars which are embedded in floor.
- For vertical components, check the top re-bar level and alignment. For horizontal components, check the protruding bars dimension and alignment.

### Table 4.2 – General Sequence of Installation Works

- Vertical structural components such as all load bearing walls including load bearing facades, columns, household shelter panels will be installed first.
- Other vertical components such refuse chutes, non load-bearing partition walls, facades walls, service ducts also need to be installed together with load-bearing vertical components
- Horizontal components will then be installed next. These include beams, slabs and staircase flights, parapets, ledges, balconies, planter boxes, and down hang panels.

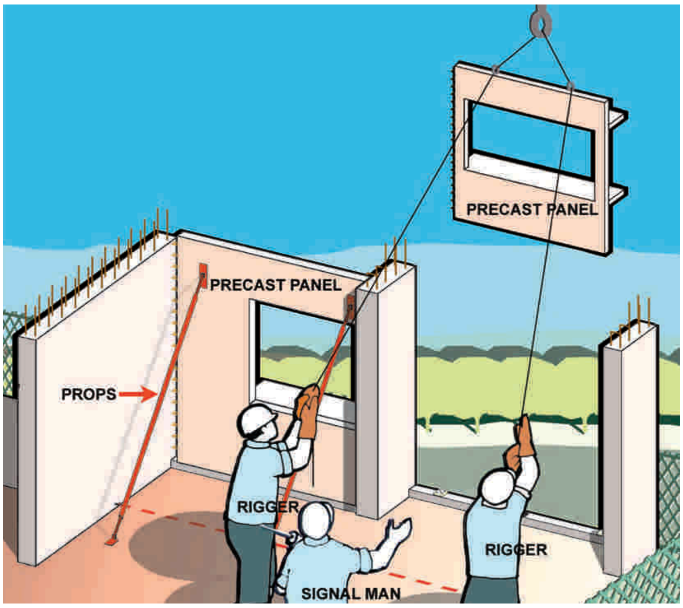
**VERTICAL COMPONENT INSTALLATION:** The method and sequence of installing the precast façade (which is also applicable to other vertical components) are outlined graphically as follows:




### Operation Flow 1

**SETTING OUT**

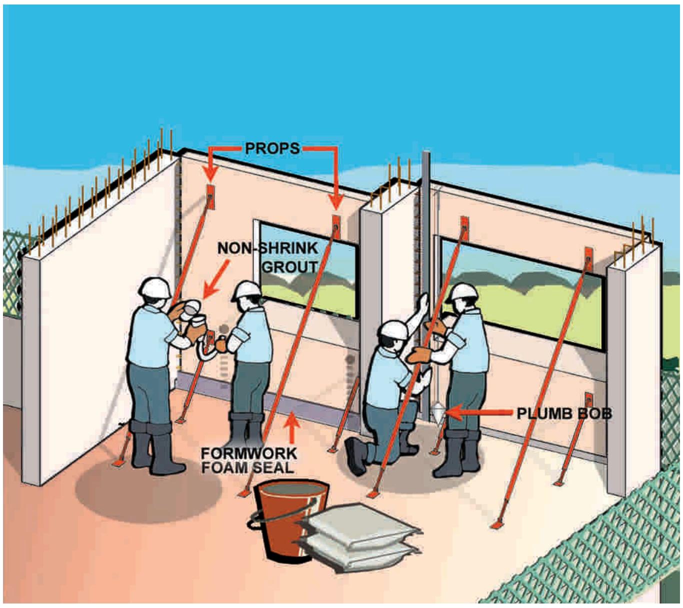
- Set reference line and offset say 1m
- Provide level pad (plastic shim) for panel setting and set level pad with non-shrink mortar
- For external wall/column, set compressible form on outer perimeter of wall




### Operation Flow 2

**LIFTING AND INSTALLING**

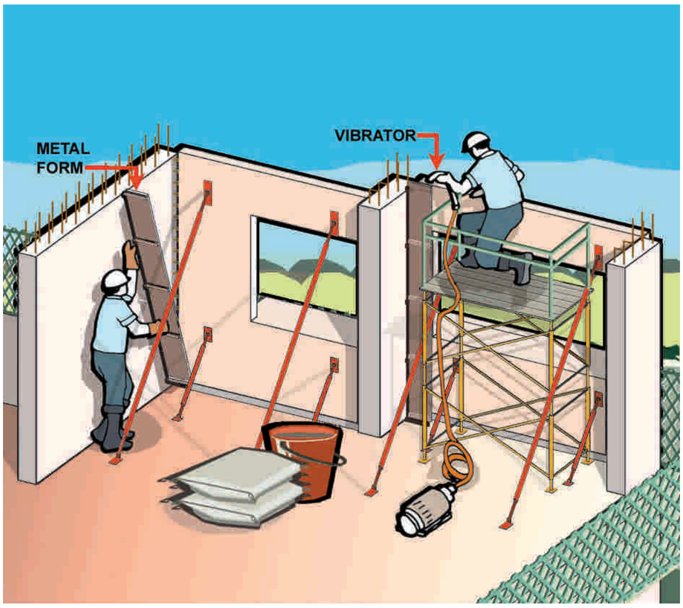
- One signal man and two riggers will be at the erection level
- Rigger will guide the panel into position and secure the panel by diagonal props
- For precast wall, props are provided on one side of the wall. For precast column or vertical shafts, props should be provided in two perpendicular directions
- After panel are being supported and aligned into corrected position, signal man will inform crane operator to release the panel




### Operation Flow 3

**GROUTING – NON-SHRINK MORTAR (for corrugated pipe where required in design)**

- Seal along bottom length of inner side of wall using formwork and foam
- Apply non-shrink mortar to specification
- Take test cubes where necessary
- Pour non-shrink mortar into corrugated pipe
- Keep component undisturbed for at least 24 hours



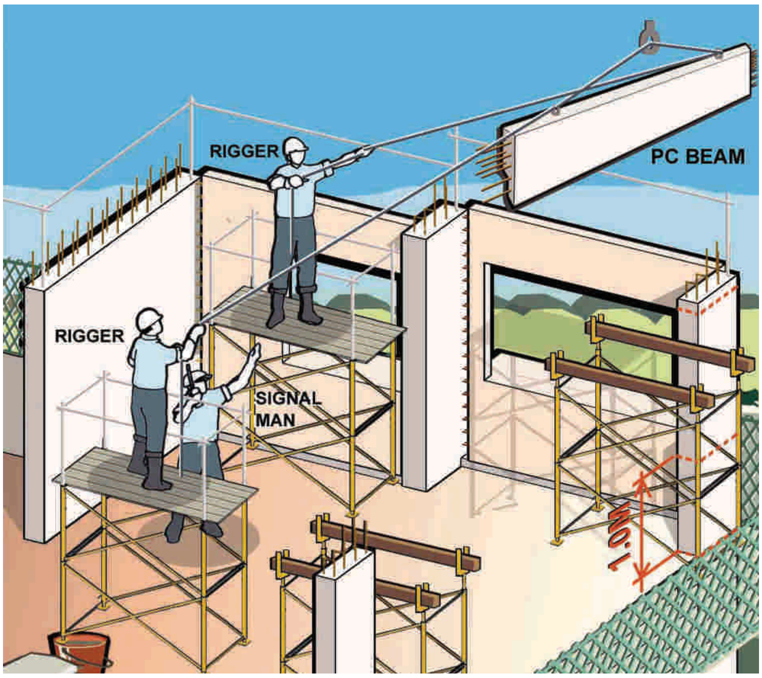

### Operation Flow 4

**VERTICAL JOINT CASTING AND SEALING (where required between vertical panels)**

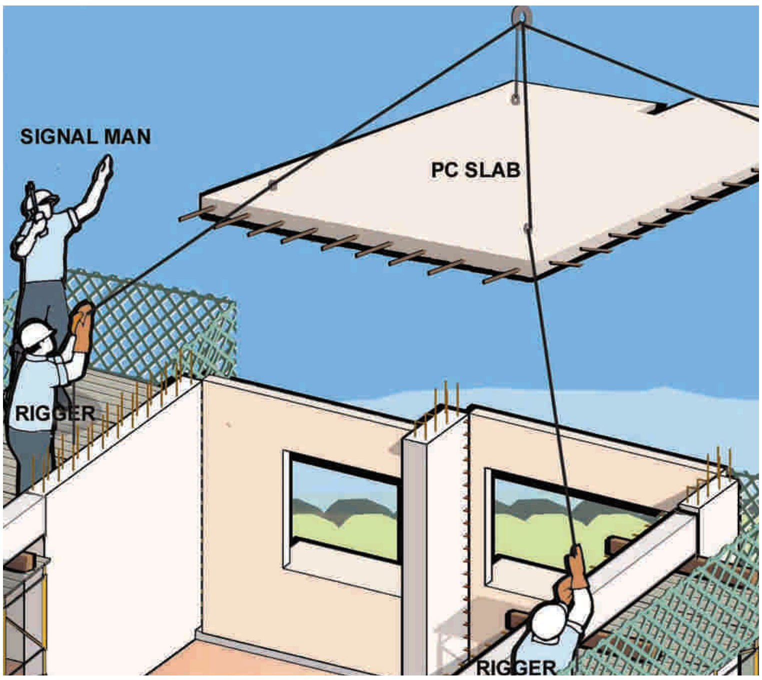
- For panel with wet connection, fix joint rebars
- Set up metal forms for the casting of the vertical joint
- Carry out concrete casting
- Remove metal forms after sufficient concrete strength achieved
- For panel with welded dry connection, place connecting plate between panels and weld as per design requirement

**HORIZONTAL COMPONENT INSTALLATION:** The following illustrations are pointers on the details and sequences of installing horizontal component such as precast beam, balcony, planter, ledge and slab.

