Building Framework

Floor Slab with Precast Façade System

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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.

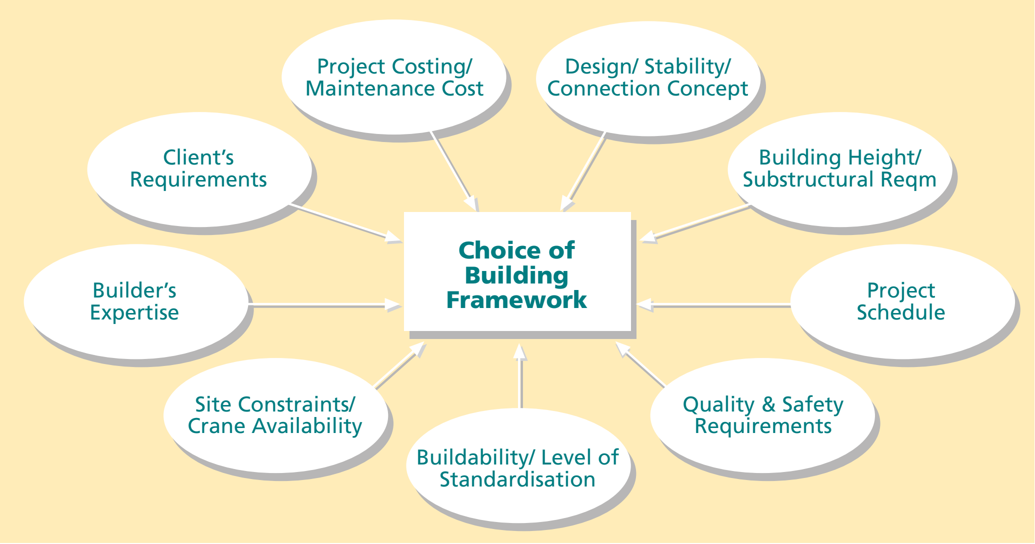


Fig. 1.1 – Factors influencing the choice of building framework

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

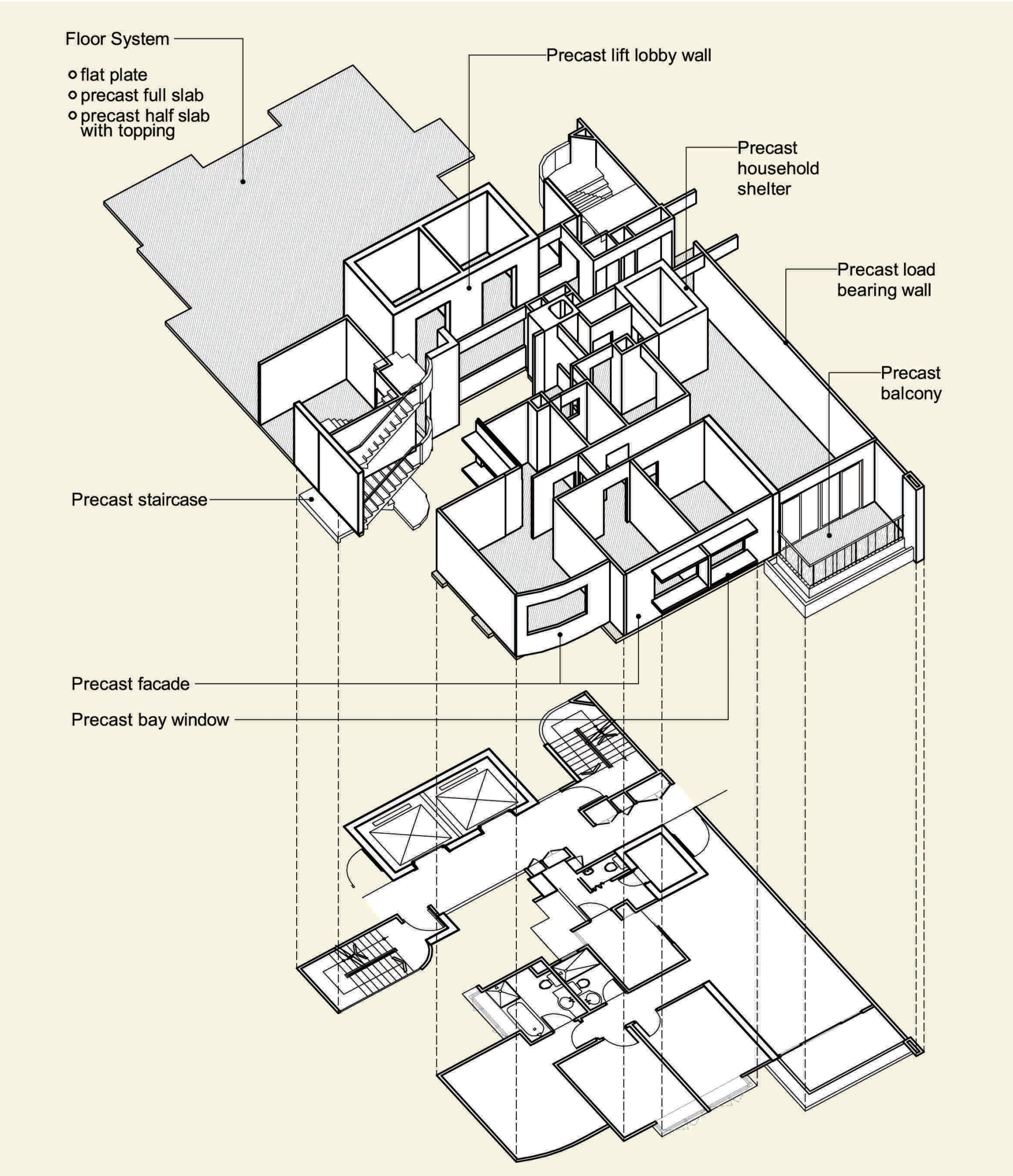


Fig. 1.2 – Example of a typical apartment unit using floor slab with precast loadbearing wall and façade system

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.

