Contents

1. Introduction

With the advancements in precast technology, precast concrete elements can be manufactured with relatively straightforward repeated process, in different forms and finishes, to meet the rising expectation for faster construction and better quality building. In recent years, there has been increased use of precast concrete elements in local building industry. In tandem with this trend, CONQUAS has incorporated the workmanship standards required for such elements.

In general, precast concrete elements being manufactured in a more controlled environment, are of better quality than the cast in-situ elements. However, it is not uncommon to come across major defects such as extensive chip-off and cracks on these elements, which can result in substantial reworks and rectification cost. It is therefore practical to address these quality related problems upfront, so as to maximise the benefits of using precast concrete elements.

This guide highlights the salient quality issues involved in the design, production, delivery, site handling, storage and installation of precast concrete elements. The requirements and recommendations given are a general presentation of the important factors that govern the quality of the precast concrete construction.

Due to the volume constraints, this guide will focus on the quality issues pertaining to the use of common precast concrete elements in residential and institutional projects such as façades, walls, columns, beams and slab panels. It adopts the quality standards set out in CONQUAS 21 and includes the CONQUAS quality assessment criteria in the recommended inspection checklists.

References have been made to the other BCA publications on "Structural Precast Concrete Handbook", "Buildable Solutions for High-Rise Residential Development", "Buildable Solutions for Landed Residential Development in Singapore" and "Good Industry Practices on Waterproofing for External Wall".

2. Design

2.1. GENERAL

The design of precast concrete elements involves understanding the method of fabrication, the implicit constraints as well as the various aspects that facilitate the erection and assembly of these elements on site. Salient guidelines for the design of precast concrete elements can be found in the Singapore Code of Practices namely CP 65[1] and CP 81[2]. In addition to the design and detailing of precast elements, it is important to carry out design checks on the overall building stability and robustness of the complete structure as recommended in these codes. The design should also consider the manufacture, transportation, hoisting and temporary stability of the element and of the structure during construction.

To achieve good quality precast concrete elements, it is important to consider the following aspects during the design stage :

- Dimensions and Shape of Precast Elements
- Concrete Constituents
- Reinforcement
- Mould Design
- Joints and Connections
- Lifting and Handling Devices

2.2. DIMENSIONS AND SHAPE OF PRECAST ELEMENTS

The optimal dimensions of the precast elements largely depend on the capacity of the lifting cranes at the fabrication yard and site as well as the transportation limitations. It is however, a good practice to design for the largest possible size to minimise jointing and handling. Integration of different elements, such as the beam-wall system, multi-tier columns and three dimensional units can be adopted to enhance dimensional controls and construction quality.

Figure 2.2 Multi-tier columns

Figure 2.1 Integrated beam and wall panels

Where possible, plan for appropriate repetition and standardisation in the dimensions and shape of the elements, which is desirable for economic of scale and quality assurance. Fewer mould changes will facilitate the production schedule and hence reduce construction time. Nevertheless, precast elements in particular the façade and wall panels, can be designed and modified from the typical mould in different profiles for greater variations as well as to maximise mould usage. However, care should be taken in the design to consider some forms of strengthening for panels with significant openings or narrow segment at the side of the openings, to prevent cracking or spalling of the elements during installation.

[1] Refer to Singapore Code of Practice for Structural Use of Concrete – CP 65 : Part 1 : 1999 and CP 65 : Part 2 : 1996 (1999)

[2] Refer to Singapore Code of Practice for Precast Concrete Slab and Wall Panels – CP 81 : 1999

2.3. CONCRETE CONSTITUENTS

Depending on the design requirements, a variety of concrete strengths and characteristics can be used to achieve optimum performance required of the precast concrete elements. The relevant standards for concrete constituents are listed in Table 2.1:

Table 2.1 Relevant standards for concrete constituents

Items	Relevant Standards	Comment
Concrete Mix	CP 65 CP 81 SS 289	Concrete mix which is composed of portland cement and water together with fine and coarse aggregates, should be designed to achieve the desired workability during concreting, and the durability and strength required of the final precast elements. In general, the mix should achieve a concrete strength of minimum 10 N/mm^2 or more at early stage for demoulding and higher production efficiency.
Cement	SS 26	Ordinary portland cement and blended cement are commonly used in precast concrete production. High alumina cement should not be used as it may cause substantial loss in concrete strength and durability in warm, humid conditions.
Aggregates	SS 31	The maximum size of the coarse aggregates should be established in the design. The size should be compatible with the minimum dimension and usage of the precast elements. As a general guide, the maximum aggregate size should not be greater than the specified cover to reinforcement or tendons. For machine-extruded concrete such as hollow core slabs, whereby the concrete mix is forced through rotating augers and steel formers to create the voids, fine aggregates have to be carefully graded. To achieve quality product, the size of the coarse aggregates should be less than 15 or 20 mm, depending on the element dimension and machinery type.
Admixtures	SS 320	Chemical admixtures may be added to enhance the performance of the concrete mix by reducing the required water content or to accelerate the rate of early strength development. It is recommended to carry out trial mixes to determine the optimum design proportion of admixtures to be added to concrete mix. Appropriate methods of batching and concreting should be used to ensure correct dosage so as to avoid any detrimental effects on precast concrete elements.

2.4. REINFORCEMENT

Apart from concrete constituents, precast concrete elements are often reinforced using welded wire meshes, bars or prestressing tendons to achieve the required structural capacity. They are required to be designed to meet the crack control, loading capacity and construction load requirements. The relevant standards for reinforcement and prestressing tendons are listed in Table 2.2.

Table 2.2 Relevant standards for reinforcement and prestressing tendons

Items	Relevant Standards
Welded Wire Meshes	SS 32
Steel Reinforcement	SS 2
Prestressing Tendons	SS 475, CP 65

In designing the reinforcement layout, it is important to also consider the presence of other cast in-items such as pipe sleeves or electrical fixtures. The layout design should be simplified wherever possible, to avoid congestion which may affect the concrete quality due to poor compaction and loss of concrete cover.

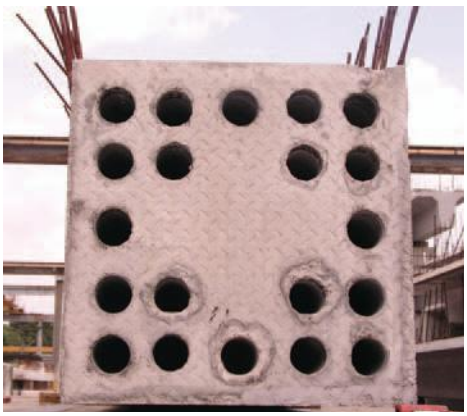


Figure 2.3 Potential congestion at connection where there are reinforcement bars and corrugated pipes sleeves

When the projecting reinforcing bars that are required for lap splicing between elements are excessively long, they may pose storage and handling problem. In this respect, it is a good practice to adopt mechanical couplers or splice system to provide for the structural continuity needed.

Figure 2.4 Long projecting bars may pose storage and handling problems

Figure 2.5 Use of splice sleeve system in place of long projecting reinforced bars

2.5. MOULD DESIGN

Moulds can be made of any suitable materials including steel, timber/plywood, glass reinforced concrete (GRC) or a combination of these. The selection of the mould materials will depend on the number of usage, required surface finish type and quality as well as the shape complexity of the precast elements.

Fig 2.6 Example of adjustable mould for the precast beam and column production

Locally, steel mould is preferred owning to its robustness and precision. In general, the steel plate thickness adopted for mould design and fabrication varies from a minimum of 4.5mm to 6mm, which can be used up to 50 ~100 times with proper care and maintenance. Besides, the mould should be designed to allow for appropriate placing and compaction of the concrete. Adequate number of braces, ties and struts should be provided for proper casting and hardening of the concrete. A minimal number of demountable parts will help to ensure good maintenance of dimensional accuracy during production as well as to facilitate easy assembly and dismantling. To enhance cost competitiveness, adjustable mould should be adopted where possible, for greater flexibility and variety in the production of precast concrete elements.

Figure 2.7 Adequate bracing is required for better dimensional controls

Figure 2.8 Examples of battery moulds and mechanised vertical moulds used for wall elements

For the production of standard elements such as refuse chutes and parapet walls, battery moulds or mechanised vertical moulds can be used for better quality and productivity.

2.6. JOINTS & CONNECTIONS

Joints and connections must be designed to adequately transfer the loads from a precast concrete element to the supporting structure or to an adjacent element to form the structure. They have to meet the design and performance criteria such as strength, ductility, fire resistance, durability and stability. Apart from these structural requirements, due considerations should be given to the production and erection process of the elements. To achieve a practical and satisfactory connection, the following items should be considered in the design :

- Standardise the joint and connection types and details
- Avoid congestion at joints
- Avoid penetration of forms
- Allow for production and erection tolerances
- Plan for easy assembly and accessibility

A compilation of connection and jointing details commonly used can be found in other BCA publications - "Structural Precast Concrete Handbook", "Buildable Solutions for High-Rise Residential Development" and "Buildable Solutions for Landed Residential Development in Singapore".

Recommendations on watertightness details and workmanship standards for external wall can be obtained from BCA's Good Industry Practices on Waterproofing for External Wall.