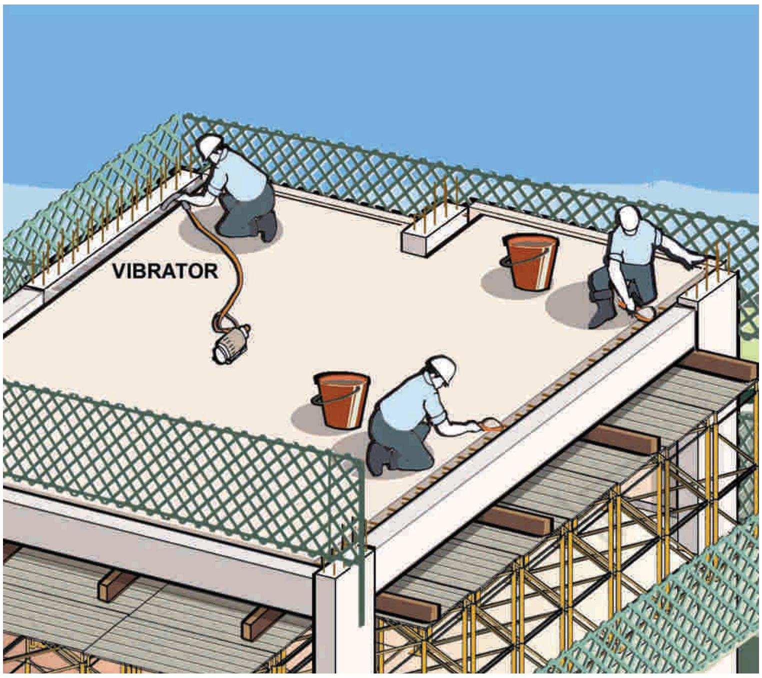
### Installation of Precast Beam




### Installation of Precast Slab



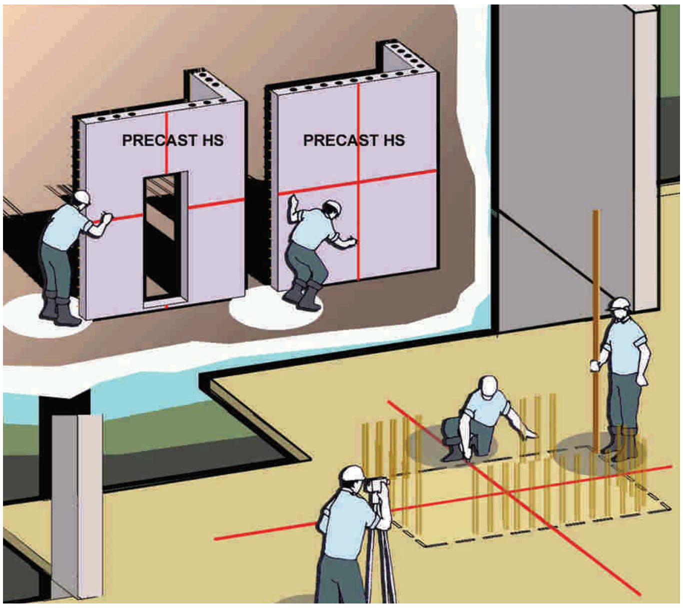
## Casting of In-situ Joint between Precast Beam and Slab




### Table 4.3 – Details for Horizontal Component Installation

| | |
|---|---|
| **Setting Out**<br>• Setting out lines and reference levels to determine the alignment and level of installation | Points to note:<br>• There should have sufficient tolerance for the placement of the rebars from horizontal components in connection with the rebars from supporting column/wall |
| **Temporary Support & Bracing**<br>• Put up temporary vertical props (where required in design) for the horizontal panel.<br>• For beam, down hang panel, each panel is supported at minimum two locations. For balcony, planter, ledge and slab, propping points will be more than two locations, depending on the width, length of panel and design consideration. | • Check that the vertical props are braced laterally<br>• Bearing area at support should be sufficient. Panels should not be in tilted position especially for beam and down hang panel) |
| **Panel Lifting & Placing**<br>• For typical precast beam & down hang panel, two numbers of lifting points at the top of panel are required for hoisting. For others, three or more lifting points are required.<br>• Align and check level to suit the required setting out before placement of precast members to final position. | • Secure the precast elements against lateral tilt or movement during casting of joints |

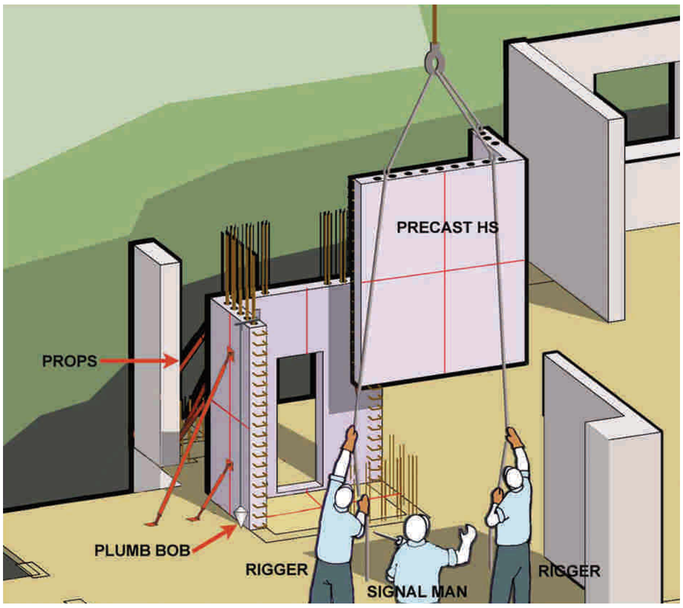
**PRECAST HOUSEHOLD SHELTER INSTALLATION:** The sequences of installing the precast household shelter with L shaped panel are as follows:




### Operation Flow 1

**PREPARATION WORK BEFORE INSTALLATION**

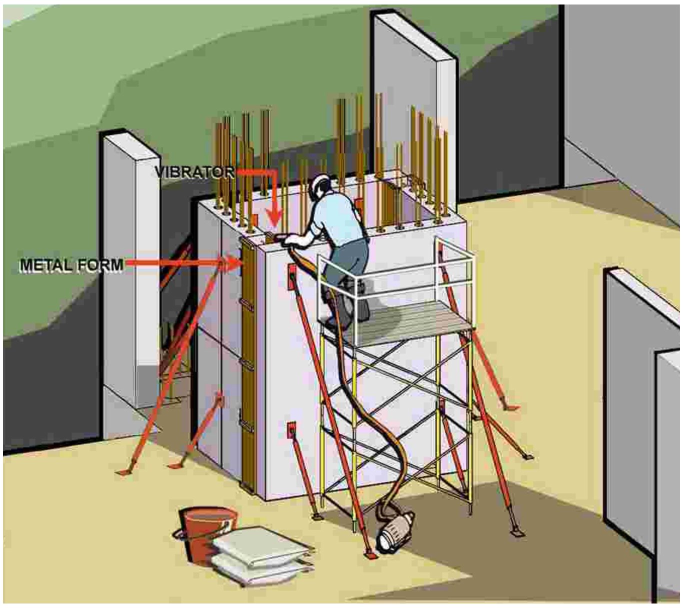
- Panel to be marked with two perpendicular lines on the rear surface
- Check that setting out lines and reference levels are correct
- Mark the wall location on the concrete floor and determine the level of the in-situ concrete




### Operation Flow 2

**PANEL LIFTING AND FIXING**

- Panel is lifted to vertical position by using 3 numbers of lifting loops at the top of panel
- At final panel location, props are used to secure the panel at the top fixing points and fasten to the concrete floor.
- Adjust level with levelling bolts
- Check verticality and alignment




**Operation Flow 3**

**CASTING OF JOINT**

- Fix the vertical joint rebars, followed by joint formwork
- Seal up the bottom horizontal joint with non-shrink mortar
- Upon installation of horizontal panel at ceiling level, check vertical continuity bars alignment, cast the vertical joint from the next floor

**PROTECTION OF PRECAST ELEMENTS:** Upon installation of precast components particularly the precast facades, it may be necessary to protect them from dirt, dust, stains and fallen debris. The face of façade panel may be protected using boards or plywood or plastic sheets to minimise damage. However, it is worthwhile to note that though the use of polythene shrink-wrapping is suitable for most panel finishes, it may cause condensation and subsequent discolouration to many surfaces. Hence, other proprietary products in aqueous form should be considered where necessary, to be applied on the precast elements upon removal from the moulds and prior to storage or delivery.

# 5



# Current Trends

## Towards Buildability

# Current Trends
## Towards Buildability

"Buildability" itself is not a system, nor a prescription for how to design and document a project. It is a recognition of the complications involved in construction and a collaborative approach by developers, consultants and contractors to create successful project outcome. Apart from the legislative requirement, other important steering forces such as adoption of design and build arrangement, have fostered a greater integration in the design and construction processes right from the start. Tightened profit margins have required the project stakeholders to carefully understand and manage the risks and reap opportunities in value creation throughout the construction activities.

The steering forces though coming from different corners, have enabled project stakeholders to better understand the consequences of their work and their ability to influence project outcome. Typically cost, quality, schedule and safety are all positively influenced by consultants, contractors and developers when working collaboratively to come up with the best solution for the project.

### 5.1 TRENDS IN HIGH-RISE RESIDENTIAL DEVELOPMENT

In recent years, there have been notable improvements in the buildability of private sector projects, in particular high-rise residential development. More developers and designers are taking initiatives and making concerted effort together with the contractors to adopt more buildable design which facilitate better use of labour efficient method of construction.