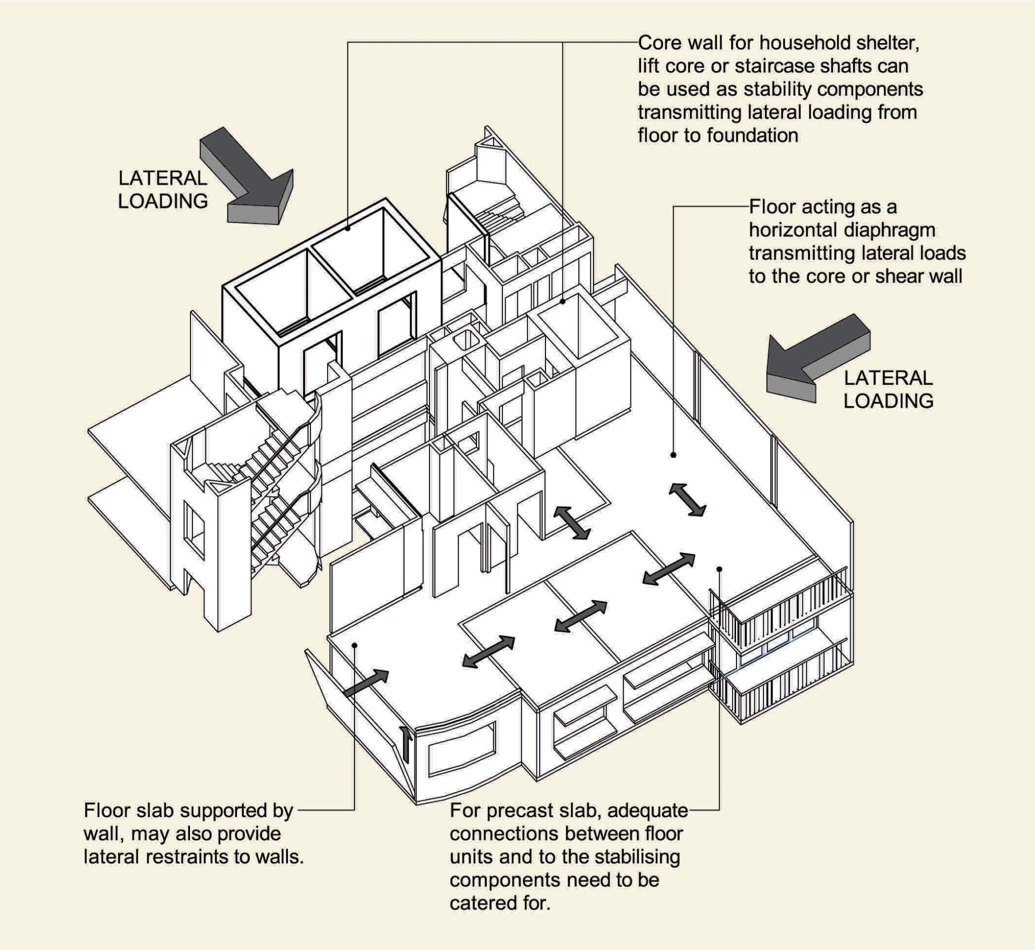


Fig. 1.3 – Stability of building provided by core walls and floor elements

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 • No beam required • Simplified and efficient formwork system can be deployed • No special provision for diaphragm action required • Services can be incorporated readily	• Formwork and propping required • Difficult to strip forms within rooms
Precast Full Slab	• Flat soffit with good finish • No formwork required • Minimum wet trade • Fast erection	• Connections may be more complicated • Greater attention needed for waterproofing and diaphragm action • Building services in slab require earlier planning and co-ordination
Precast Half Slab with Topping	• Flat soffit with good finish • Minimum formwork • In-situ topping provides good waterproofing and horizontal diaphragm action • Connections details simplified • Services can be readily incorporated in topping	• More propping required • Limited space for building services • 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.

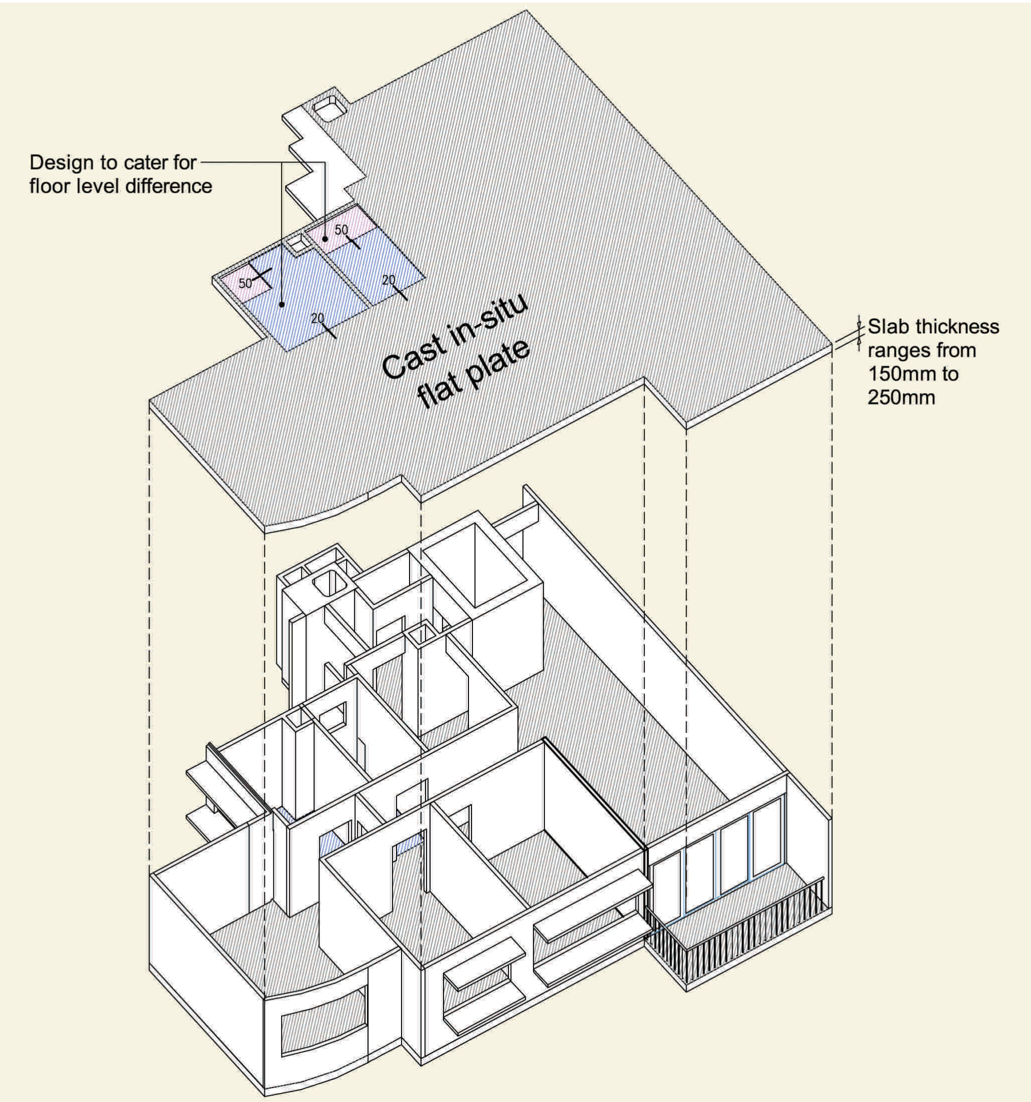


Fig. 1.4 – Use of in-situ flat plate as floor system

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.