Figure 2.9 Examples of joints and connections between different precast elements

2.7. LIFTING AND HANDLING DEVICES

In precast concrete construction, lifting and handling devices are required and placed within the elements to facilitate the demoulding, handling and erection processes. The type, number and location of these temporary lifting and handling devices play an important role, in ensuring that the precast elements are not excessively stressed during lifting operation and before jointing works commenced. The factors to be considered are as follows:

- Capacity of the lifting and handling devices
- Weight and shape of the precast elements
- Strength of the concrete at the time of lifting
- Position of any opening or cut-out in the precast elements
- Rigging arrangement
- Type of lifting clutch, hook or shackle used for handling and installation

Figure 2.10 Lifting and handling devices are required to facilitate the erection process

Lifting and handling devices can be prestressing strands or cable loops projecting from the elements, coil threaded inserts or proprietary lifting devices. Prestressing strands or cable loops should be designed with adequate safety factors before use. Reinforcing bars unless specifically designed, should not be used as lifting loops as they are susceptible to breakage during hoisting operations in view of their low ductility.

Where possible, these lifting and handling devices should be placed at locations that require little or no patching after use. If they are required to be located on the finished face of architectural component such as façade wall panels, it will be good to provide recesses. These recesses can then be filled up with proper grout after installation to achieve better wall finishes.

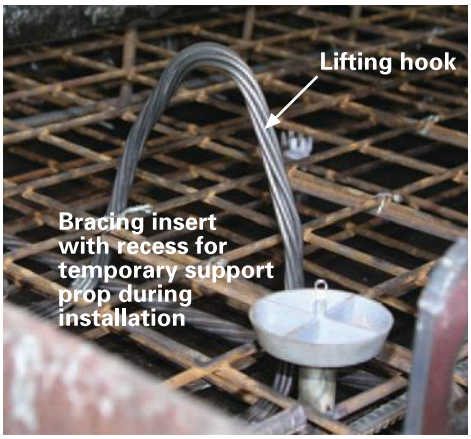


Figure 2.11 Different types of devices for lifting operation and temporary support

Figure 2.12 Provision of lifting anchor with recess former for better finishes

It is a good practice to adopt proprietary lifting devices that come with specified design load capacity for safe and efficient handling. These devices normally come with proper accessories to form recesses, which can be easily patched up after installation.

3. Fabrication Process

3.1. GENERAL

Before fabrication, shop drawings of individual precast elements are required to be prepared and detailed with the following information :

- Project location, reference number of elements, and their locations with respect to the building layout and elevation
- Dimensions of elements, centre of gravity, weight and concrete volume
- Locations of all reinforcing steel, cast-in items for connection, lifting and bracing
- Locations of embedded items such as service conduits, blockouts and recesses as well as openings
- Jointing and interfacing details between elements
- Watertightness details at joints
- Architectural details and treatments where applicable

Any discrepancies among the architectural, structural and production requirements should be resolved before confirming these drawings for fabrication to minimise abortive works.

Generally, there are two main types of precast concrete elements, namely precast reinforced concrete elements and precast prestressed concrete elements.

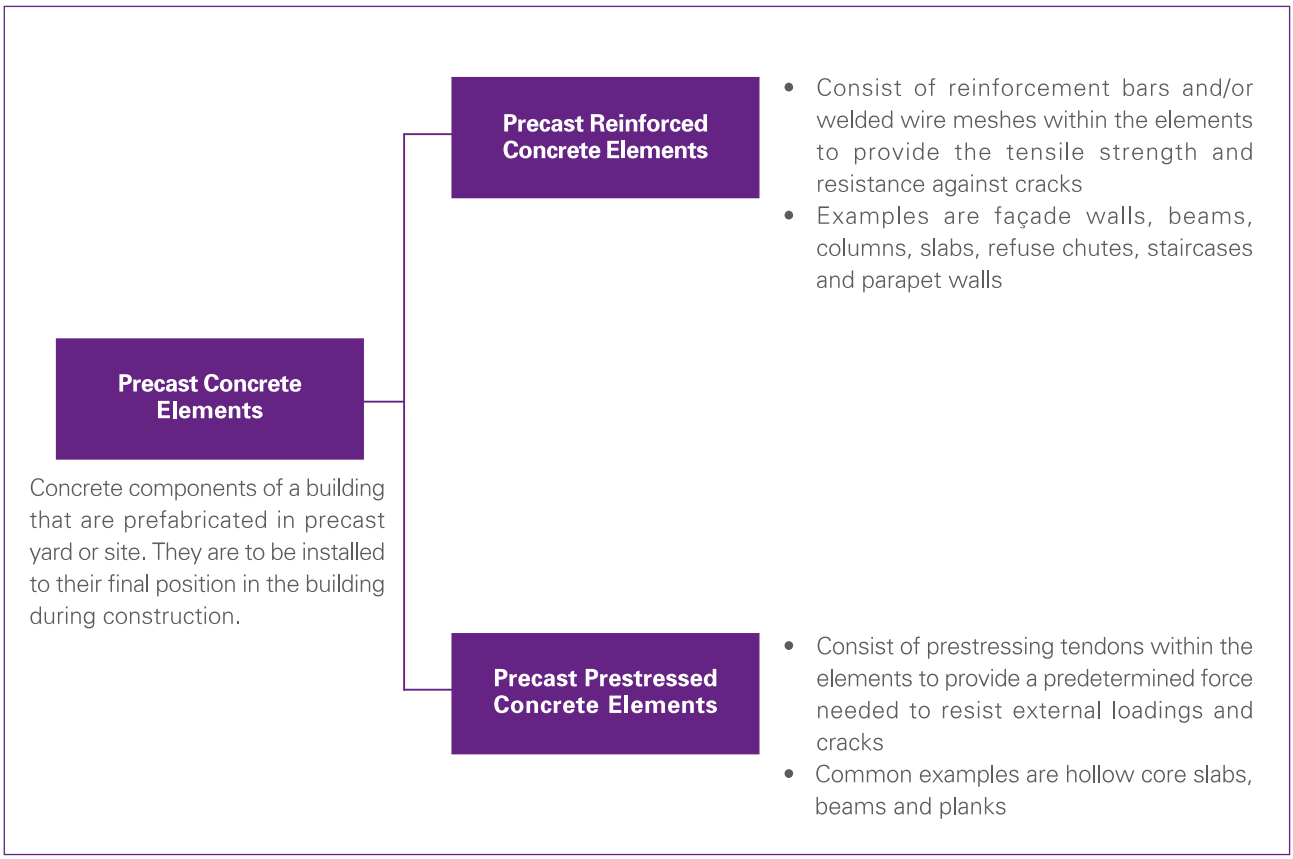


Figure 3.1 Types of precast concrete elements

In fabrication, most of the precast concrete elements are produced using the normal wet casting method. However, for hollow core slabs and walls, dry casting process or extrusion method is adopted to create the voids.

3.2. NORMAL CASTING PROCESS FOR PRECAST REINFORCED OR PRESTRESSED CONCRETE ELEMENTS

Table 3.1 highlights some of the good practices recommended for normal wet casting of precast concrete elements.

Table 3.1 Normal Casting Fabrication Process

Fabrication process	Good practices
1. Assembly of mould   	• Check the level and flatness of the base mould before assembling the mould for panel casting. • Ensure that the dimensions of mould are within the specified tolerances.  • Check the squareness of the mould forms. 

Fabrication process	Good practices
2. Mould cleaning and preparation   	• The mould should be clean and free from debris and old mortars using remover or scaling bars. • Form oil or mould release agent should be applied evenly over the mould surfaces.  • Check that the joints and edges of the mould, bolts, stoppers, tie rods, side props and rubber seal are intact and properly secured. 
3. Fixing of rebars / cast in items / prestressing strands 	• Check that the rebar size, spacing and lap length are in accordance with the drawings. 

Fabrication process	Good practices

3. Fixing of rebars / cast in items / prestressing strands (cont'd)


Fixing of staircase slab reinforcement

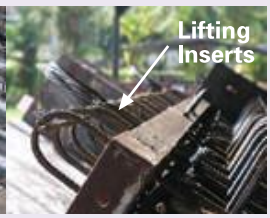

Fixing of beam reinforcement


Proper measurement before rebar fabrication

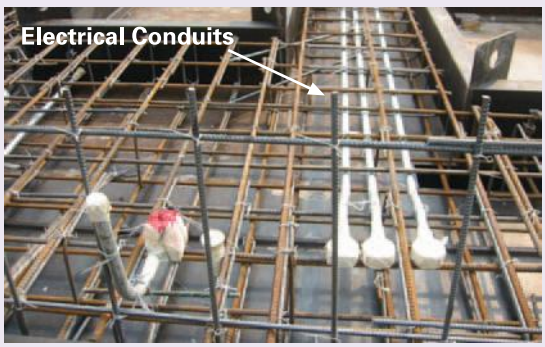

Rebars properly secured

- Rebars, cast in-items, corrugated sleeve pipes, recesses, lifting hooks and inserts must be correctly positioned and properly secured.


Corrugated pipe sleeves


Lifting Inserts


Provision of recesses


Electrical Conduits

- Use of fabrication rig can help to ensure the accuracy of rebars fixing and spacing.