Modern architecture being the trend in today's residential buildings emphasises on clean, simple and lineal forms of building expression. It has encouraged more extensive use of prefabricated system. Locally, the combined use of precast and cast in-situ concrete elements are commonly adopted by designer because of its considerable benefits in terms of aesthetics, function as well as speed of construction. Precast building components, in particular, façade walls and bay windows are used to a greater extent for their quality surface finishes which require minimal treatment. Some examples of more buildable solutions adopted in the private high-rise residential development are presented in the following sections.

## 5.2 EXAMPLES OF RECENT PROJECTS

### THE ESPARIS EXECUTIVE CONDOMINIUM

Buildability Features:

- Flat Plate with Precast Façade
- Precast Shear Wall
- Precast Household Shelter
- Precast Column and Beam
- Precast Internal Wall
- Precast Staircase
- Prefabricated Vertical Shaft

CLIENT:
City Developments Limited

ARCHITECT:
Team Design Architects Pte Ltd

STRUCTURAL ENGINEER:
Meinhardt (S'pore) Pte Ltd

MAIN CONTRACTOR (D&B):
Ando Corporation

### SAVANNAH CONDO PARK

Buildability Features:

- Precast Beam
- Precast Slab
- Precast Bay Window
- Dry Partition Wall
- Precast Staircase
- Use of System Formwork for External Wall

CLIENT:
City Developments Limited

ARCHITECT:
Axis Architects Planners

STRUCTURAL ENGINEER:
KTP Consultants Pte Ltd

MAIN CONTRACTOR (D&B):
Dragages Singapore Pte Ltd

## CASABLANCA


Buildability Features:

- Precast Slab and Beam
- Precast Façade
- Precast Bay Window
- Precast Internal Wall
- Precast Staircase and Planter Box
- Prefabricated Vertical Shaft

CLIENT:
Mediterranean Properties Pte Ltd

ARCHITECT:
DP Architects Pte Ltd

STRUCTURAL ENGINEER:
KTP Consultants Pte Ltd

MAIN CONTRACTOR (D&B):
Chiu Teng Enterprises Pte Ltd

## CHANGI RISE CONDOMINIUM

Buildability Features:

- Flat Plate with Precast Façade
- Precast Internal Wall
- Precast Staircase
- Prefabricated Vertical Shaft

CLIENT:
City Developments Ltd

ARCHITECT:
Axis Architects Planners

STRUCTURAL ENGINEER:
Parsons Brinckerhoff Pte Ltd

MAIN CONTRACTOR (D&B):
Ssangyong Engineering
& Construction Co Ltd

## GOLDENHILL PARK

Buildability Features:

- Flat Plate with Precast Bay Window
- Use of System Formwork for Column and Wall
- Table Form for Flat Plate
- Precast Staircase and Planter Box
- Prefabricated Vertical Shaft

CLIENT:
City Developments Limited

ARCHITECT:
ADDP Architects

STRUCTURAL ENGINEER:
LSW Consulting Engineers

MAIN CONTRACTOR (D&B):
Hyundai Engineering & Construction Co Ltd

## KERRISDALE

Buildability Features:

- Precast External Wall & Façade
- Precast Internal Wall
- Precast Staircase and Planter Box
- Prefabricated Vertical Shaft

CLIENT:
Allgreen Properties Limited

ARCHITECT:
Design Link Architects

STRUCTURAL ENGINEER:
HCE Consultants Pte Ltd

MAIN CONTRACTOR (D&B):
Kimly Construction Pte Ltd

## THE EQUATORIAL


Buildability Features:

- Precast Beam
- Precast Slab
- Precast Staircase
- Prefabricated Vertical Shaft
- Use of System Formwork for Wall

CLIENT:
City Developments Limited

ARCHITECT:
Team Design Architects Pte Ltd

STRUCTURAL ENGINEER:
KTP Consultants Pte Ltd

MAIN CONTRACTOR (D&B):
Dragages Singapore Pte Ltd

## NUOVO EXECUTIVE CONDOMINIUM

Buildability Features:

- Precast Beam
- Precast Slab
- Precast Façade
- Precast Internal Wall
- Precast Staircase
- Prefabricated Vertical Shaft

CLIENT:
City Developments Limited

ARCHITECT:
Architects Vista Pte Ltd

STRUCTURAL ENGINEER:
KTP Consultants Pte Ltd

MAIN CONTRACTOR (D&B):
Poh Lian Construction Pte Ltd

## TRELLIS TOWERS

Buildability Features:

- Precast Shear Wall with Flat Plate
- Single Integrated Wall Panels for Bathroom
- Precast Internal Wall
- Precast Staircase
- Prefabricated Vertical Shaft

CLIENT:
City Developments Limited

ARCHITECT:
APCO Architects & Town Planners Collaborative Pte Ltd

STRUCTURAL ENGINEER:
TY Lin South East Asia Pte Ltd

MAIN CONTRACTOR:
Shimizu Corporation

## PARK GREEN EXECUTIVE CONDOMINIUM

Buildability Features:

- Flat Plate with Precast Façade
- Precast Internal Wall
- Precast Balcony and Planter Box
- Precast Staircase
- Prefabricated Vertical Shaft

CLIENT:
NTUC Choice Homes Co-operative Ltd

ARCHITECT:
Chao Tse Ann & Partners Pte Ltd

STRUCTURAL ENGINEER:
P & T Consultants Pte Ltd

MAIN CONTRACTOR (D&B):
Tiong Seng Contractors Pte Ltd

## WOODSVALE CONDOMINIUM

Buildability Features:

- Precast Column
- Precast Beam
- Precast Slab
- Precast Staircase
- Curtain Wall Façade
- Use of System Formwork for External Wall

CLIENT:
Woodsvale Land Pte Ltd

ARCHITECT:
Consortium 168 Architects Pte Ltd

STRUCTURAL ENGINEER:
P & T Consultants Pte Ltd

MAIN CONTRACTOR (D&B):
Nakano S'pore Pte Ltd

## TANGLIN VIEW CONDOMINIUM

Buildability Features:

- Precast Column
- Precast Beam
- Precast Slab
- Precast Façade
- Precast Staircase
- Precast Internal Wall

CLIENT:
Far East Organisation

ARCHITECT:
TAA Architects Pte Ltd

STRUCTURAL ENGINEER:
KTP Consultants Pte Ltd

MAIN CONTRACTOR:
Chiu Teng/ Multiplex Joint Venture

# 6 Case Studies

# Case Study 1
## Park Green

### 6.1 PARK GREEN EXECUTIVE CONDOMINIUM

Fig. 6.1 – Artistic Impression of Park Green

#### 6.1.1 Background

Park Green is a executive condominium housing developments comprising two blocks of 17/18 storey and three blocks of 18 storey residential buildings with one basement carpark and communal facilities at Rivervale Link / Buangkok Drive / Sengkang East Avenue.

park green


Fig. 6.2 – Site Location

### Project Team

Developer: NTUC Choice Homes Co-operative Ltd

Main Contractor (Design and Build): Tiong Seng Contractors Pte Ltd

Architect: Chao Tse Ann & Partners Pte Ltd

Structural Engineer: P & T Consultants Pte Ltd

M&E Engineer: United Project Consultants Pte Ltd

Project Manager: SLF Management Services Pte Ltd

Precast Supplier: Fermold Pte Ltd

### Project Data

Contract Sum: $63.18 million

Contract Period: 36 months

Site Area: 17000 $m^2$

Gross Floor Area: 51000 $m^2$

Building Height: 55.5 m

## 6.1.2 Design Concept and Considerations

Based on the project objectives and assessment, the team had adopted the combined use of flat plate system with precast façade and wall elements for the main buildings of the development. Precast façades were extensively adopted as the load-bearing elements to support the load from the floors. Precast façade elements were detailed to serve as the finished exterior of the buildings as well as formworks for cast in-situ joints to form an efficient building envelope. With proper jointing details, most of the site work could be done internally without the need of external scaffolding system.

The architectural layout was kept simple yet functional to facilitate the use of precast elements. Other prefabricated components such as precast bay window, precast balcony, precast planter ledges, precast refuse chutes and precast staircases were integrated to the building system. Precision block wall was used internally to enhance buildability and to reduce construction time.

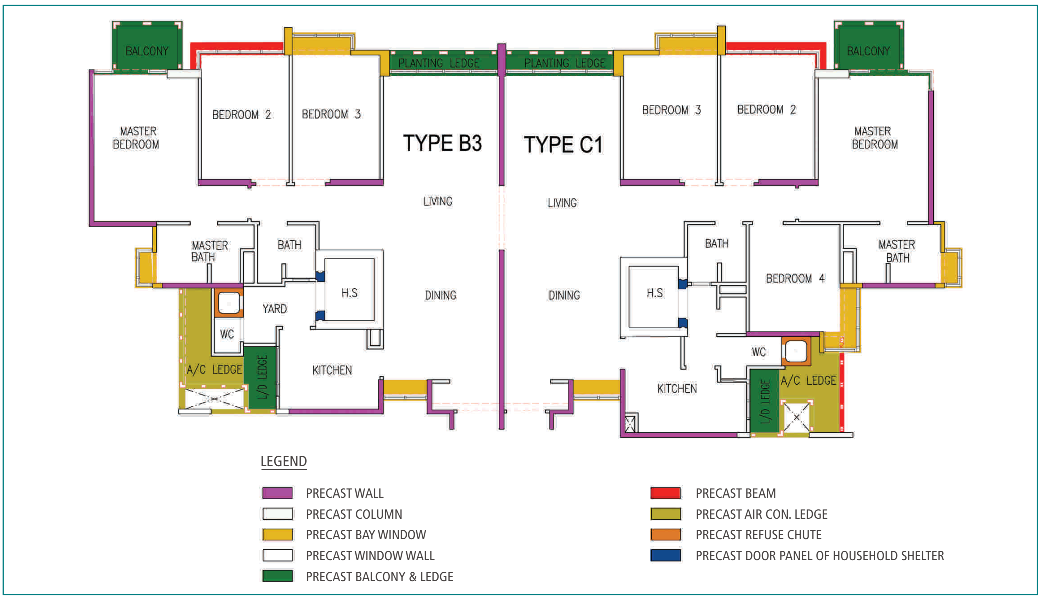



**Fig. 6.3 – Floor layout showing the location of precast elements**

The basement was designed as flat slab and the residential blocks were supported on piles. The 1$^{st}$ storey was designed as flat slab with transfer beam system.