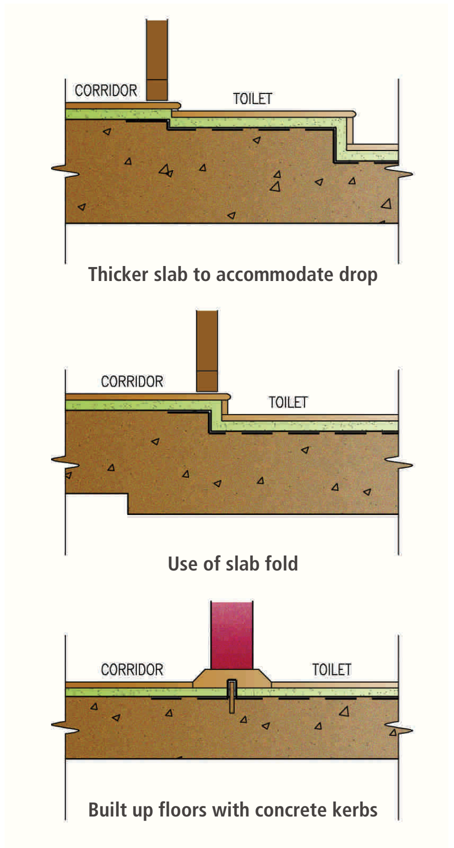


Fig. 1.5 – Provisions for floor level difference

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.

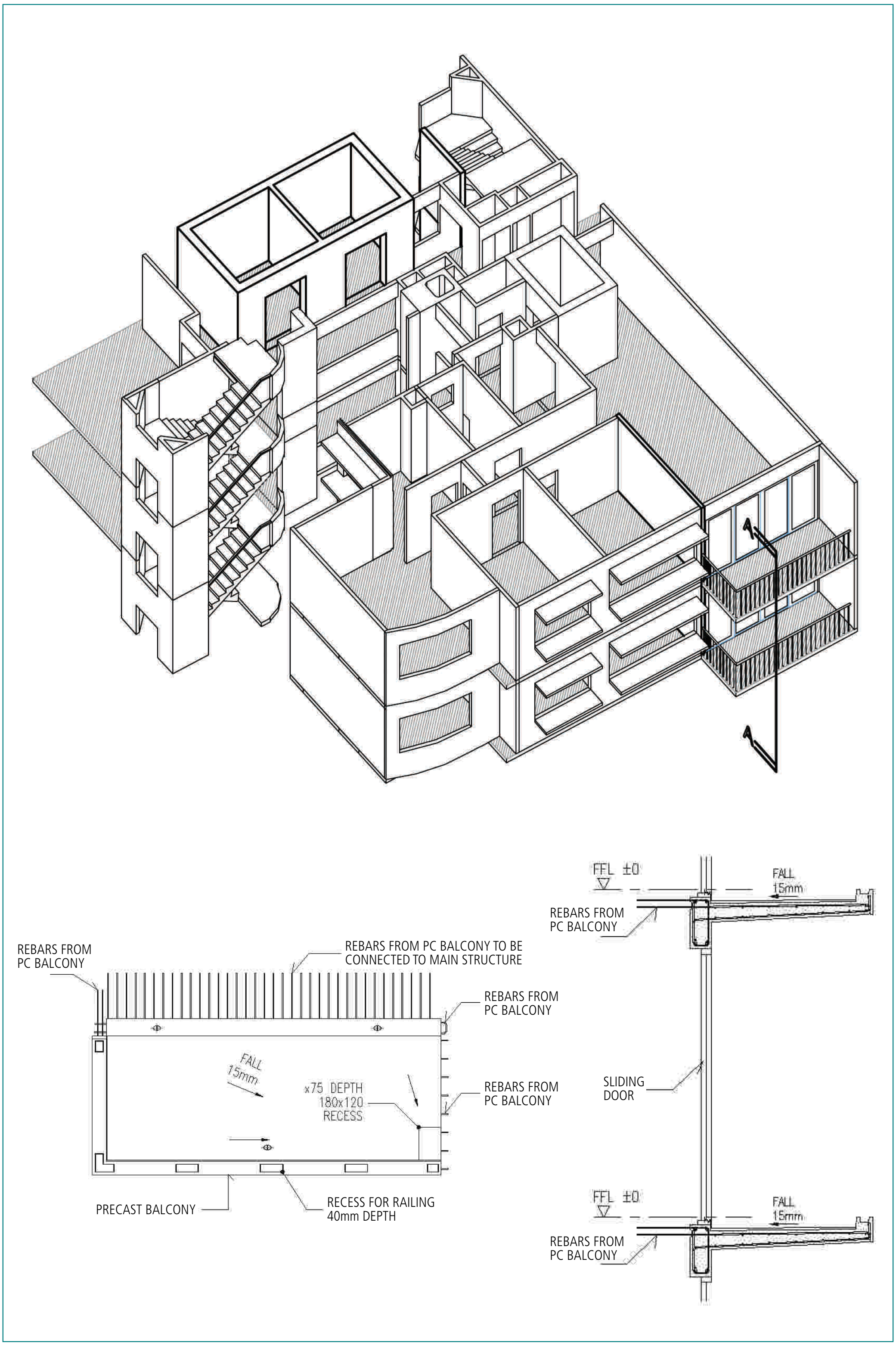


Fig. 1.6 – Precast balcony details

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.