Fabrication process	Good practices

3. Fixing of rebars / cast in items / prestressing strands (cont'd)

Beam reinforcement cage

Placing the beam cage to the mould

Rebars placed in mould ready for casting

- Where needed, tack welding may be carried out to secure these items.

- Sufficient number of spacers with the correct sizes should be properly placed and secured to achieve the required concrete cover during casting.

- For precast prestressed concrete element such as planks, the strand hauling should only be carried out when the form release agent has dried to a certain degree that will not contaminate the strands.

Fabrication process	Good practices
4. Final inspection before casting	• Check and verify that all details comply with drawings.

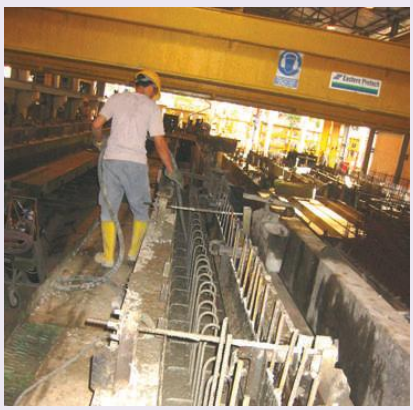
- Check the mould fitting conditions including blockout details.

- It is good to check the base mould level again before casting, in particular for site precasting where other concurrent site activities may have shifted the mould level.

Fabrication process	Good practices
5. Concreting	• Check that concrete grade used is according to design specifications. • Conduct slump test in compliance with SS 78 to assess the workability of the concrete mix before placing the concrete to the mould.

• The drop height of concrete mix should not exceed more than 1m.

• Proper vibration and compaction should be carried out in particular, in more congestion areas.



• Form vibrator can be used for slender and thin elements.

• Spreading and levelling of concrete surface level after initial set.

• Maintain the required thickness by use of screeder.

Fabrication process	Good practices
5. Concreting (cont'd) 	• Use of power trowel / float is recommended for smooth surface finishes. 
6. Curing 	• Observe adequate curing time and desired environment. • Concrete cubes should be subjected to the same curing conditions as the precast concrete elements. 
7. Demoulding  	• Depending on the anchor length of inserts and type of precast elements for e.g. thin floor slabs, the minimum concrete strength required may be higher to overcome the suction and frictional forces during demoulding. • Cube tests should be conducted to verify the concrete strength of elements before demoulding. • As a general guide, ensure that the concrete strengths attained for reinforced precast elements and prestressed precast elements are minimum 10 N/mm^2 or 25 N/mm^2 respectively. • Loosen and remove all bolts & pins and end and side mould forms before lifting. • For prestressed elements, cut strands before lifting.

Fabrication process	Good practices
8. Final inspection / Transfer to storage yard	• Check the condition of the finished product.

Finishing works before delivery to site

- Verify the critical dimensions.

- Proper identification markings should be placed on elements showing the location, member type, size, weight and orientation as per shop drawing.

- Check that the elements have achieved 75% of their design concrete strength before delivery to site for erection.

3.3. Dry Casting Process (Extrusion Method) for Precast Hollow Core Elements

The dry casting or extrusion method is mainly used to produce hollow core slab or wall panels. Table 3.2 highlights some of the good practices recommended for dry casting or extrusion method of precast hollow core panels.

Table 3.2 Dry Casting Fabrication Process

Fabrication process	Good practices
1. Base mould cleaning and preparation     Application of Form Release Agent	• Check that the base mould is clean and free from debris and old mortars. • Check that the extrusion machine including the vibrator are in good working condition.  • Form release agent used should have anti-rust properties and be relatively dry after application so that the strands will not be contaminated. It should be applied evenly over the mould surfaces. 

Fabrication process	Good practices
2. Prestressing strand hauling and tensioning  	• Check the strand size, spacing and pattern. • Strand hauling should be carried out only when the release agent has dried to a degree that it will not contaminate the strands. 
3. Concreting  	• Before concreting, check machine setting for concrete cover and panel thickness. • Check that concrete grade used is according to design specifications. • Conduct slump test to ensure adequate workability of the concrete mix.  • Check that the clamp-on vibrator provide good compaction.

Fabrication process	Good practices
3. Concreting (cont'd)  	• Carry out visual inspection of the surface finish to ensure there is no serious defect like honeycomb, dimensional changes, cracks etc.  • Stop operation to investigate if serious defect detected. 
4. Curing  	• Protect the hollow core panels with tarpaulin or canvas to prevent rapid moisture loss and shrinkage cracks. • Observe adequate curing time and desired environment. • Concrete cubes should be subjected to the same curing conditions as the elements. 

Fabrication process	Good practices
5. Detensioning of strands  	• Cube tests should be conducted to verify the concrete strength of elements.  • Check that the concrete has attained the designed transfer strength of minimum 35 N/mm^2 or as specified before detensioning. • Drilled water holes at the bottom of panels should be between 300 mm to 500 mm from the end of the panels.
6. Final inspection / Transfer to storage yard  	• Ensure that dimensions of the hollow core panels meet the design specifications.  • Check that proper identification markings are in place for easy retrieval and tracing. • Check for possible slippage of strands at both ends of hollow core panels. The values of allowable slippage should meet the design specifications. • Check if there are any major cracks along the element section. • Plugging of hollow core openings with plastic caps before transferring to storage yard. • Check that the elements have achieved 75% of their design concrete strength before delivery to site for erection.

4. Delivery, Handling and Storage

4.1. DELIVERY

Delivery of precast elements should be planned according to the general erection sequence to minimise unnecessary site storage and handling. Where possible, it is desirable to transport the precast elements into a manner which they can be lifted directly for erection or storage without much change in orientation and sequence. For example, wall panels can be transported using A-Frame type trailer in upright position.

Precast elements should be loaded and delivered with proper supports, frames, cushioning and tie-downs to prevent in-transit damage. Adequate packing or protection to the edges of precast elements should also be provided to minimise risk of damages during transit.

Figure 4.1 The manner of delivery will depend on the type, dimension and weight of the precast elements

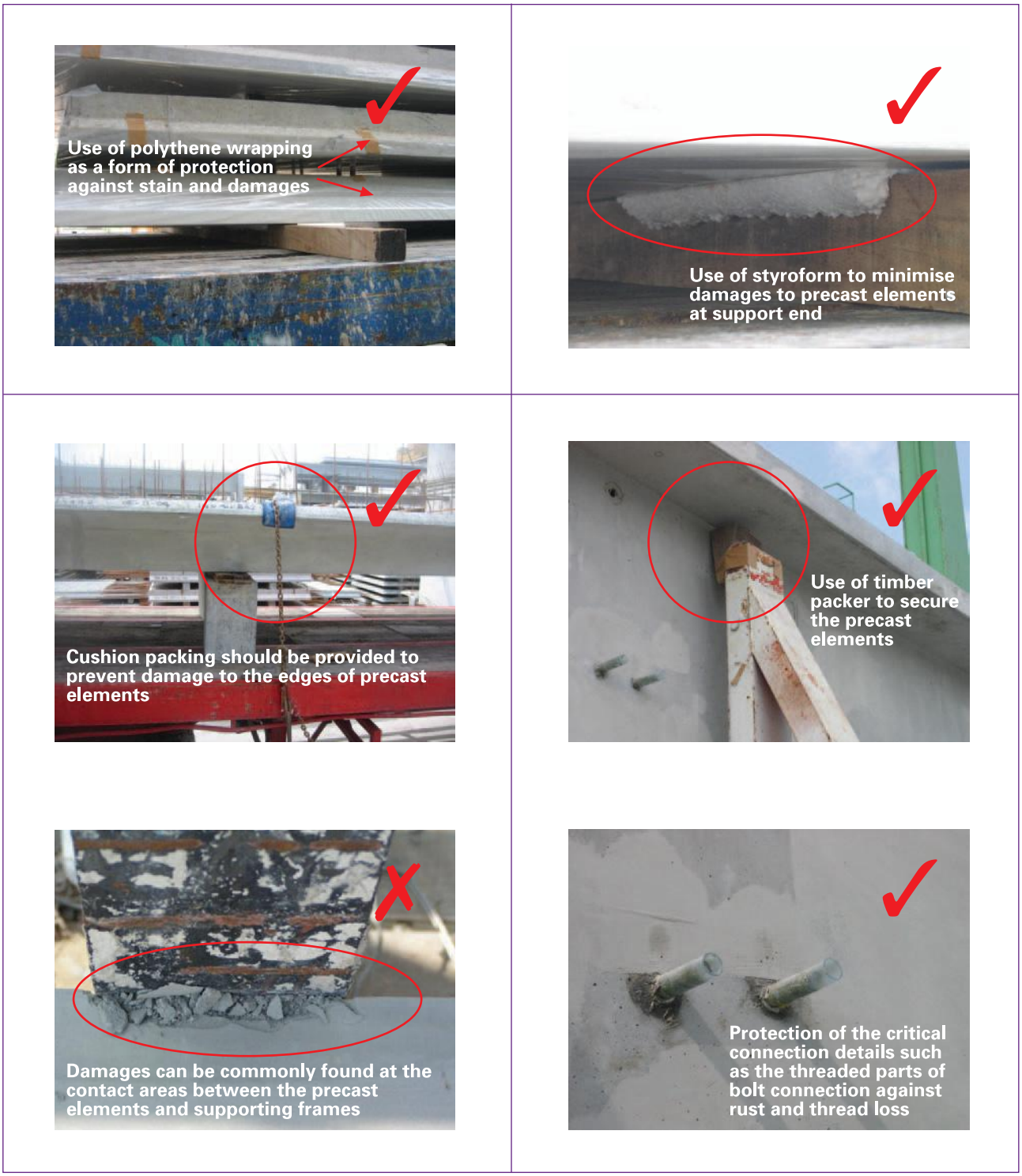


Figure 4.2 Protection measures such as the use of cushion packing or polythene wrapping can be used to minimise damages to precast concrete elements.