**Fig. 6.4 – With proper jointing, the need for external scaffolding system was eliminated**

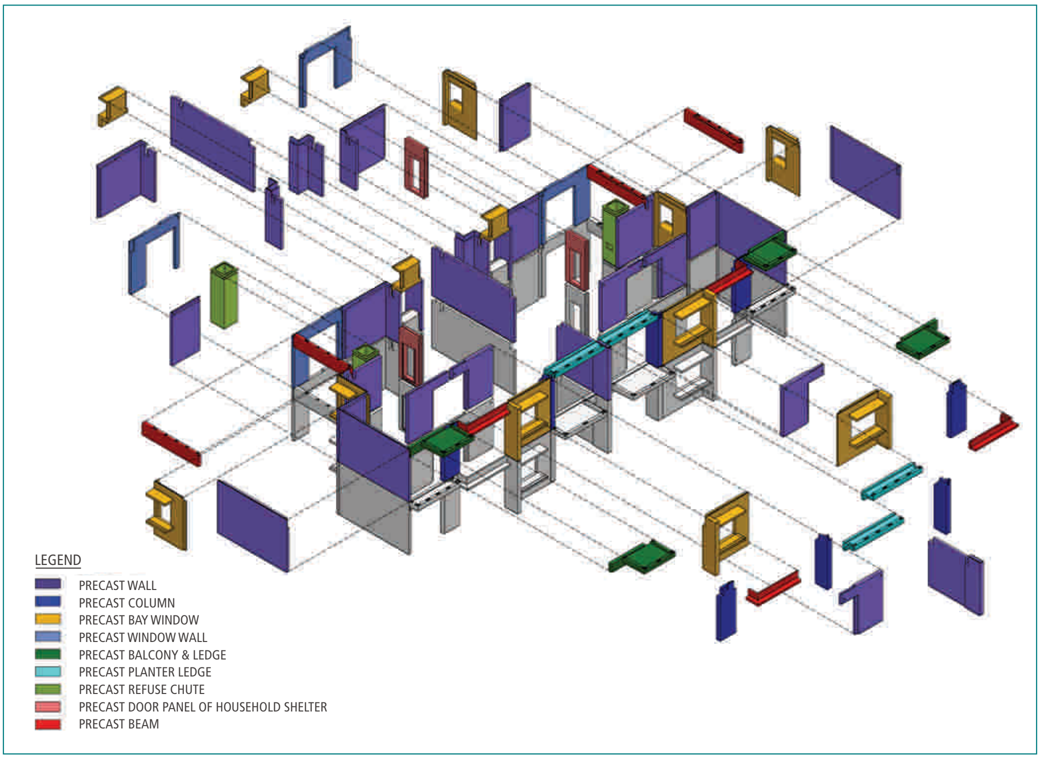



Fig. 6.5 – Isometric view of precast components used

Fig. 6.6 – Precast bay window

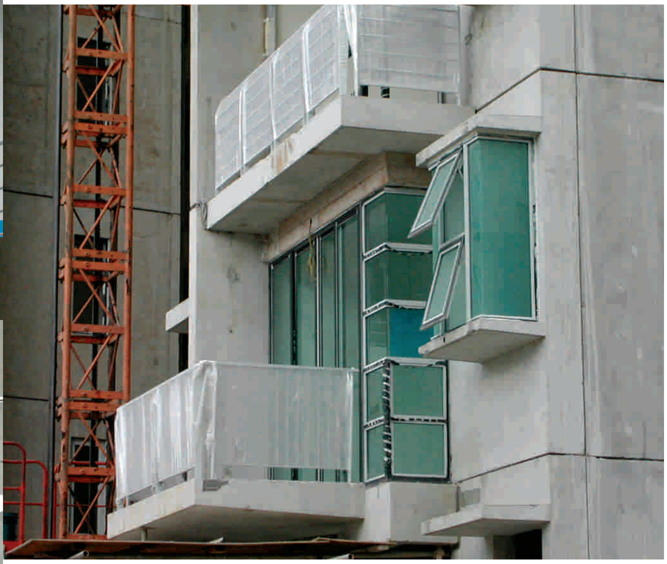


Fig. 6.8 – Precast balcony with metal railing

Fig. 6.7 – Precast air con ledges

### 6.1.3 Construction Considerations

The construction cycle achieved was about 8 days per floor. The typical floor cycle of construction involved was as follows:

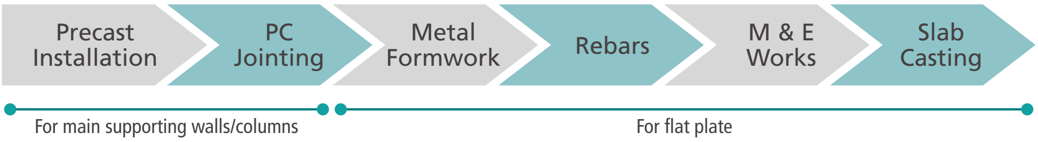



**Fig. 6.9 – Lowering of precast wall panel during installation**

As the façade walls were critical elements, the overall speed of construction was therefore dependent on the rate and manner at which these elements were installed. While it is preferred to cast and install big panels due to lower handling cost, constraints such as crane lifting capacity and transportation logistics would influence the panel division or sizing. In this project, maximum panel weight was limited to six tonnes.

**Fig. 6.10 – Preparation for casting of in-situ flat plate**

**Fig. 6.11 – On-site precasting for simpler components**

The team had adopted a combination of off-site and on-site precasting for different precast components. This was possible as there was sufficient space within centre of the development where swimming pools are situated. There were two main advantages of added site precasting. Firstly, by placing production next to place of installation the turnaround time from panel production to panel installation was reduced. The other advantage was that there would be direct savings as compared to off site precasting, in land and logistics costs. However, only simpler components were cast on site, the more intricate precast wall elements were done in the precast yard to ensure quality finishes.

### 6.1.4 Challenges Faced and Solutions

The key to providing aesthetically pleasing architectural expressions using precast technology lies with the design considerations for precasting. Essentially, precast solutions take advantage of repetitive use of mould. Different panel sizes, in particular precast facades have to be coordinated, modularised and integrated into the structural system for maximum benefits and minimum cost. Hence, the project team had to work hand in hand to achieve an efficient and cost effective building envelope that comes with intricate architectural expressions. Besides, good site management was of utmost importance to ensure that the construction processes were well co-ordinated. Requisite precast panels had to be made available on time for installation to pre-empt delays to subsequent site activities.

**Fig. 6.12 – Contemporary clean-cut design**

**Fig. 6.13 – Use of precast façade elements as building envelope**

As the building was designed with precast façades as the envelope and supporting structure, the precision and accuracy of these facades became important. The out of tolerance if undetected, may result in problems in connecting the precast façade panels at later stage. Hence, there was a need for greater accuracy for precast façades at design and during installation. Besides, the locations of the M & E services within these walls, sizes and locations of windows, skirting etc had to be predetermined at an early stage for prefabrication as well as to pre-empt any misalignment during installation.


**Fig. 6.15 –** **Recesses incorporated in precast wall to conceal M & E services at later stage**

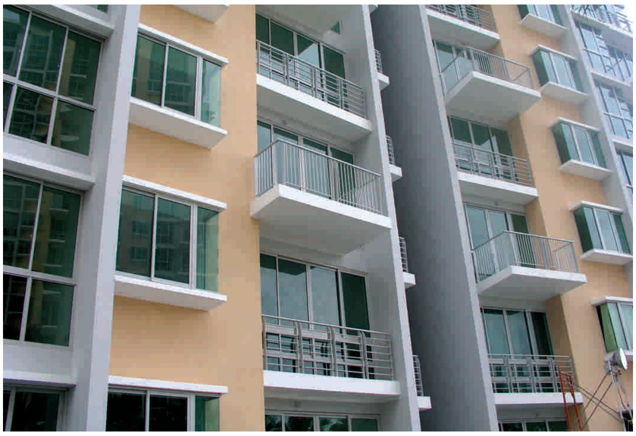


**Fig. 6.14 –** **Precast balcony and planter box at alternate floor level**

The elimination of external scaffolding system had imposed some limits on the availability of work access. Hence, it was important for the designer to work with the builder on the connection details and installation method for some external components such as precast balcony and planter ledges.

**Fig. 6.16 –** **Use of precast staircase and landing**

As a whole, the team had adopted an integrated approach in the design and construction. Architectural, structural, M & E and interior finishing requirements were carefully worked out and integrated in the construction process. This resulted in better design functionality and higher site productivity. The details of the precast components were meticulously crafted taking into consideration all factors including logistics, quality standards and site management. With the dynamic involvement of the project stakeholders, high buildability and good quality workmanship of the building development were successfully attained using precast technology.