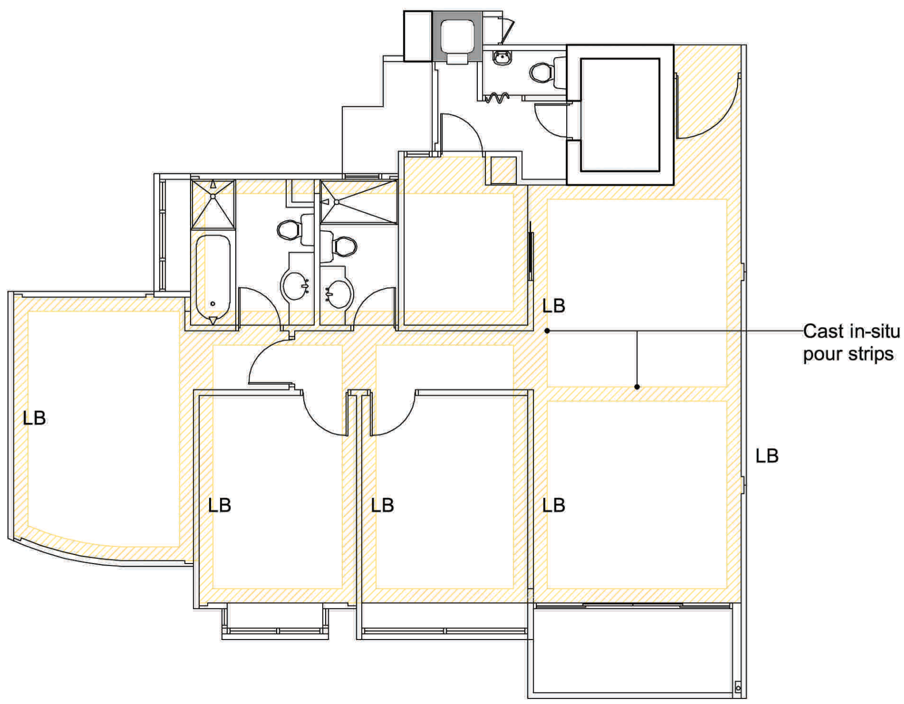


Fig. 1.7 – Layout using precast slab supported by load-bearing walls

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

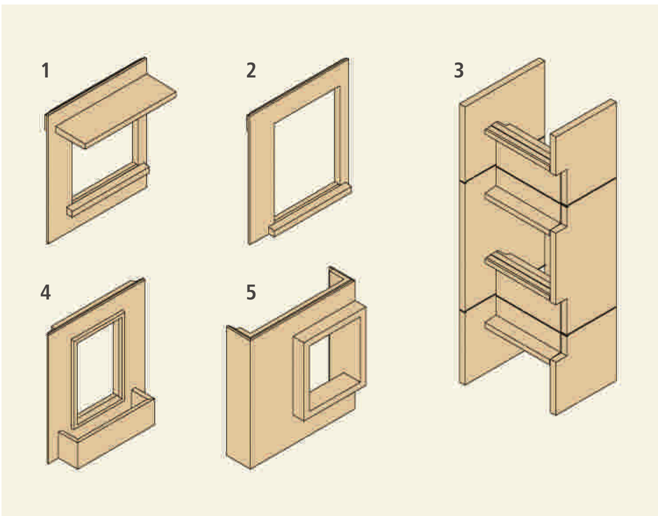


Fig. 1.9 – Examples of precast façades in different forms

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.