Figure 4.3 Precast elements should be adequately fixed and secured to pre-empt movement or accidental spillage during transit

4.2. HANDLING

The handling process mainly involves the removal of the precast elements from the mould, transportation to the storage yard, loading and unloading operation and erection of these elements at the job site. Different sets of lifting points and cast-in devices will have to be used for various handling stages.

Typically, precast concrete elements are demoulded and lifted from their casting position to storage yard and delivery to site once they reach the expected concrete strength required. As these elements have not gained their full designed strength, they are generally more susceptible to damages during handling. It is therefore important to ensure that they are handled in a way that is consistent with their shapes and sizes, to avoid excessive stresses or damages. For elements with large openings, temporary bracing, ties or strongbacks should be provided for safe handling as shown in Figure 4.4.

The handling requirements depends on the following factors :

- Position of the casting mould (i.e vertical casting vs horizontal casting)
- Minimum concrete strength of the precast elements for demoulding, delivery and erection
- Adequacy of the design reinforcement to resist handling stresses
- Size and weight of the precast element
- Number, size and location of lifting points and type of inserts/devices
- Method of lifting, type of lifting equipment and crane capacity
- Support points for storage and transportation

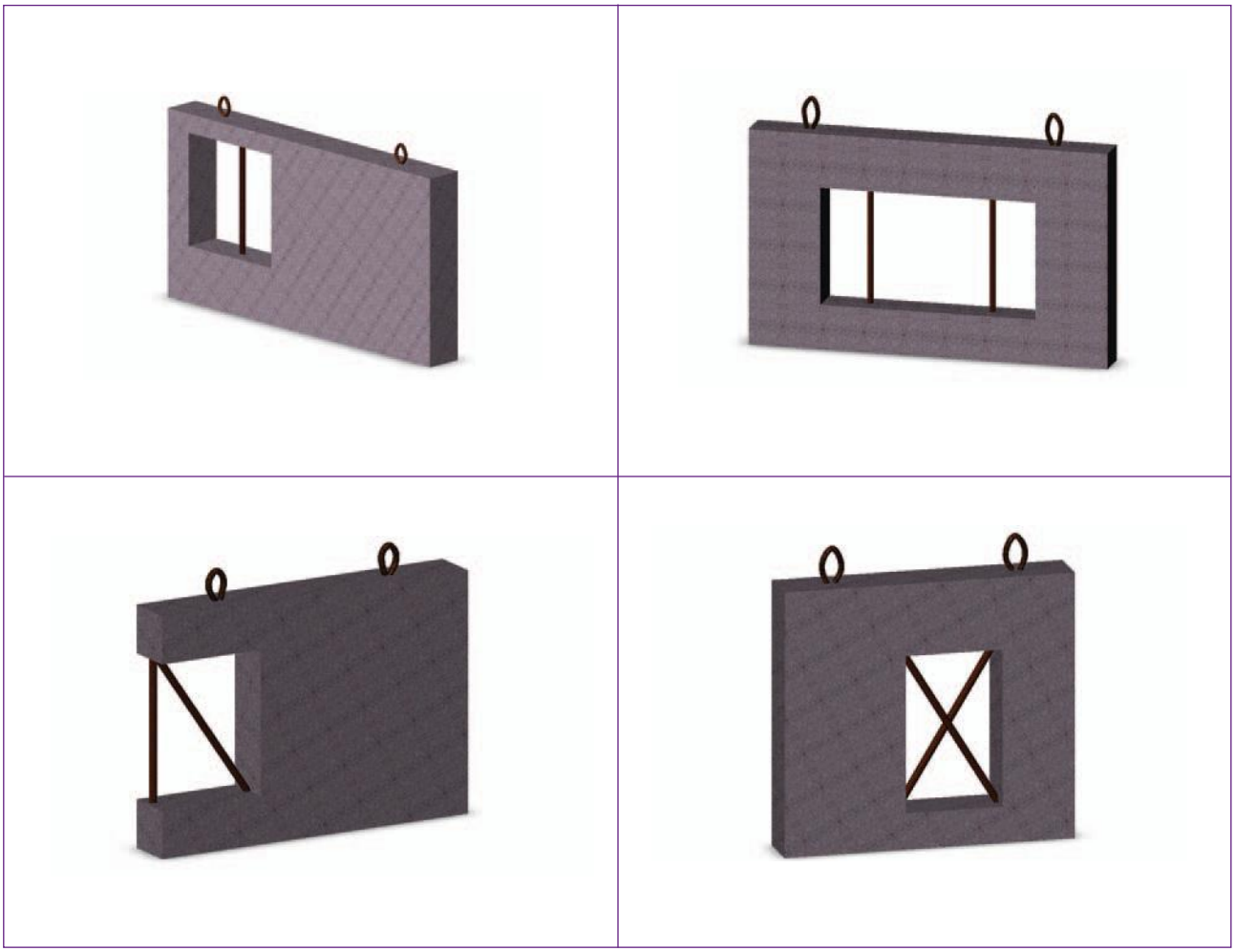
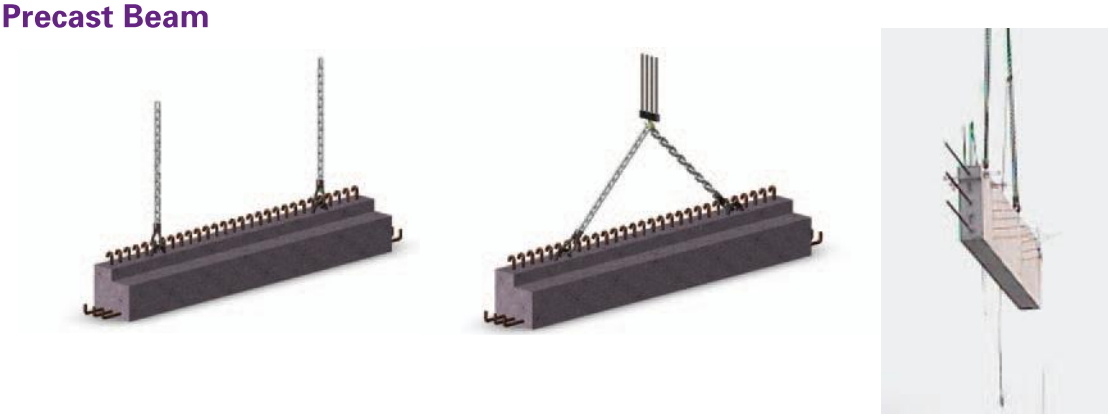


Figure 4.4 Temporary strengthening of panels with openings

Basically, the elements when handled must be balanced and in line with their centre of gravity. The general hoisting methods used for different precast concrete elements are illustrated in the following Figure 4.5 - Figure 4.8.

Precast Beam



Note : The lifting points should be designed and located to limit the bending moments within the beam element. As a general guide, they should be located at about one fifth of the beam length measured from the edge.

Figure 4.5 General hoisting method for beam

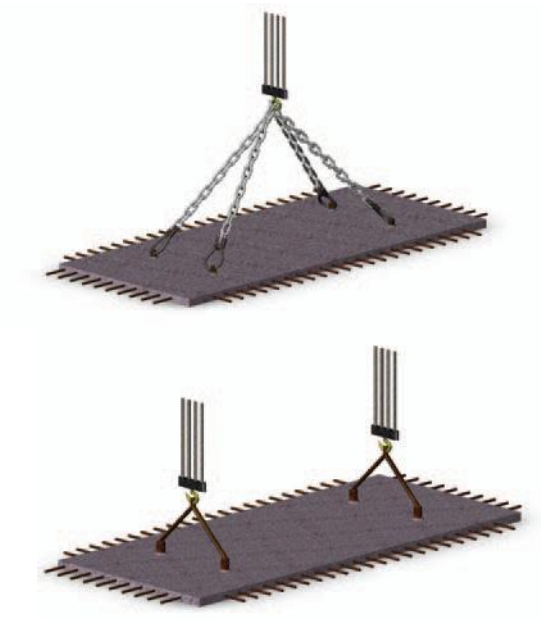
Precast Wall

For wall panels, it is recommended to lift the panel in vertical position for installation so that turning is not required.

Hoisting method adopted for demoulding of wall panels that are cast horizontally.

Figure 4.6 General hoisting method for wall

Precast Plank / Slab



Note : Where necessary, multiple lifting points can be designed and located to minimise undue stresses within the slab elements, in particular for slender panels such as precast planks.