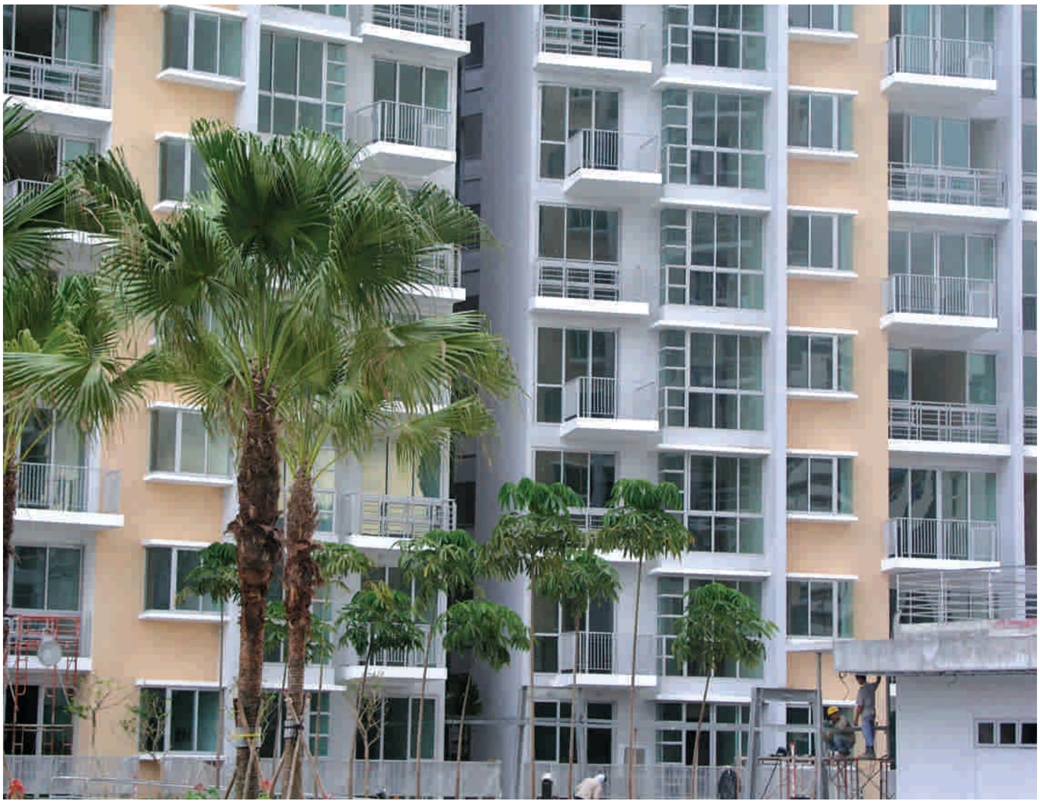


**Fig. 6.17 – High buildability and good quality workmanship attained using precast technology**

# Case Study 2
## The Jade

## 6.2 THE JADE

### 6.2.1 Background

The Jade is a 31-storey building with one basement located at Bukit Batok Central. It is bounded by Bukit Batok MRT station, the Westmall and HDB flats.

Fig. 6.18 – Artist Impression of The Jade

Fig. 6.19 – The Jade under construction
Two tower cranes were deployed
for the site construction

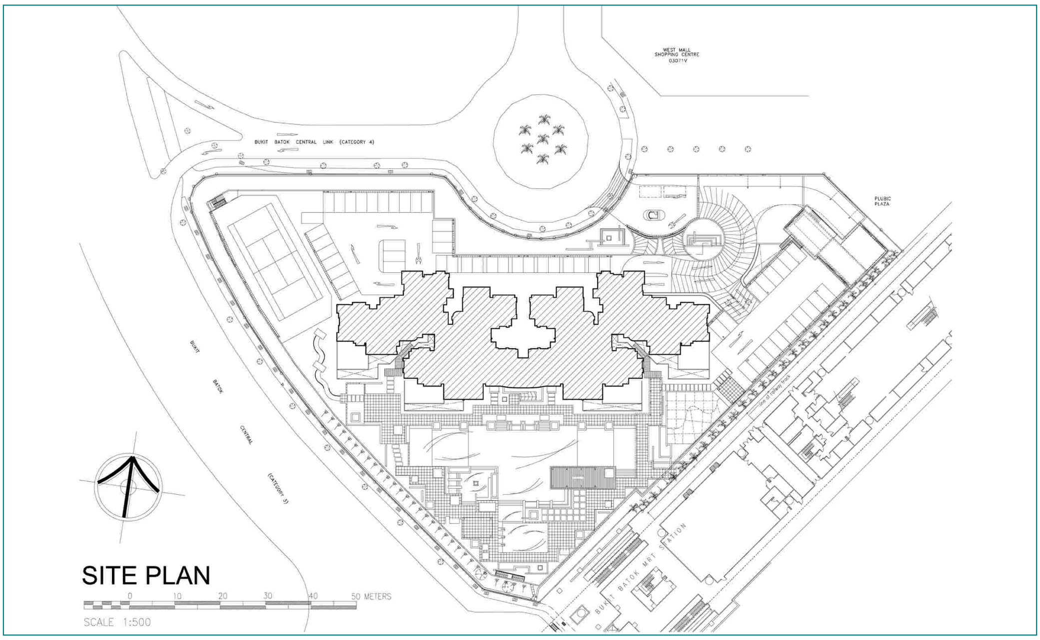



**Fig. 6.20 – Site Location**

### Project Team

Owner: Sim Lian (Bukit Batok Central) Pte Ltd
Main Contractor (D&B): Sim Lian Construction
Architect: Design Link Architects
Structural Engineer: Engineers Partnership
M&E Engineer: Beca Carter Holling Ferner
Precast Supplier: Poh Cheong Pte Ltd

### Project Data

Contract Sum: $43.4 million
Contract Period: 29 months
Site Area: 8705.5 $m^2$
Building Area: 1735 $m^2$
Plot Ratio: 3.5
Total Floor Area: 30489.25 $m^2$
Building Height: 120 m

## 6.2.2 Challenges Faced

The constraints posed by the site were as follows:

- The site area was small with very limited working space
- The site was very close to the existing MRT line
- The earth was generally made up of rock bed

The proximity of the MRT station posed a great challenge as stringent criteria and restrictions are imposed by LTA. Monitoring devices need to be installed to ensure that the existing MRT structures are not affected (or damaged) by the on-going construction. The tower cranes were also not allowed to tower over the MRT station for safety reasons, which posed some restrictions on the crane usage and boom length.

### 6.2.3 Design Concept and Considerations

In view of the constraints, the project team had initially decided to adopt in-situ flat plate system supported on cast in-situ columns with brickwall. With more in-depth study, the use of precast facades was found to be a good and viable alternative as

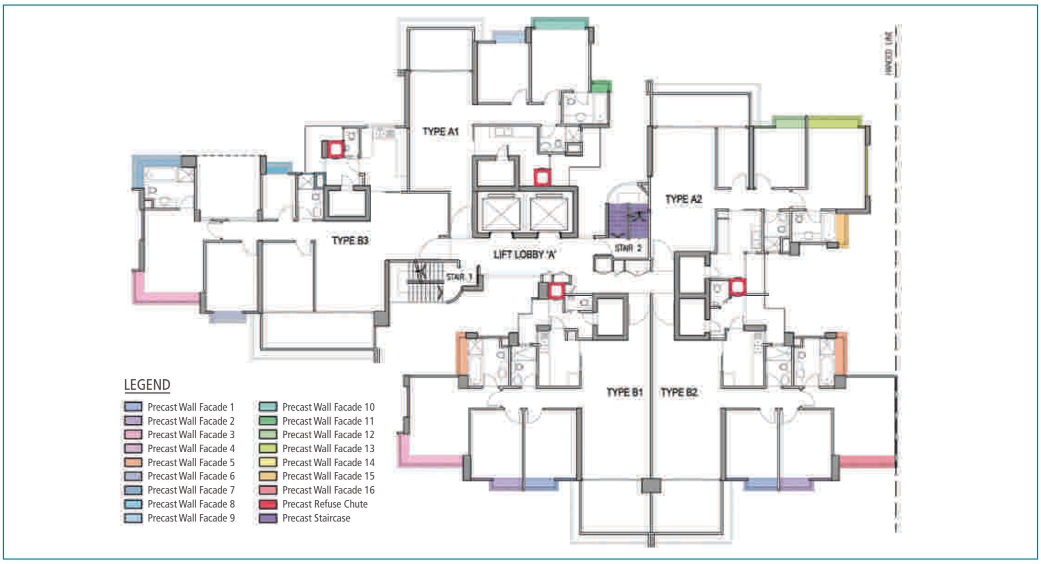



**Fig. 6.21 – Simplicity in Layout**

compared to the use of brickwall. The team had finally opted to use precast facades so as to achieve better quality wall finishes on the exterior of the building as well to reduce construction time, noise and inconvenience to the general public. The layout plan was kept simple and floor heights were repeated to facilitate the use of precast elements. Prefabricated components such as precast refuse chutes and precast staircases were also used.