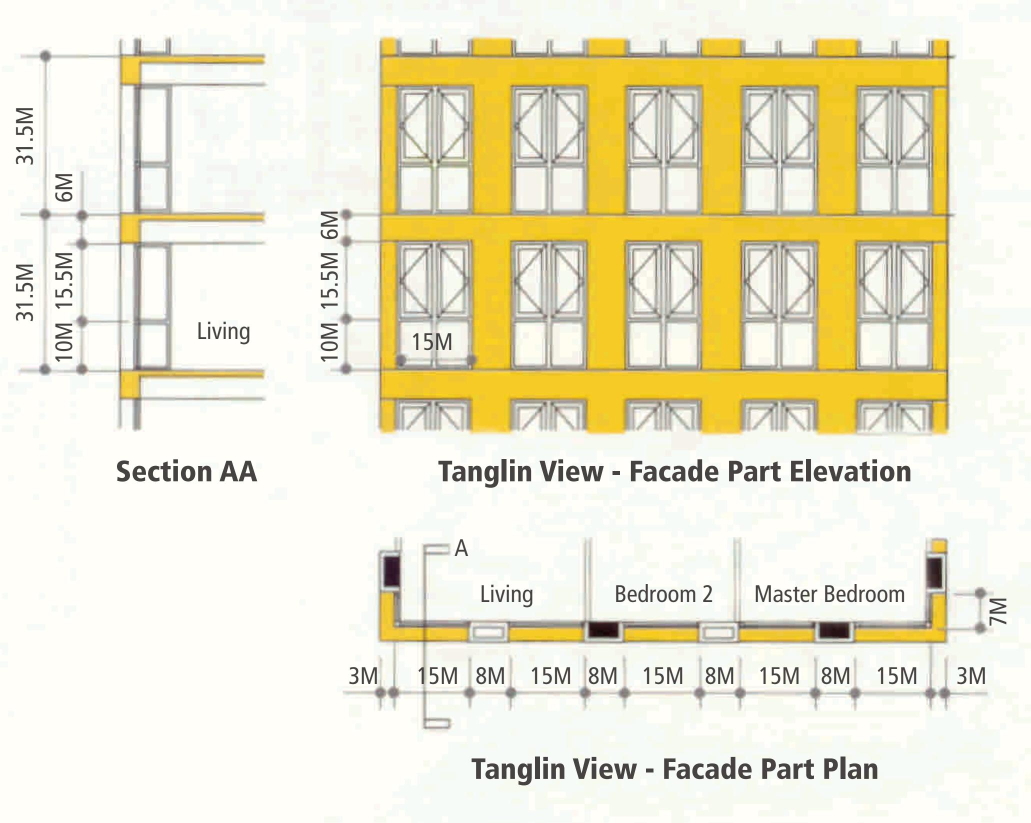


Fig. 1.10 – Modular grid system used for building façade

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

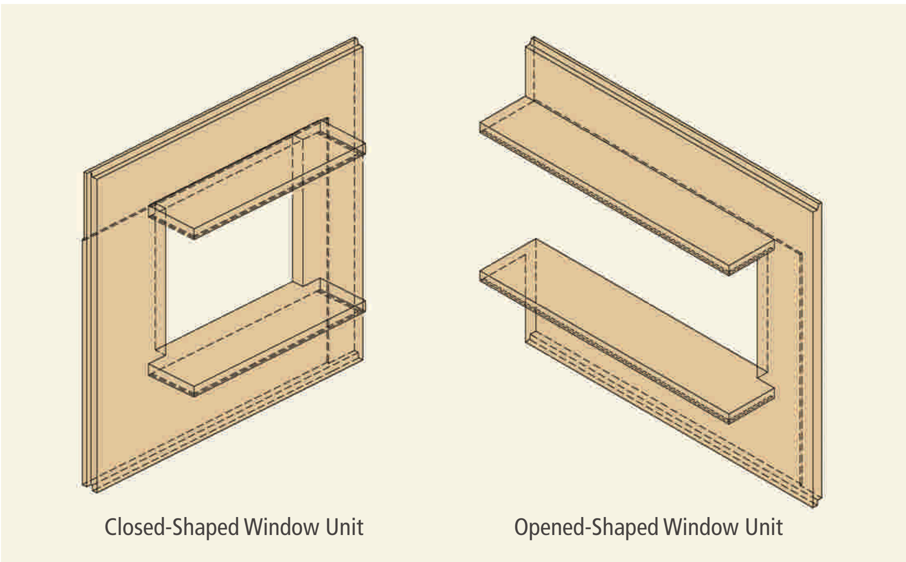


Fig. 1.14 – Example of closed and opened-shaped units

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.

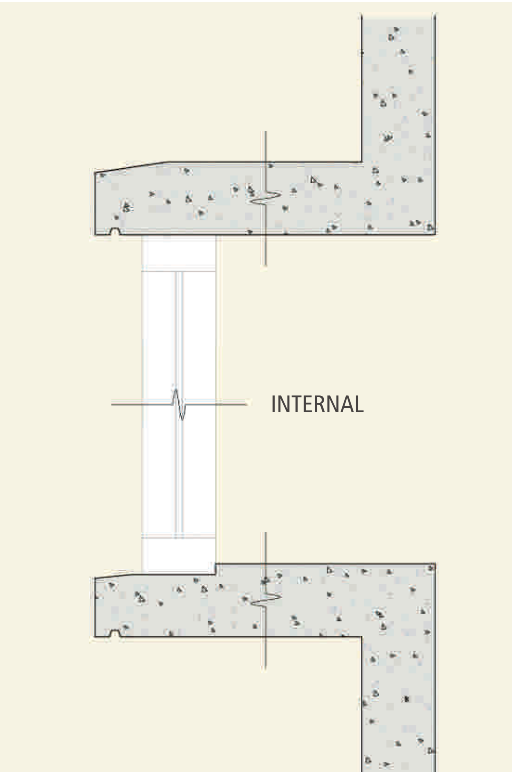


Fig. 1.16 – **Section showing drip details**

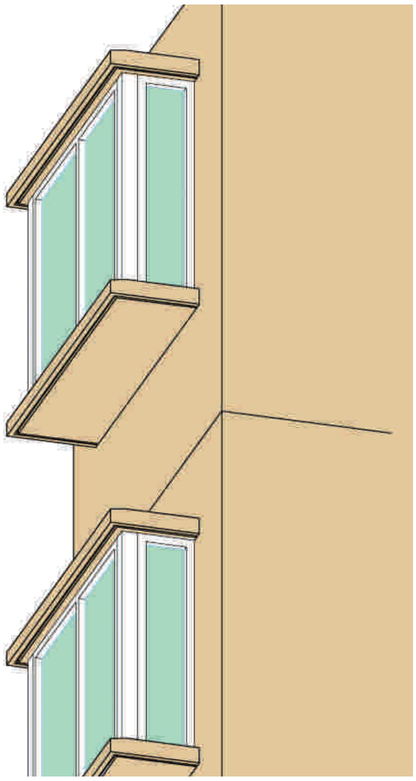


Fig. 1.17 – **Drip grooves on bay window façade to control weathering**

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.

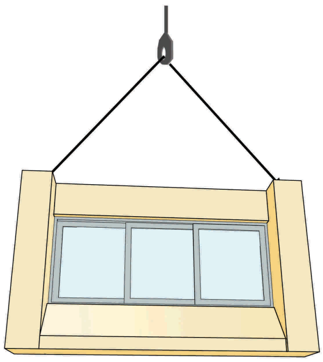


Fig. 1.18 – **Cast in-window façade wall panel**

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.