Figure 4.7 General hoisting method for plank/slab

Precast Column

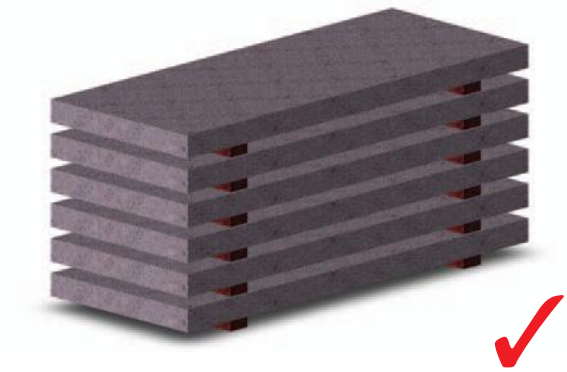
Note : Columns are usually first handled in horizontal position. Slings are attached to the inserts at the top to facilitate the rotation of the elements to vertical position, before hoisting and placing to their designated location.

Figure 4.8 General hoisting method for column

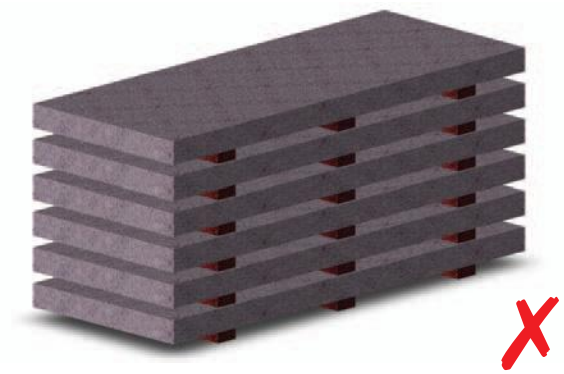
4.3. STORAGE

The storage area provided in the yard and job site should be adequate to permit easy access and handling of the precast elements. The area should be relatively level, firm and well drained to avoid any differential ground settlements which may damage the stored elements.

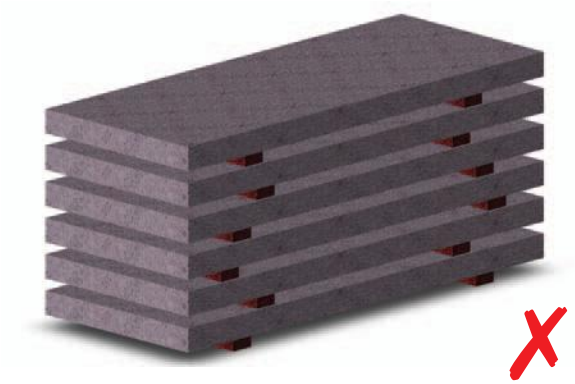
Appropriate stacking method should be used to store the precast concrete elements to prevent any undue stresses and damages (see Fig 4.9 and 4.10). Horizontal precast concrete elements such as precast slabs, planks, beams and hollowcore panels, can be stacked and supported separately using strips of woods or battens across the full width of the designated bearing points. Precast walls and façade panels are usually stored in vertical position supporting their own weight using racks with stabilising wall. Storage conditions can be an important factor in achieving and maintaining panel bowing and warping tolerances. More lateral support should be given to slender panels, which are more likely to bow or warp. To minimise handling, the elements should also be stored based on the erection sequence.



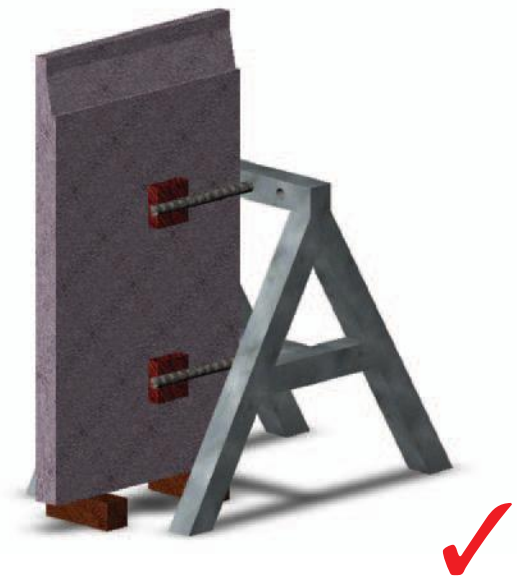
Stacking method and packers (or support spacers) vary according to the types of precast elements. Horizontal stacking of slab/beam or column units can be done with suitable packers or support spacers shown above. As a guide, the storage support position for beams and planks should be within 300mm from the lifting points.



Do not use more than two support points in particular for prestressed element such as hollow core slab.



The packers or support spacers should not be misaligned as shown.



Wall panels should be stored vertically and braced in position by A-frames or a racking system.

Figure 4.9 General guidelines on stacking method of precast elements

Figure 4.10 Different storage and stacking requirements for different precast elements

Figure 4.11 Examples of improper storage and stacking methods

The storage area at the job site should preferably be close to the locations where the precast elements are to be installed to minimise the risk of damage by handling.

Figure 4.12 Precast concrete elements should preferably be stored near their final position for easy handling

5. Installation

5.1. GENERAL

Proper planning and preparatory works are required before the actual erection of precast concrete elements to ensure efficient and quality installation. The following items should be carefully planned:

- Method and sequence of assembly and erection
- Method of providing temporary supports
- Provision for final structural connections and joint details
- Erection tolerances
- Handling and rigging requirements

Prior to the installation of the precast concrete elements, it is important to consider the following work items and checks listed in Table 5.1:

Table 5.1 Preparatory works items and checklists

- Check for site accessibility for the delivery of precast elements
- Check delivery checklist for correct type, quantity and panel identification
- Check for adequate crane capacity and working clearance for hoisting of precast concrete elements

- Conduct sample measurement to confirm on the accuracy of the critical dimensions of precast concrete elements and openings
- Conduct visual inspection on concrete finishes and check for any major defects

- Check the locations and conditions of lifting inserts before hoisting

- Check on the accessibility of unloading point and storage area
- Check that the storage area is of hard, level, clean and well drained ground
- Store the precast elements where required using "First In First Out" principle according to the delivery schedule and erection sequence

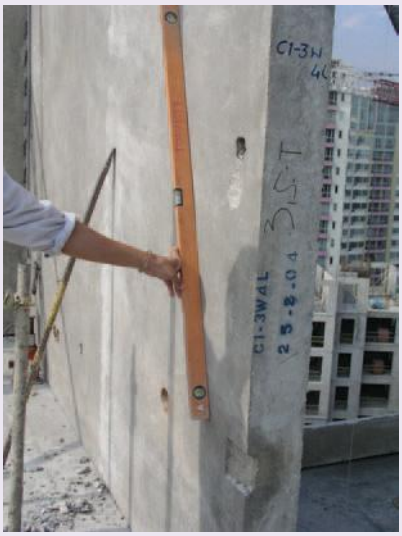
5.2. INSTALLATION OF VERTICAL PRECAST COMPONENT

The method and sequence of installing the precast wall panels (which is also applicable to other vertical components) are outlined in Table 5.2

Table 5.2 Vertical component installation

Installation sequence	Good practices
1. Setting out	
1.1. Set reference line and offset line to determine the position of the precast elements to be installed. 	• Check the accuracy of the offset lines. • Check the shim plate level and stability. • For vertical precast component, check the positions and alignment of the starter bars before hoisting for installation. 
1.2. Provide level pads (or shim plates) for setting the level of the elements. Set the level pads in position using non-shrink mortar. 	
1.3. For precast external wall/ column, fix the compressible form or backer rod on the outer perimeters of wall. 	• Check that the compressible form or backer rod are properly secured. 

Installation sequence	Good practices
2. Lifting and installation	
2.1. Lift and rig the panel to its designated location with the use of wire ropes.	• Check the hoisting condition of the precast element. • Check alignment and verticality of the panel. If necessary, adjust the temporary propping to achieve the level and position of the precast element.
2.2. Adjust the panel to position and secure it with diagonal props.	• Check the stability of the erected props before releasing the hoisting cable.



Installation sequence	Good practices
3. Grouting work	
3.1. Prepare and apply non-shrink mortar to seal the gaps along the bottom edge of the inner side of the panel. 	• Check that the joint width between panels are within design allowances before grouting. 
3.2. For corrugated pipe sleeve or splice sleeve connection, prepare and pour non-shrink grout or proprietary grout into the pipe inlets provided. 	• Non-shrink grout used at the interface with the precast elements should preferably be free flowing and self compacting in nature so as to ensure good compaction at the joint and to minimise the risk of cracking. • Non-shrink grout should be prepared in accordance with the specifications. 
3.3. Keep the installed panels undisturbed for at least 24 hours.	• Check that all horizontal joints are properly sealed. • Collect sample test cubes of the grout mix used for critical elements such loading bearing walls for testing.

Installation sequence	Good practices
4. Joint casting and sealing	

4.1. For panels with cast in-situ joints, install the joint rebars as required.

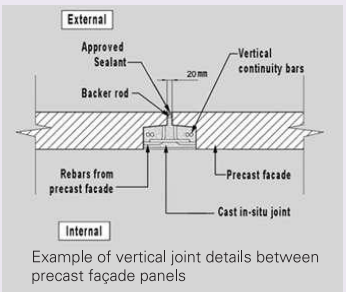
- The joint rebars should be correctly placed in accordance with the design specifications.
- The formwork should be properly secured during the casting operation of the joint.