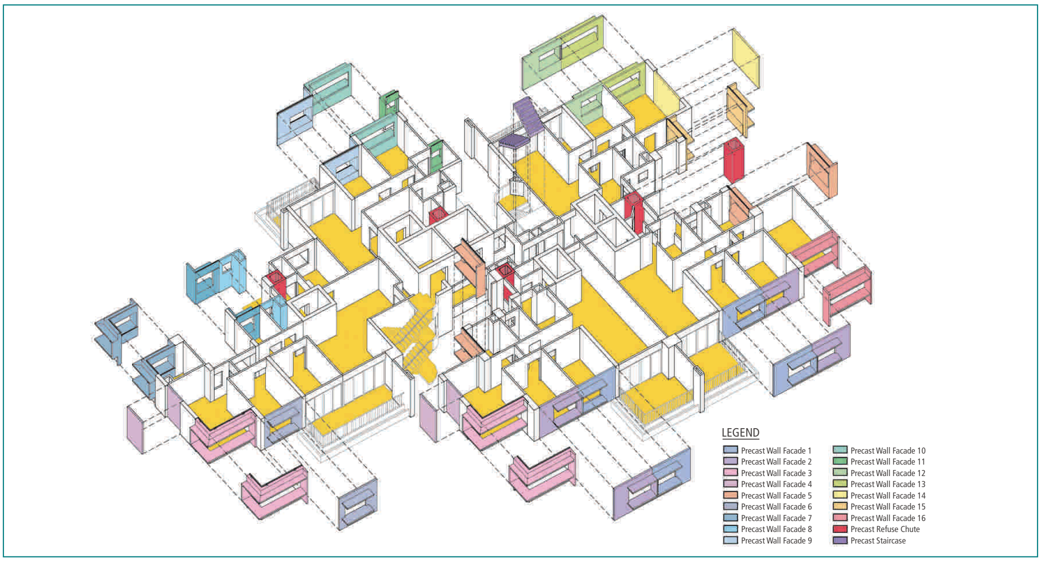



**Fig. 6.22 – Isometric view of the precast façades used**

The basement was designed as flat slab supported on piles and the residential blocks were all founded on piles.

For this project, the precast facades were non load-bearing. They were designed to serve as the finished exterior of the building as well as forms for cast in-situ columns whereby formwork could be eliminated.

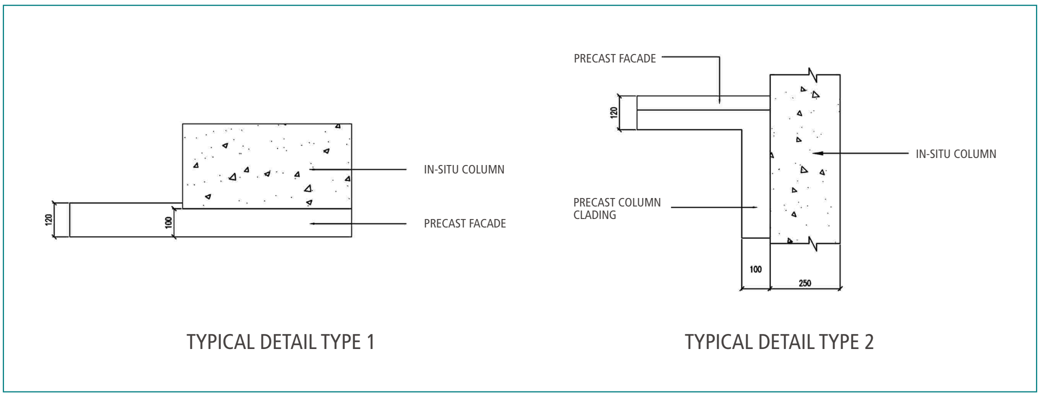



**Fig. 6.23 – Examples of precast façade as the form for cast in situ column**

As for the vertical and horizontal joint treatment, the architect had adopted the following vertical waterproofing details between the precast façade with in-situ column for Detail Type 1 & 2.

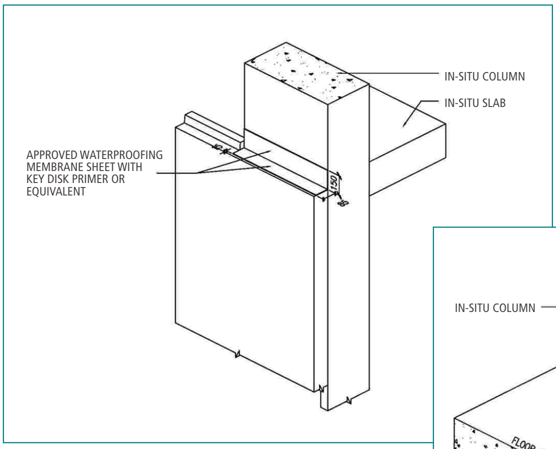



**Fig. 6.24 – Isometric View for Type 1**

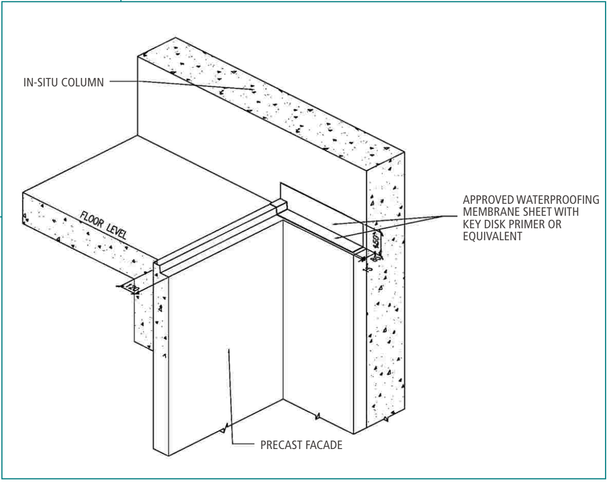



**Fig. 6.25 – Isometric View for Type 2**

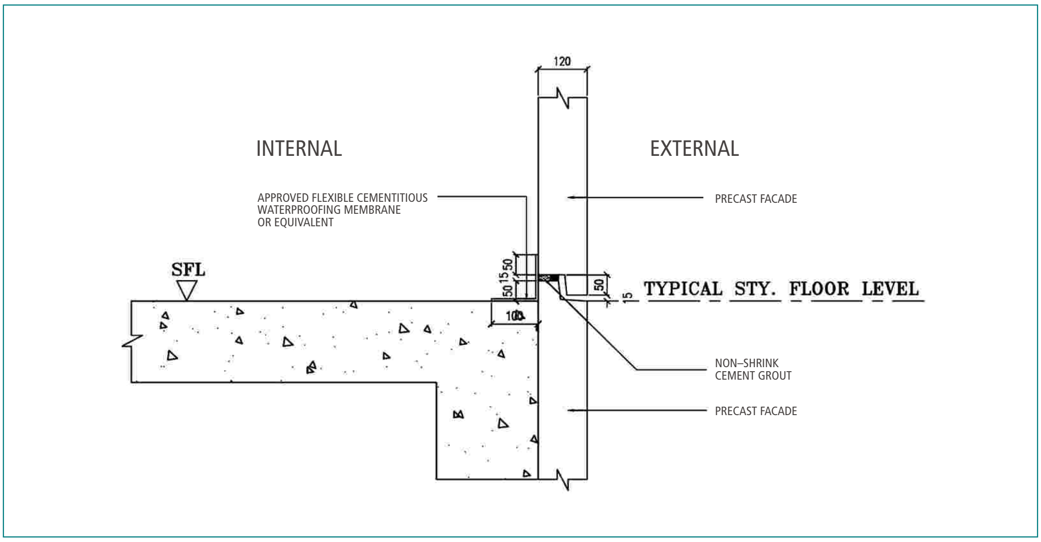



**Fig. 6.26 – Horizontal Waterproofing Details**

## 6.2.4 Construction Method and Sequence

Metal formworks were used for the building construction. The construction cycle achieved was about 10 days per floor. The combined use of precast elements such as façades with flat plate would entail requirements pertaining to precast panel installation to be incorporated in the planning. For this project, the team had adopted site casting for simpler, flat wall panels and off-site casting for more intricate façade panels. The production and delivery schedule of the precast elements were planned and blended with the site progress for the in-situ flat plates and columns.

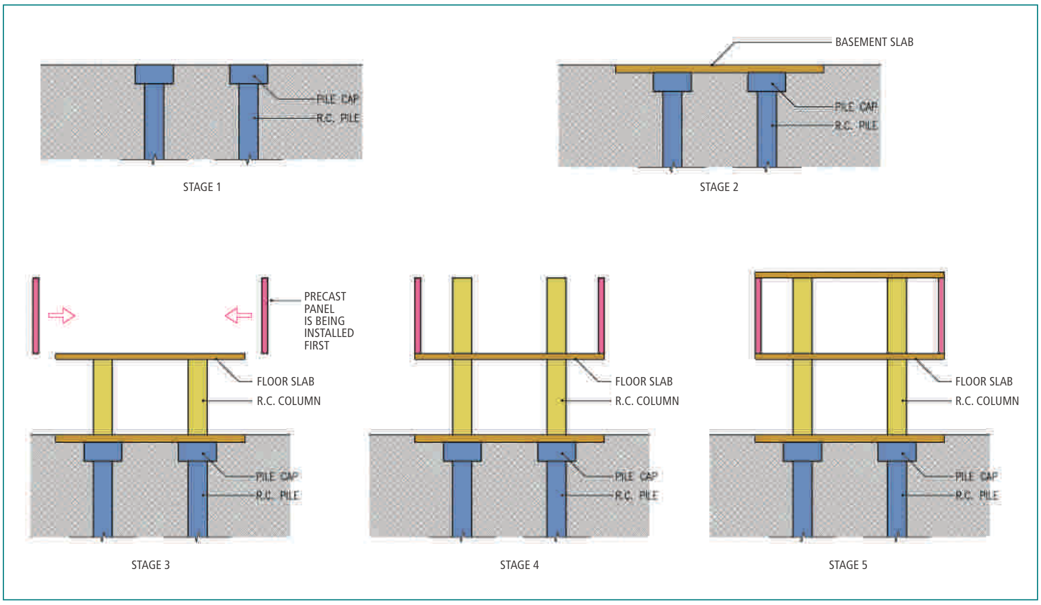



**Fig. 6.27 – Sequence of construction**

Twelve-tonnes crane was used for lifting the precast components of about 4.5 tonnes. Due to the restriction of the swing of the boom of the tower crane, the crane could only be above the completed structures by two floors.