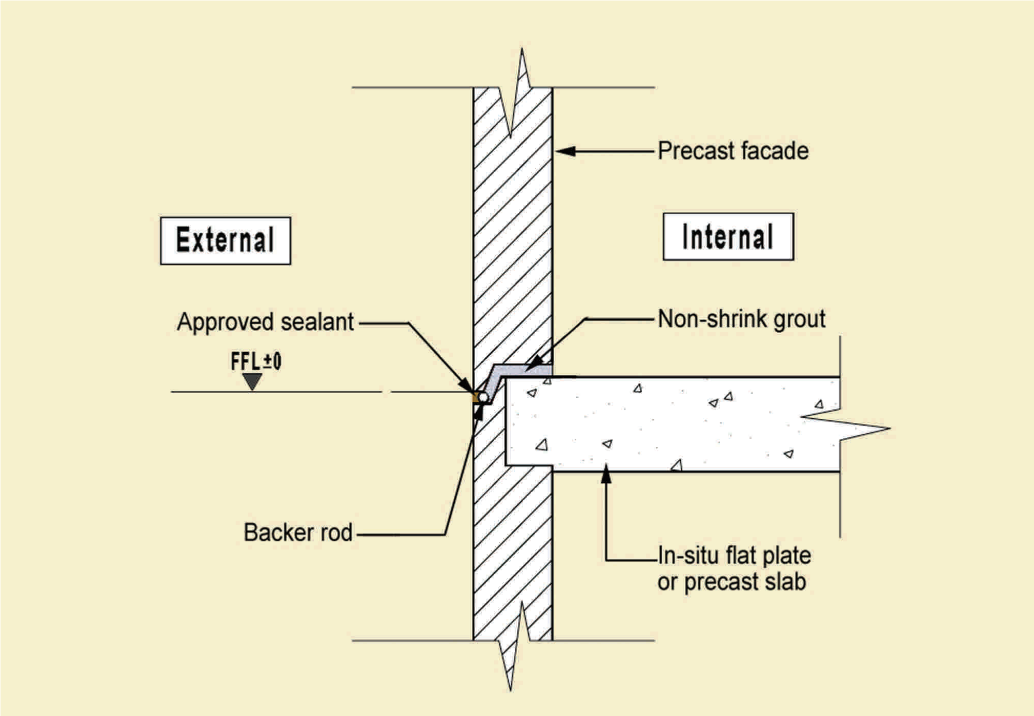


Fig. 1.21 – Horizontal joints between precast façade and floor elements

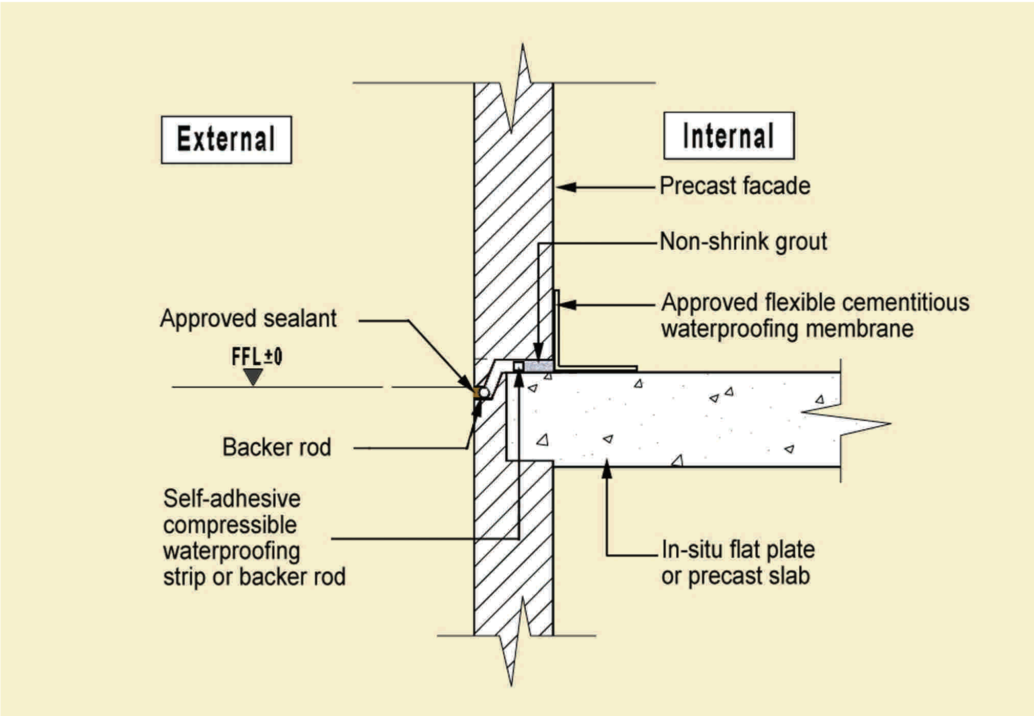


Fig. 1.22 – Horizontal joints between non-load bearing precast façade and floor elements

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.

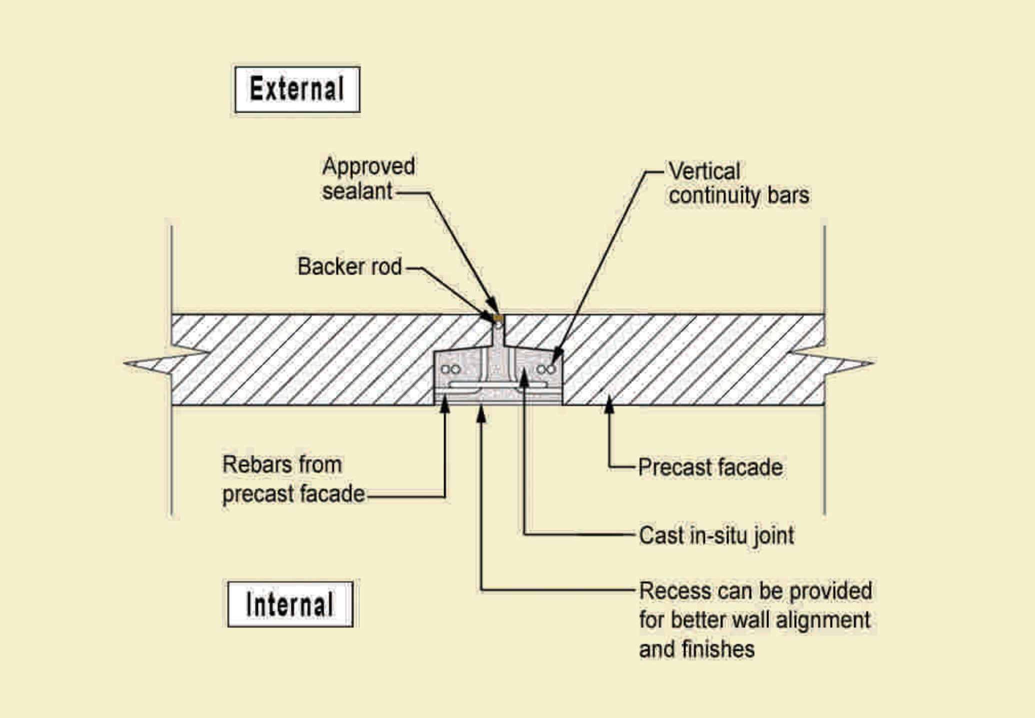


Fig. 1.23 – Vertical joints between precast façade panels

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.