4.2. Set up forms for the casting of the vertical joint.

4.3. Carry out concrete casting.

4.4. Remove forms after sufficient concrete strength has been achieved.

4.5. For joints between façade walls or between external columns with beams or walls elements, approved sealant and grout will be installed at later stage.

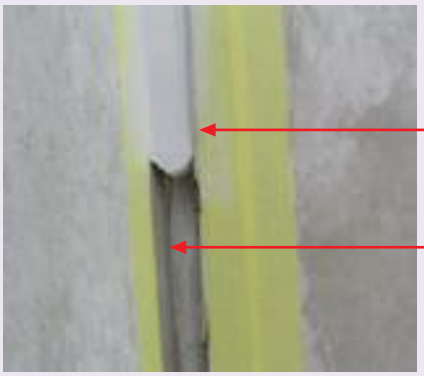


Example of vertical joint details between precast façade panels

- The joint gaps should be consistent to allow for proper installation of sealant or grout for better watertightness.

Consistent joint gap to for proper sealant or grout installation

4.6. For panel with welded connection, place the connecting plate between the panels and carry out welding as per design requirement.



Sealant application

Backer rod

5.3. INSTALLATION OF HORIZONTAL PRECAST COMPONENT

The method and sequence of installing the precast slabs and beams (which is also applicable to other horizontal components) are outlined in Table 5.3.

Table 5.3 Horizontal component installation

Installation sequence	Good practices
1. Setting out	
1.1. Set reference line and offset line to determine the required alignment and level of the precast slab/beam elements during installation.  	• Check the accuracy of the offset lines. • Check the level and stability of the shim plates. • Before hoisting, check that the dimensions and alignment of the protruding bars are within the specified tolerance, to prevent any obstruction during the erection process. 
2. Lifting and installation	
2.1. Put up temporary props to support the precast slab/beam elements. 	• Beam elements should be supported at minimum two locations during hoisting. 

Installation sequence	Good practices
2. Lifting and installation (cont'd)	
2.2. Lift and rig the elements to designated location with the use of wire ropes.	• Balcony, planter ledge and slab should be supported at more than two locations, depending on the dimensions of the elements and design consideration.
2.3. Align and check level to suit the required setting out before placement of precast members to final position.	• It is important to check on the levelness of the precast elements as well as between the elements before proceeding to do the jointing works.

Installation sequence	Good practices
3. Casting of joints	
3.1. For components with cast in-situ joints, place and lap the rebars as required. 	• The joint rebars should be correctly placed in accordance with the design specifications. 
3.2. Set up the formwork for the casting of the joint. 	• The formwork should be properly secured during casting of the in-situ joint. • Supporting beams can be designed to form part of the formwork for the casting of joint.  
3.3. Carry out concrete casting.	
3.4. Remove forms after sufficient concrete strength has been achieved. 	

6. Quality Inspection

6.1. GENERAL

It is important to have quality inspections as part of the integral process in managing quality of precast concrete elements. Close supervision should be provided for both critical in-process and finished works so as to achieve high workmanship quality.

Quality assurance and control starts with good planning and management. It is a good practice to prepare an Inspection and Test Plan, ITP (see Appendix A) which summarises the projects' inspection, acceptance criteria and frequency of inspections. Checklists for the in-process and final inspection of precast concrete elements should also be prepared (as in Appendix B) to detail the checks required at critical stages.

Quality inspections for the in-process works are highlighted in Chapter 3 – Fabrication Process. This section will only cover quality inspections for the finished precast concrete elements delivered and erected on site.

6.2. INSPECTION OF PRECAST CONCRETE ELEMENTS

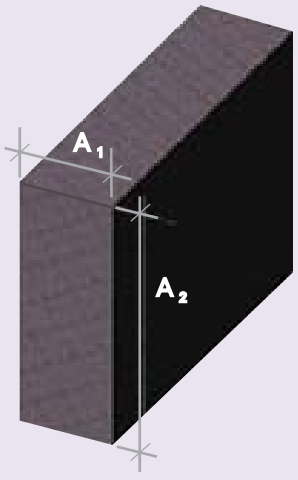
The finished precast concrete elements and works should be inspected to ensure they meet the client's requirement and standards. Table 6.1 shows the recommended checklist for final inspection of the precast concrete elements based on CONQUAS 21 quality assessment criteria.

Table 6.1 Checklist for final inspection of precast concrete elements

Inspection checklist
1. CONQUAS 21 Assessment – Dimension for elements / opening for services

1.1. Tolerance of cross sectional dimensions of precast elements : +10mm / - 5mm

Note : It is common to have the actual dimensions of a precast concrete element to be slightly different from its designed dimensions. However, the variation in cross sections should be within acceptable tolerances.



Maximum dimension :
A_1 +10mm OR A_2 +10mm

Minimum dimension :
A_1 - 5mm OR A_2 - 5mm

Inspection checklist

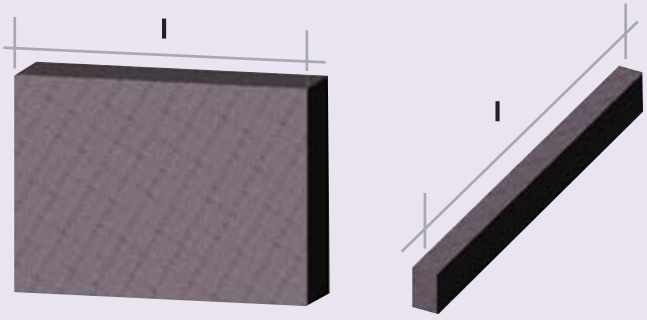
1. CONQUAS 21 Assessment – Dimension for elements / opening for services (cont'd)

1.2. Tolerance for penetration/opening for services : +10mm for size and ± 25mm for location

Note : It is important to ensure that the penetration / opening for services are within tolerances for proper connection and linkages of the M & E services.

1.3. Tolerance for length of precast members (major dimension of unit) :

- Up to 3m : ± 6mm
- 3m to 4.5m : ± 9mm
- 4.5m to 6m : ± 12mm
- Additional deviation for every subsequent 6m : ± 6mm



Dimensional length of precast members :

L ± 6mm for L ≤ 3m
L ± 9mm for 3m < L ≤ 4.5m
L ± 12mm for 4.5m < L ≤ 6m

Inspection checklist

1. CONQUAS 21 Assessment – Dimension for elements / opening for services (cont'd)

1.4. Straightness or bow (deviation from intended line) of precast member :

- Up to 3m : 6mm
- 3m to 4.5m : 9mm
- 4.5m to 6m : 12mm
- Additional deviation for every subsequent 6m : 6mm

1.5. Squareness of precast member – Difference between the greatest and shortest dimensions should not exceed the following:

Length of the shorter sides

- Up to and including 1.2m : 6mm
- Over 1.2m but less than 1.8m : 9mm
- 1.8m and over : 12mm

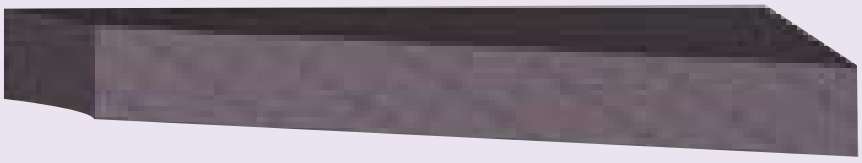
Note : When considering the squareness of a corner, the longer of two adjacent sides being checked should be taken as the baseline. The difference between the greatest and least dimensions of the shorter sides could then be used to check if the precast member is within tolerances specified.

Inspection checklist

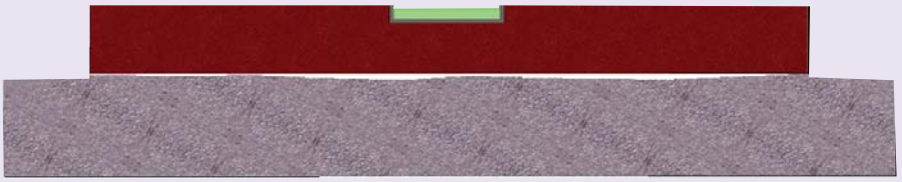
1. CONQUAS 21 Assessment – Dimension for elements / opening for services (cont'd)

1.6. Twist of precast member – Any corner should not be more than the deviation stated from the plane containing the other 3 corners:

a. Up to 600mm wide and 6m in length : 6mm
b. Over 600mm wide and for any length : 12mm



1.7. Flatness : 6mm per 1.5m



Note : Flatness refer to the variation or smoothness of the element surface. Under this criteria, the maximum deviation from a 1.5m straight edge placed in any position on a nominally plan surface should not exceed 6mm.