**Fig. 6.28 –** **Installation of different non load-bearing precast façade wall elements**

**Fig. 6.29 –** Overview of the building envelope using non load-bearing precast façades

**Fig. 6.30 –** Closer view of the building completed

The team had successfully adopted a combined use of cast in-situ columns with non load-bearing precast facades as the external envelope of the building. The typical external brickwall concept was abandoned for the better wall finishes that could be achieved using precast facades. With good site planning and co-ordination, the casting and delivery of the precast façade elements were done in tandem with the progress of in-situ construction. The use of precast facades as integrated formwork for cast in-situ columns had also reduced the construction time thereby achieving higher productivity and quality for the project.

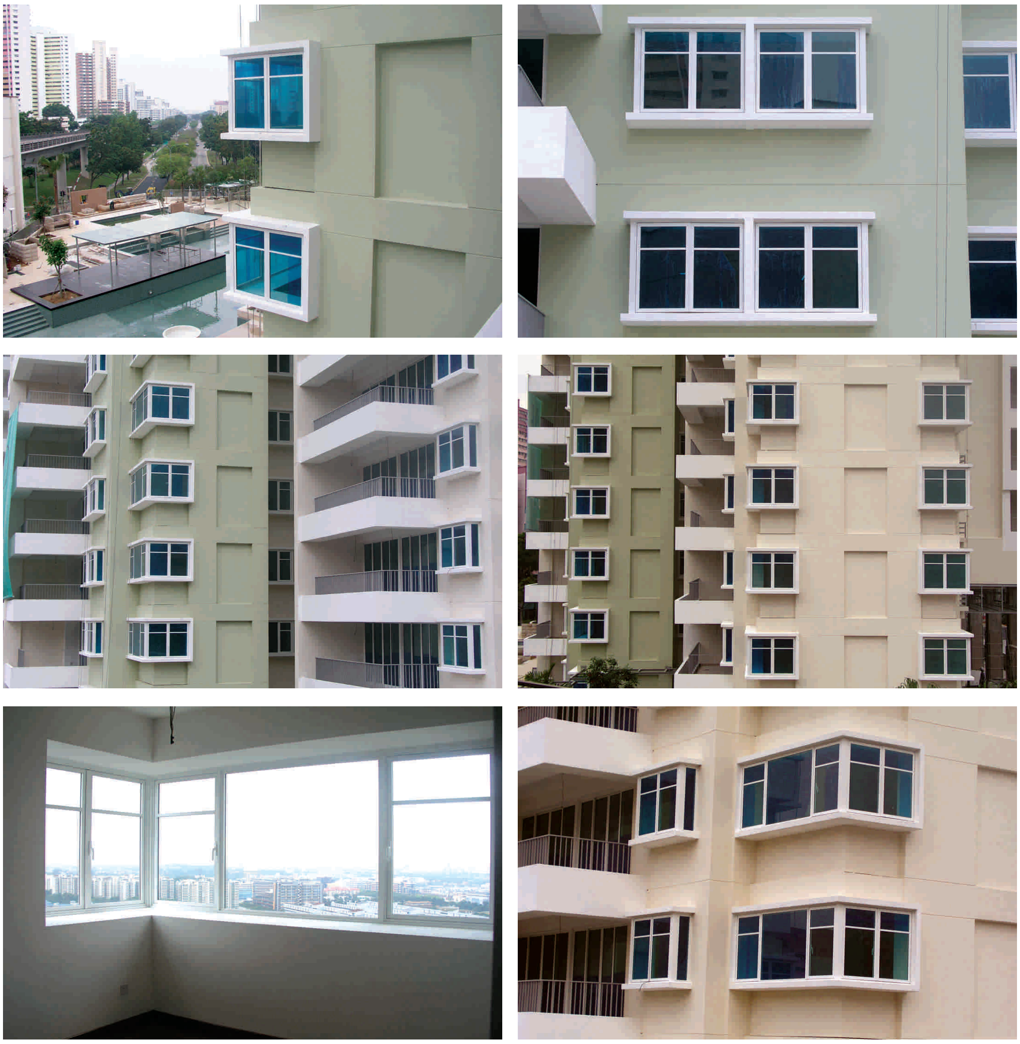


**Fig. 6.31 – Better wall finishes can be achieved using precast façades comprising window wall units and bay windows**

# Case Study 3
## Newton.GEMS

## 6.3 NEWTON.GEMS CONDOMINIUM

### 6.3.1 Background

Newton.Gems is a 30-storey residential development with a basement at Newton Road/Lincoln Road. This project comprises two identical towers with a total of 190 units.

Fig. 6.32 – Artistic Impression of Newton.GEMS

Fig. 6.33 – Newton.GEMS under construction

Fig. 6.34 – Computer modelling of Newton.GEMS

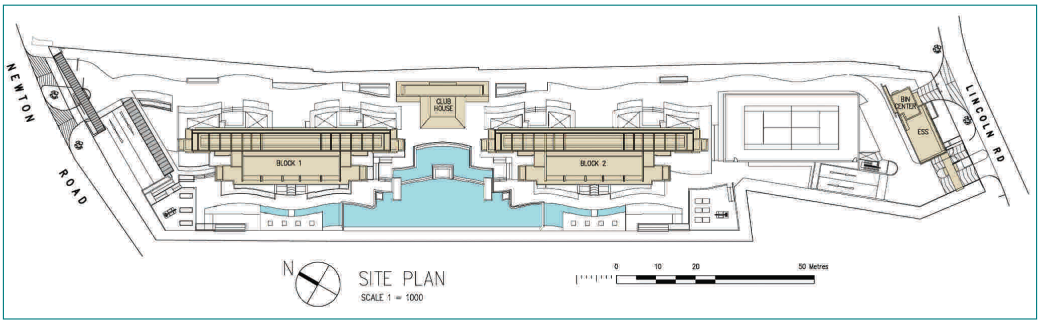



**Fig. 6.35 – Site Location**

## Project Team

Owner: Great Eastern Life Assurance Pte Ltd
Main Contractor (D&B): Shimizu Corporation
Architect: Architects 61 Pte Ltd
Structural Engineer: Meinhardt (Singapore) Pte Ltd
M&E Engineer: Squire Mech (Pte) Ltd
Precast Supplier: Fermold Pte Ltd

## Project Data

Contract Sum: $61.8 million
Contract Period: 26 months
Site Area: 9754.10 $m^2$
Total GFA: 28,818.97 $m^2$
Building Height: 120 m

## 6.3.2 Challenges Faced

The site was bounded by private residential buildings and next to the Royal Hotel. The proposed building is rectilinear with length to width ratio of about 4 and has an aspect ratio (that is height/width ratio) of 8.15. Narrowest and widest section of the building itself measured about 6m and 14m respectively at the typical floor. Apart from the intricate design of such a slender building, the site constraints had posed many challenges to the project team. They were: -

**Fig. 6.36 – Slender elevation of the building**

- **Limited site access**

The site generally had very limited site access. Available access was along narrow strip of 6m to 8m clear space on two sides of the building. Coupled with ongoing basement construction activities, the availability of access were at times limited to one side only to be used for panels delivery as well as for the use of other heavy vehicles such as ready mix trucks.

Fig. 6.37 – Limited site access for panel delivery

- **Potential environmental disturbance to local communities**

Being "sandwiched" between nearby residential units and a hotel, there was environmental impact consideration such as noise and dust to be taken into account. Conventional metal formwork system would generate relatively high noise level during fixing, casting of in-situ concrete as well as striking of formwork which may pose some limits on working hours and hence affect the site progress.

### 6.3.3 Design Concept and Considerations

With the site constraints and design complexity, the team had worked together to blend an optimal use of precast concrete components with cast in-situ elements to overcome these limitations. Maximum prefabrication off-site was intended to enable much work to be done with minimum working space at site. The adoption of precast façade and appropriate joint details had enabled the installation of precast panels to be done from building interior, eliminating the need to have external scaffolding. With less wet trades and debris generated using prefabrication, more clear space could be used for the critical access. Besides, noise generated during precast panels installation was usually within acceptable level, which would help to minimise disturbances to neighbouring occupants.