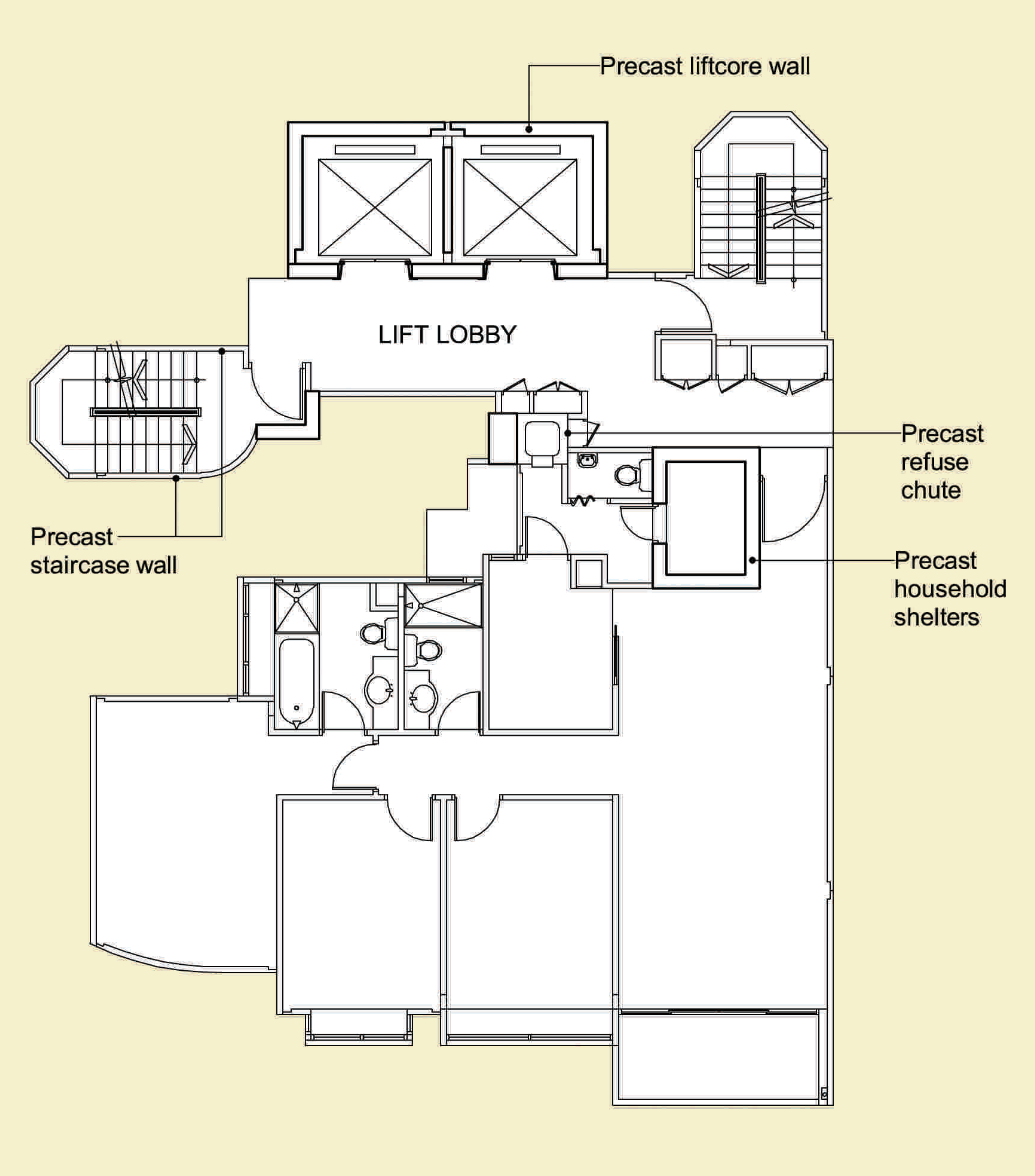


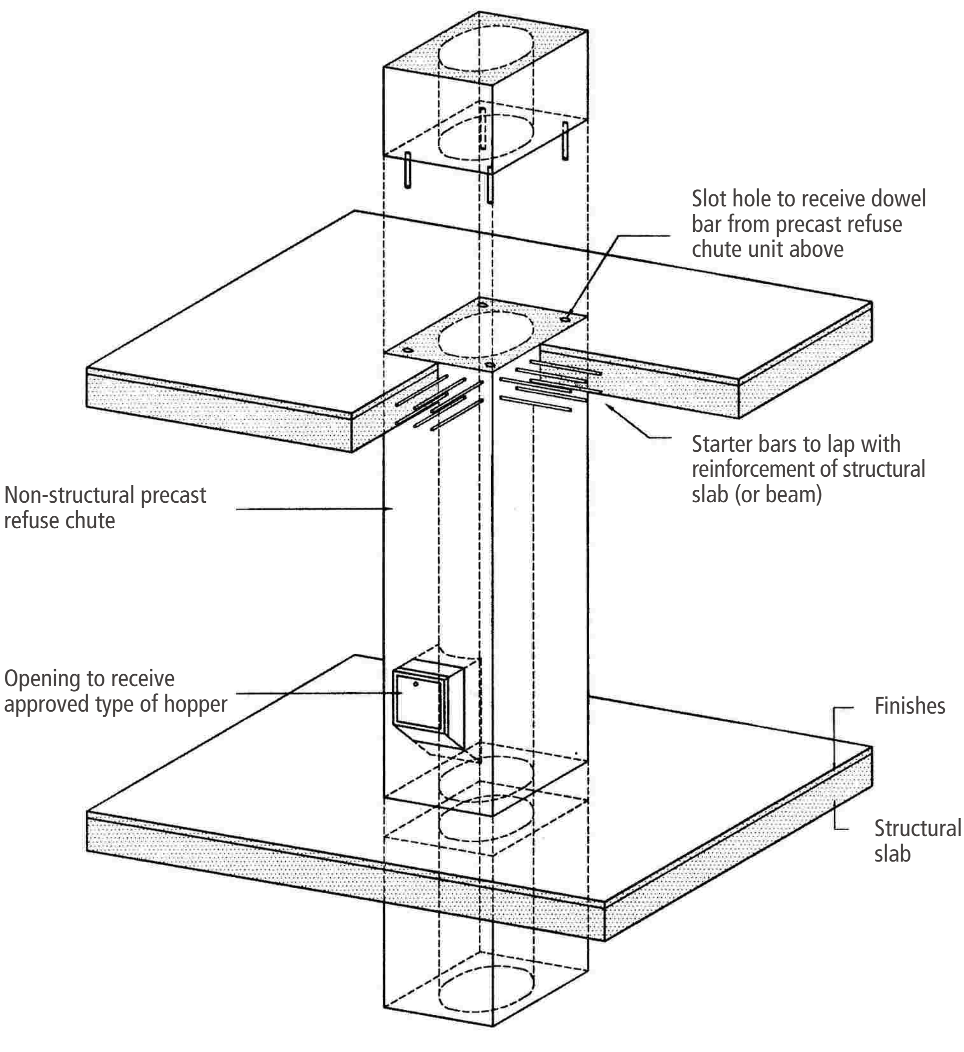
Fig. 1.25 – **Other precast concrete components which can be used in combination**

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.