Inspection checklist

2. CONQUAS 21 Assessment – Alignment, plumb and level

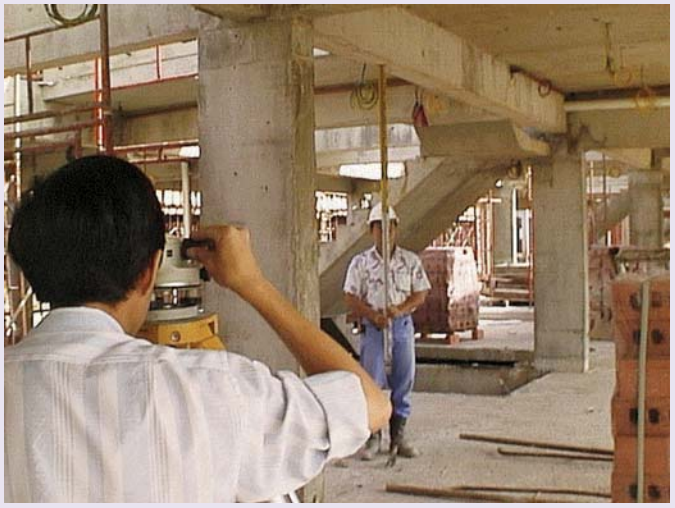
2.1. Tolerance for departure of any point from its position: ± 10mm

2.2. Tolerance for plumb : 3mm/m, maximum 20mm for floor to floor height and 40mm for entire building height

Inspection checklist

2. CONQUAS 21 Assessment – Alignment, plumb and level (cont'd)

2.3. Maximum deviation of mean level : ± 10mm



Note : This requirement is applicable for slab and precast beam elements. The mean level taken from any of the three points on the same element should not deviate by 10 mm.

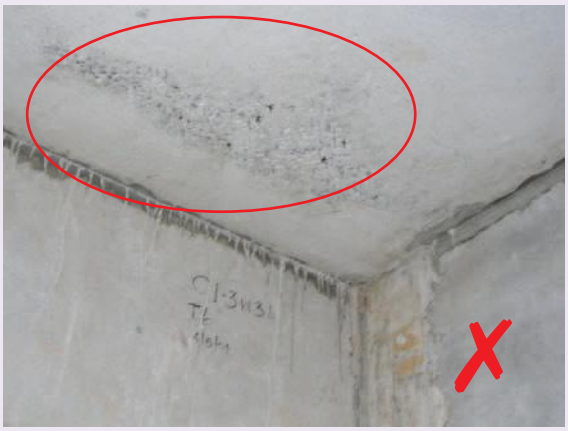
2.4. Camber at mid-span : according to specifications

Note : This is applicable to precast prestressed concrete elements such as prestressed slab, planks, hollow core slab and beams. The predicted camber of prestressed units is usually specified and stated in the drawings. As a general rule, the actual camber should not exceed the predicted camber by more than 50% as recommended in CP 65 : Part 1: 1999

Inspection checklist

3. CONQUAS 21 Assessment – Exposed surface conditions

3.1. No honeycomb – should not have visual exposure of groups of coarse aggregates resulting from grout leakage

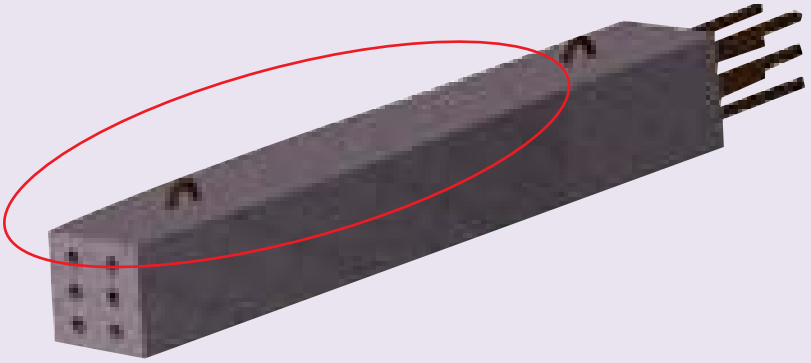


3.2. Cold joint & formwork joint must be smooth

Inspection checklist

3. CONQUAS 21 Assessment – Exposed surface conditions

3.3. No bulging of structural elements

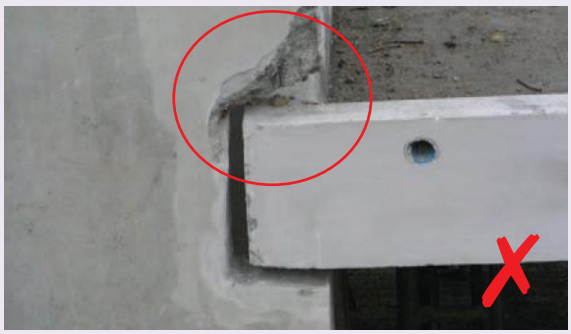


3.4. All formwork, nails, zinc strips, etc must be removed

Inspection checklist

3. CONQUAS 21 Assessment – Exposed surface conditions (cont'd)

3.5. No cracks or damages



4. CONQUAS 21 Assessment – Lifting points and inserts

4.1. Tolerance for position : ± 20mm from centre line location in drawing

Inspection checklist

4. CONQUAS 21 Assessment – Lifting points and inserts

4.2. Lifting devices and inserts free from damages

5. CONQUAS 21 Assessment – Sleeve system / connections

5.1. Tolerance for position : ± 6mm from centre line location in drawings

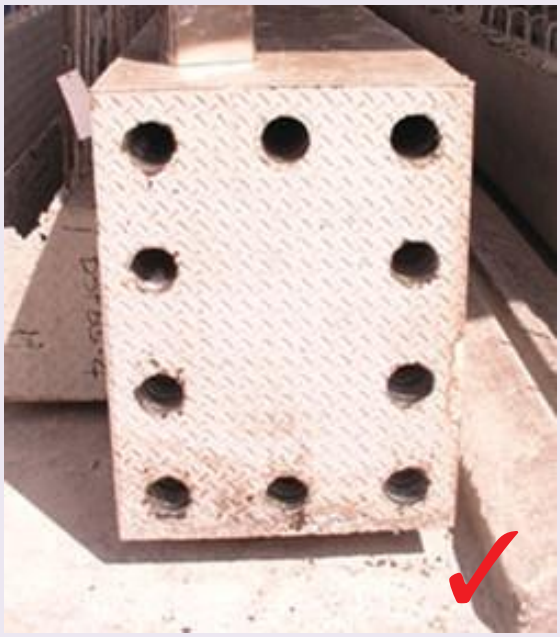
5.2. Bar protrusion length according to requirements. No bending, cranking or damages to bars

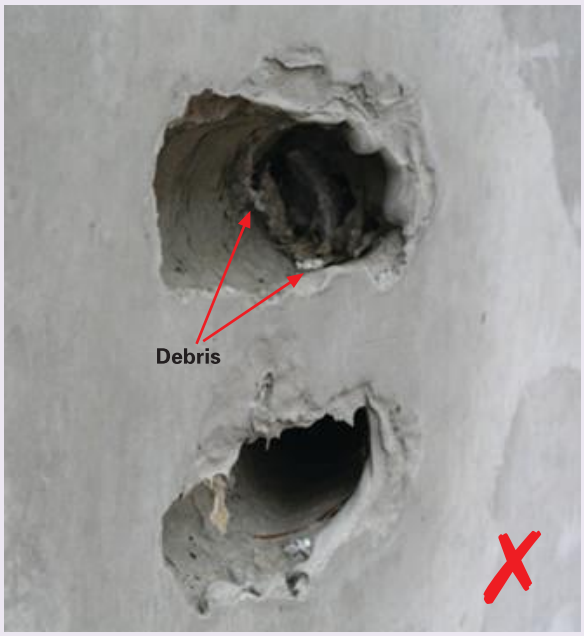
Inspection checklist

5. CONQUAS 21 Assessment – Sleeve system / connections (cont'd)

5.3. Bars free from concrete droppings or corrosion

5.4. Sleeves, grout holes, grout tubes not congested with debris





Inspection checklist

6. CONQUAS 21 Assessment – Interface / joint requirements

6.1. Joint Taper :

- Over 3m length : 6mm
- Maximum for entire length : 9mm

6.2. Alignment of horizontal and vertical joint : ± 6mm

Note : This item refers to panel alignment.

Inspection checklist

6. CONQUAS 21 Assessment – Interface / joint requirements (cont'd)

6.3. Jog in alignment of matching edges : 6mm

Note : This item refers to panel alignment.

6.4. Sitting of elements : according to specifications

Note : It is important to ensure that the sitting of the elements is in accordance with the design requirement to pre-empt spalling at support.

Inspection checklist

6. CONQUAS 21 Assessment – Interface / joint requirements (cont'd)

6.5. Installation of sealant and waterproofing : according to specifications

Note : It is important to ensure that the backer rods required are properly installed to pre-empt leakage of grout shown.

7. CONQUAS 21 Assessment – Cast-in steel items / welded & bolted connections

7.1. Tolerance for position of cast-in steel items: ± 6mm from centre line location in drawings

Note: Examples of cast-in steel items are inserts for temporary support as shown. The accuracy of these inserts' position is important in facilitating the installation process.