Fig. 6.38 – External scaffolding is not required for full precast façades

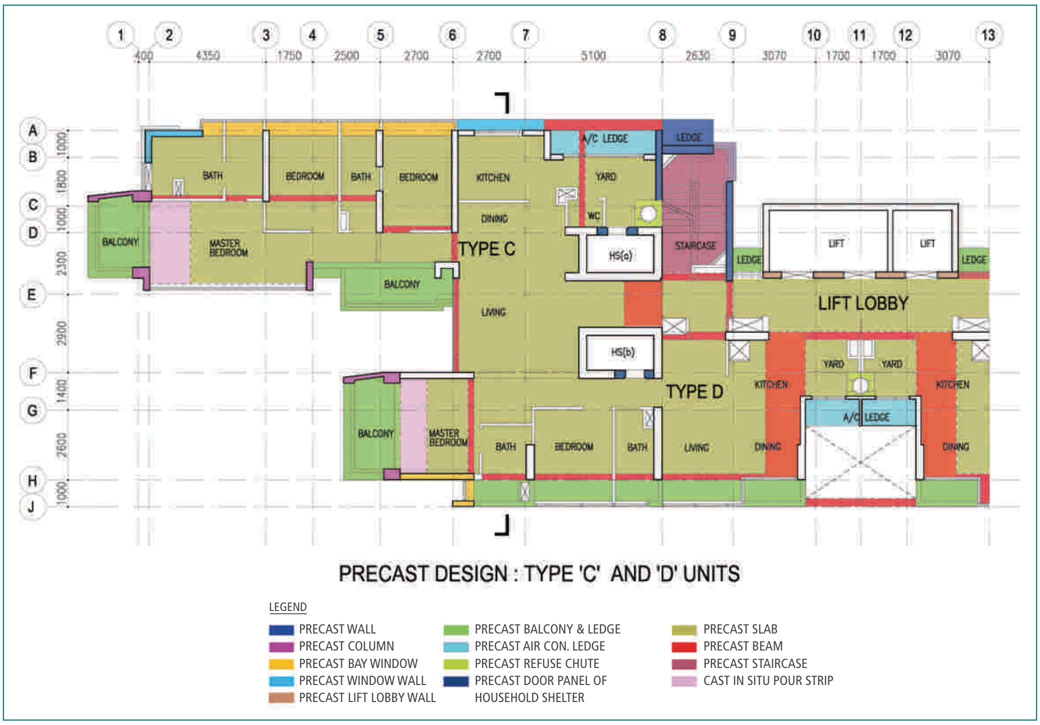



**Fig. 6.39 –** **Floor layout showing the different precast concrete components used**

- ## Vertical Precast Concrete Components

Cast in-situ columns and shear walls were designed and located on the interior of building for structural stability. Such stability was further enhanced using coupled shear walls via coupling beams to transfer shear. Precast load-bearing elements including columns, shear walls, bay windows and staircase cores were adopted to form the building envelope supporting structures. Other vertical components such precast lift lobby wall panels, household shelters wall panels with door openings, and precast refuse chutes were used to integrate with the cast in-situ elements.

**Fig. 6.40 –** **Bay window integrated with load-bearing vertical elements**

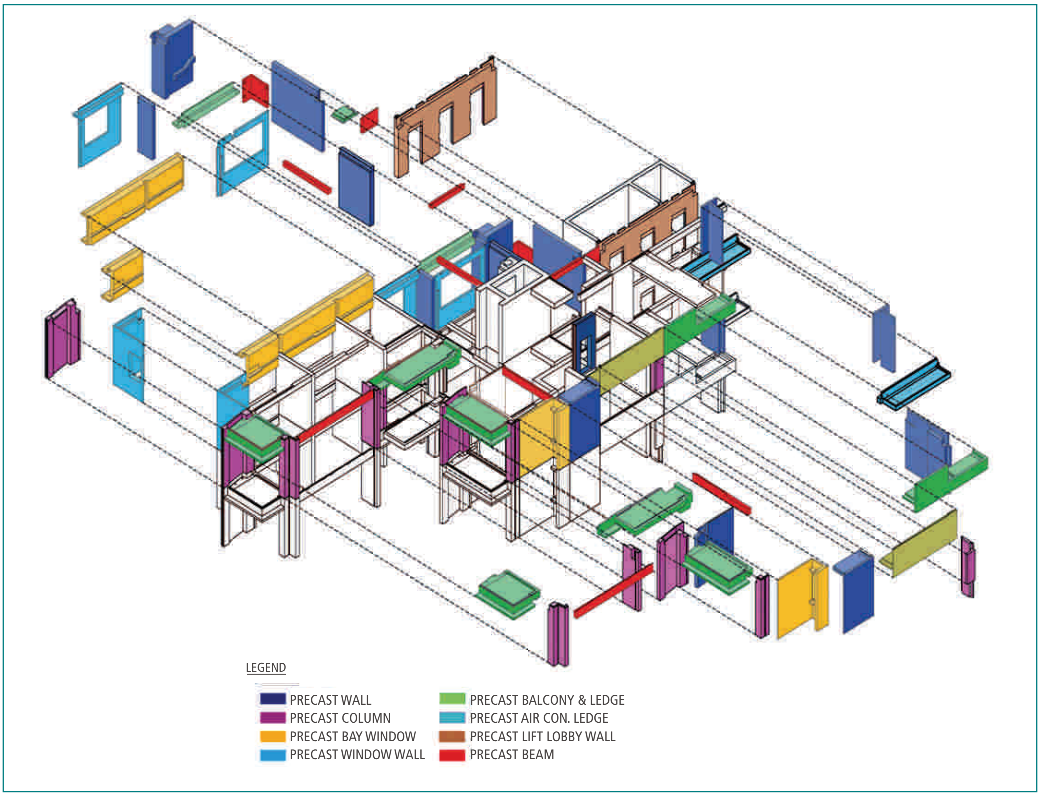



**Fig. 6.41 – Isometric view of precast building components used**

- ### Horizontal Precast Concrete Components

As vertical elements were not aligned in X-Y directions, coupled with drops as well as cantilevers at building exterior, transfer of horizontal floor loads would have to be done using floor beams. These beams served to stiffen horizontal plate for lateral resistance of building. Almost the entire horizontal elements were precast; precast beams (including bay window spandrel and coupling beams), precast full slabs and half slabs frames into the columns and walls system. Other horizontal components consisting of precast balconies, ledges parapets, down hang beams, sun shading ledges, staircase landings and flights were also used.

**Fig. 6.42 – Precast beams profiled with drop level**

**Fig. 6.43 – Non load-bearing window wall integrated with beam to form an enclosed window panel**

- **Variety of Exterior Face Shapes, Profile and Groove Line Details**

Exterior vertical load bearing elements were profiled with recesses to cater for aluminium curtain walls and windows interface. Likewise, exterior horizontal elements including bay windows spandrels were also profiled for weather protection around the window joints. By using precast system, it would be easier to produce profiled panels to finished dimensions by designing moulds that allows for projecting ledges to be cast with mould face-down. Vertically cast methods as necessitated using in situ construction would be cumbersome, and frequently honeycombing occurs around deeply profiled edges and recesses unless formworks are intricately designed.

**Fig. 6.44 – The fabrication of the precast mould takes into account the blockouts, recesses, groove lines etc. to create the necessary profiles and eliminate "re-work" at site**

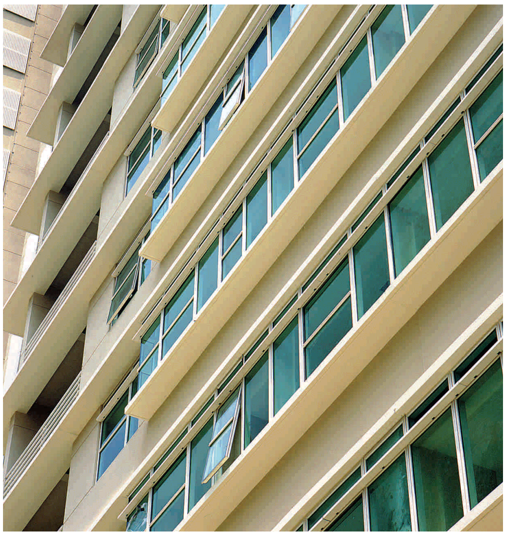


**Fig. 6.45 – Deep profiled precast bay windows, sun-shading ledges for aesthetic and functional purpose**

- **High Level Roof Trellis with Intertwined Features**

The roof level trellises or crown structure measured approximately 156m from the roof level. With a narrow strip of about 6m footprint of floor slab, it would have been a daunting task to put up formwork support and bracing system for constructing high level in-situ columns and trellises without external scaffolding system. The team had adopted the use of precast concrete components to do away with such need. The whole roof structure was fully prefabricated and erected in planned sequence.

**Fig. 6.46 – Photo showing part of the crown structure at about 15 m above the building roof level**

### 6.3.4 Construction Considerations

The two towers were almost identical, with minor variations at some corners of a few floors. Based on the configuration of floor layout and the maximum tower crane lifting capacity of 12 tonnes at 20m radius, precast panels were designed to the maximum size and within the transportable limit. Heaviest components used weighed 11.5 tonnes.

Crane time availability was critical as precast components were used for almost the entire building, except for some shear walls and internal column. For this project, a total four (4) tower cranes were used. At the peak of construction, the cycle time was about 6–8 days per floor. Other than installation of panels, major crane usage during construction involved was the casting of in situ walls and columns. Hence, segregation of these two activities within the same zone requires careful interfacing work plan. For example, when panel installations were carried out at one construction zone, in-situ work activities that do not require the usage of crane could be scheduled for the other areas, to ensure smooth continuity of works for different trade.

**Fig. 6.47 –** Two cranes for each block

In this project, most of the floor slab elements were precast full slabs so that there would be minimal in-situ concreting works. This method allowed for small work units

**Fig. 6.48 –** The mould for the casting of precast full slab. Rebars installed before casting

**Fig. 6.49 –** Casting of pour strip after installation of precast floor slab

to be carried out simultaneously within the same floor, as the floor plate was immediately usable upon panel installation as working platform. The panel jointing work can be divided into several discrete locations.

The precast panel installation followed the conventional sequence of work: vertical elements were installed, and propped followed by horizontal elements installation. Except for some non-structural elements, most panels are connected through wet joints to ensure water tightness control. Precast works precede in situ works so as to allow interfacing sections to be cast together with in situ concrete.

For M&E services, conduits and cast in items for socket outlets were cast into the panels. Services connections were provided for in the false ceiling space. In this way, there was no cast-in conduits required within the precast full slabs. This eliminate the risk of conduits' damage by drilling works during provision of props' anchorage to floor slab for vertical panel installation.

Overall, the project team had successfully integrated the use of prefabrication with cast in-situ construction.  Good design co-ordination, construction method and site management right from the conceptual stage had enabled them to realise the full benefits of precast works.

**Fig. 6.50 – The integration of prefabrication and cast in-situ construction**

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