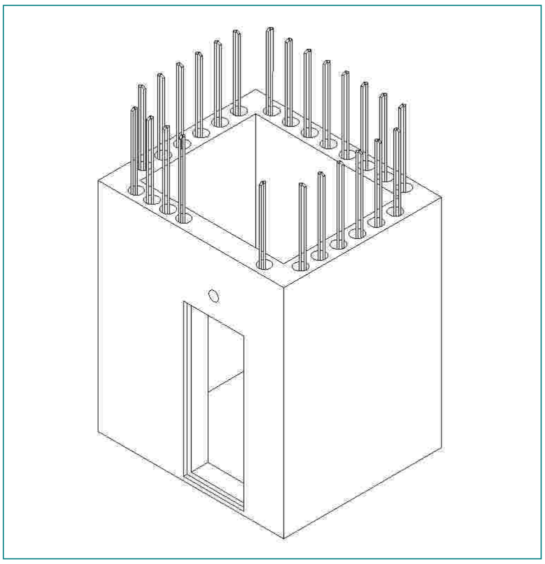


Fig. 1.28 – A fully precast household shelter unit (Patented)

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

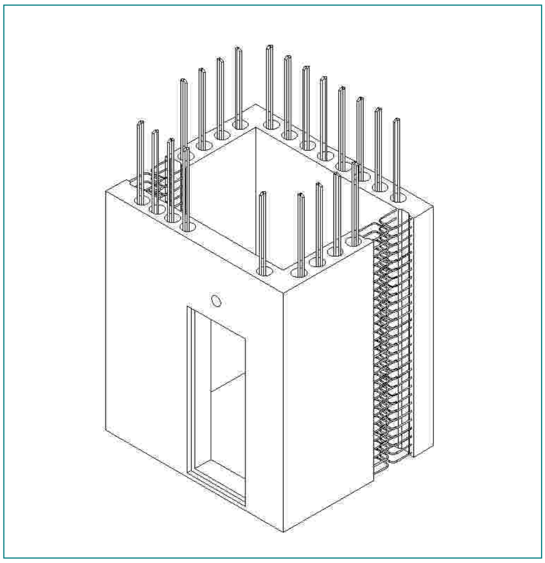


Fig. 1.30 – Precast household shelter in 2 separate 'L-shaped' panels (Patented)

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 [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 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.

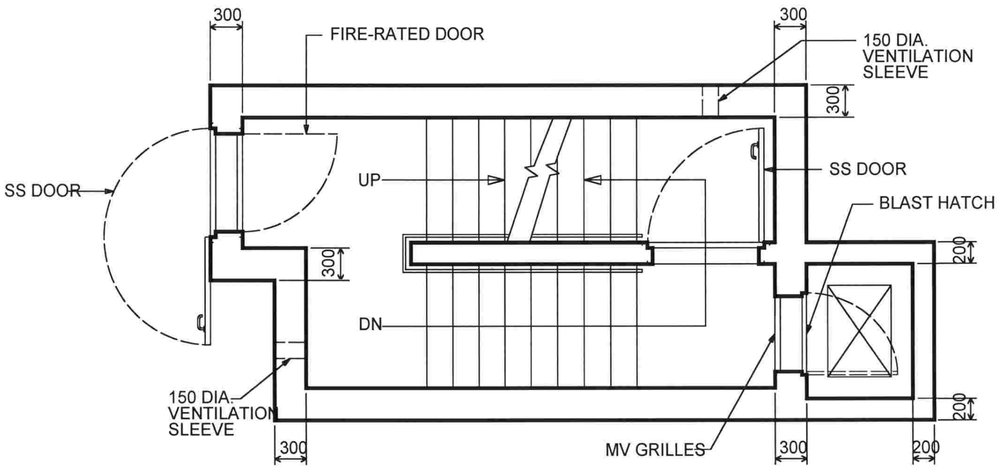


Fig. 1.32 – Typical layout plan of a staircase storey shelter

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.

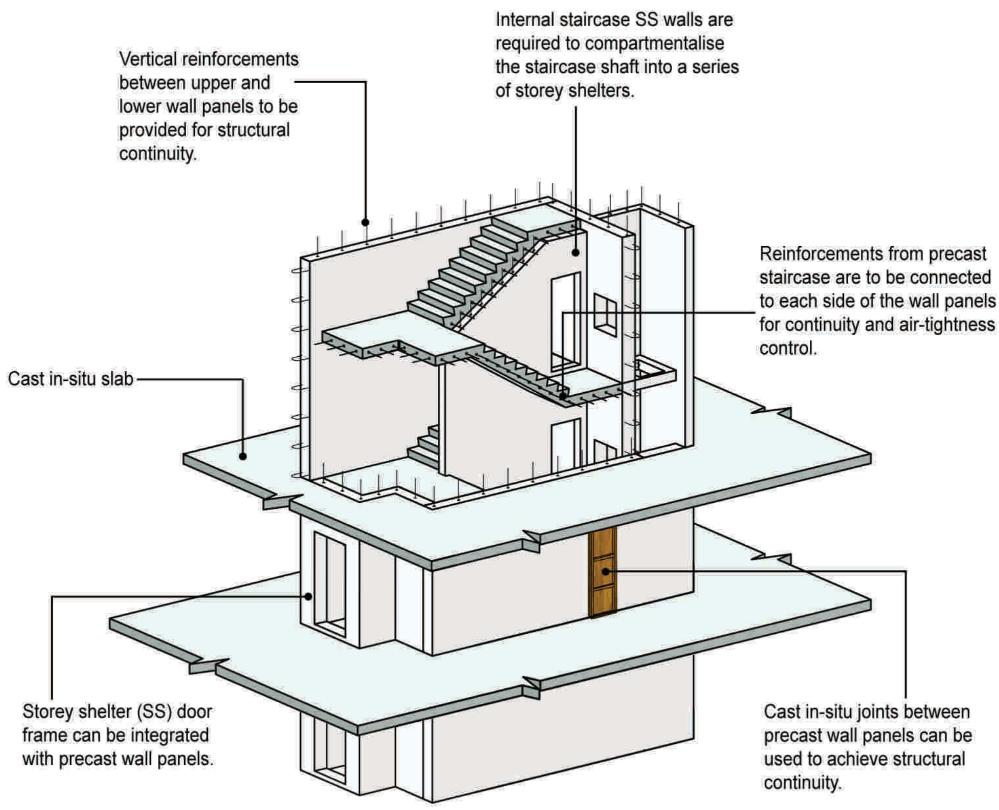


Fig. 1.33 – Key considerations in the design of precast staircase storey shelter

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.*