Inspection checklist

7. CONQUAS 21 Assessment – Cast-in steel items / welded & bolted connections (cont'd)

7.2. Tolerance for position of openings for bolt connections: ± 3mm from centre line location in drawings

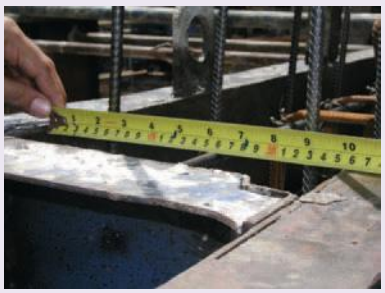
7.3. Relevant requirements in CONQUAS steelwork standards to be used where applicable

7. Common Defects

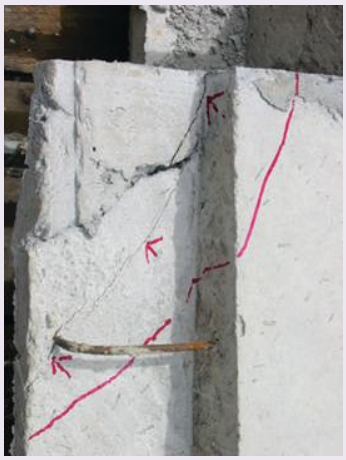
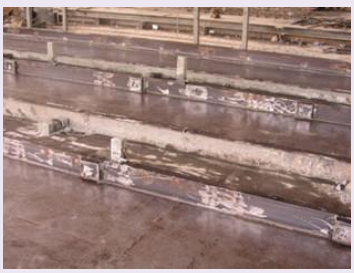
7.1. COMMON DEFECTS AND REMEDIES

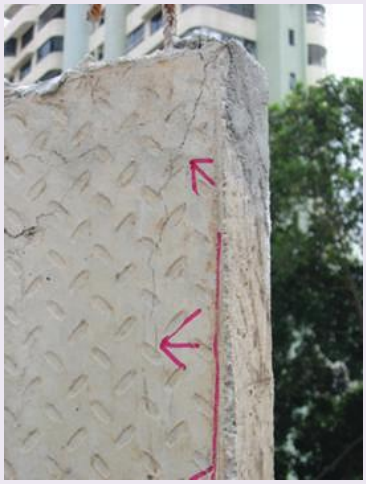
As defects in precast concrete elements would inevitably result in direct and indirect cost in terms of rectification and construction time, it is worthwhile to ensure that they are produced and handled in a way to reduce such incidences. The following table illustrates some of these common defects, their causes and preventive measures.

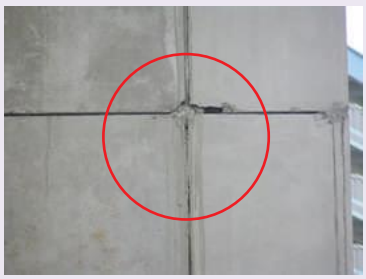
Table 7.1 List of common defects and recommended measures

Common Defects	Possible Causes	Recommendations
1. Dimensional Deviation   *Variation in the dimension of precast elements would affect the joint alignment between these elements when erected*	a) Mould forms may not be sufficiently rigid to maintain specified tolerances during concrete placement.  b) Precast elements may not have gained sufficient concrete strength when demoulded. c) Top surface finish of precast elements may not be properly leveled and troweled during production which result in different sectional thickness.	a) Regular check on the dimensions and rigidity of mould forms before casting operations. As a general guide, the recommended plate thickness for steel mould are: 4.5mm – Up to 50 castings 6 mm – Up to 100 castings 9mm – Up to 200 castings Mould forms conditions will deteriorate with time and usage. They should be repaired, stiffened or replaced when needed. b) Cube tests should be conducted to ascertain the concrete strength of elements before demoulding. c) Spreading and leveling of concrete placement using appropriate tools such as screeder. 
 *Precast slab element may warp due to insufficient concrete strength at lifting or improper storage condition*	 d) Precast elements (especially slender wall or slab panels) may be subjected to undue stress and deformation when they are not properly supported during storage.	d) Precast elements should be properly stored and stacked at designated points using suitable support spacers and frame rack system.

Common Defects	Remedial Measures
1. Dimensional Deviation (cont'd)	• For minor deviation, corrective measures such as surface grinding, trimming/hacking and skim coat application can be appropriately used to remedy the situation. *Note :* *Precast elements that are not within acceptable tolerance limits and have significant effects on the structural integrity or architectural performance should not be used.*

2. Cracks	Possible Causes	Recommendations
	a) Precast elements may not have attained sufficient strength before demoulding.	a) (i)Proper curing method, curing time and temperature should be adopted. (ii)Cube test should be conducted to ascertain the concrete strength of elements before demoulding.
		
	b) Cracks may have occurred during initial lifting due to friction between the elements and the casting mould forms.	b) Appropriate form release agents should be used and uniformly applied onto the mould surface to minimise friction.
		
	c) The thickness of the precast elements may be too thin (70mm or less) and flimsy for safe demoulding and handling.	c) Sectional thickness of precast element should be increased to accommodate demoulding and handling stresses.
	d) Cracks may have occurred during erection due to lack of planning and provisions given to the precast panel geometry, crane rigging configuration and location of openings.	d) (i)Proper handling techniques should be adopted. (ii)Sufficient lifting points should be used to minimise overstressing on certain areas. (iii)Additional reinforcing bars should be placed around the openings and odd corners. (iv)Temporary stiffeners for openings should be provided during erection.

Common Defects	Remedial Measures
2. Cracks (cont'd) 	• All cracks should be examined by a qualified engineer to determine if they present a structural problem. • Depending on the locations and seriousness of the cracks, different repairs method can be used to make good the affected precast elements. • Hairline cracks (not more than 0.3mm) can be repaired by cutting a V groove of specified minimum depth along the cracklines, followed by patching. • For surface cracks (more than 0.3mm) or through cracks, epoxy injection method should be used to ensure that the cracks are completely bound and filled with epoxy. *Note :* *Refer to Annex A of CP 81:1999 - for more detailed information on the prevention and repairs for various types of cracks.*

	Possible Causes	Recommendations
3. Chip-off and Damages   	a) Chip-off at panel edges are usually caused by the hard bearing at supports or excessive force exerted on the elements when handling.  b) Improper storage method. 	a) Precautions should be taken to avoid damaging the elements in the course of placement on vehicle, travel to site and during the unloading operation. Bearing pads should be used to cushion the contact areas from damage.  b) (i)The storage area should be relatively flat and dry. (ii)Precast elements should be properly stored and stacked at designated points using suitable support spacers and frame rack system.

Common Defects	Possible Causes	Recommendations
3. Chip-off and Damages (cont'd)    	c) Localised spalling of the concrete may occur when the precast elements stick to the casting slab or mould due to the presence of old mortar or debris or insufficient application of form release agents. d) Certain areas of the precast elements may be susceptible to damages due to insufficient provision of concrete cover during production.  e) Lifting inserts or hooks used may not be adequate in taking the load or are not properly embedded in elements.	c) (i)The casting slab or mould form should be thoroughly cleansed, leveled to achieve a smooth surface. (ii)The coverage of form release agents should be adequate and uniformly applied onto the mould surface. d) Spacers of the correct sizes should be used and well secured to maintain the concrete cover required during casting.  e) (i)Lifting inserts and concrete strength of elements should be of adequate capacity for the intended lift. Use lifting proprietary products for safe and efficient handling. (ii)Lifting inserts or hooks should be inspected for proper location. They should be fastened to specified depth prior to concrete placement.

Remedial Measures

- Remove all loose concrete and wash off any dust or dirt in the affected area.
- Apply bonding agent to affected concrete surface.
- Welded wire mesh can be included to provide support for the patch mix concrete or grout.
- Patch mix composition or grout should be consistent with the strength requirements of the adjacent concrete.
- Formwork is to be put up where necessary to contain the patch mix or grout.
- Protect the affected area from any disturbance during curing period.

Common Defects	Possible Causes	Recommendations
4. Honeycomb and Excessive Pinholes     	a) Poor concrete compaction due to ineffective vibration or rebars congestion.   b) Grout leakage along the perimeter side forms due to: (i) loose or missing bolts/fixing pins. (ii) damaged rubber gasket seal. (iii) mould part is defective.	a) (i)Proper compaction method should be adopted and carried out. (ii)Concrete mix design and workability should be reviewed and adjusted when needed. (iii)Appropriate concrete vibrator such as clamp-on form vibrator can be used to attain better compaction. (iv)Rebar congestion can be alleviated by having larger (that is, lesser) rebars or by increasing the sectional dimensions of elements where possible. (v) Mechanical couplers or sleeves can be used to simplify the reinforcement layout and to minimise rebar congestion. b) Defective mould forms and accessories should be repaired or replaced to prevent grout leakage during concreting.

Remedial Measures

- Remove all loose concrete and wash off any dust or dirt in the affected area.
- Apply bonding agent to affected concrete surface.
- Welded wire mesh can be included to provide support for the patch mix concrete or grout.
- Patch mix composition or grout should be consistent with the strength requirements of the adjacent concrete.
- Formwork is to be put up where necessary to contain the patch mix or grout.
- Protect the affected area from any disturbance during curing period.

Common Defects	Possible Causes	Recommendations
5. Missing or wrong details such as cast in–items, architectural nib and groove details, lifting hooks, reinforcement / starter bars/ blockout / corrugated pipes.  	a) Items may not have been included in the shop drawings. b) Quality checks may not be properly in place.	a) All items should be reflected in the shop drawings for production. Any changes should be made known to the production team. b) The use of checklists (as in Appendix B) during inspection can help to ensure that all items specified in drawings are included before casting.

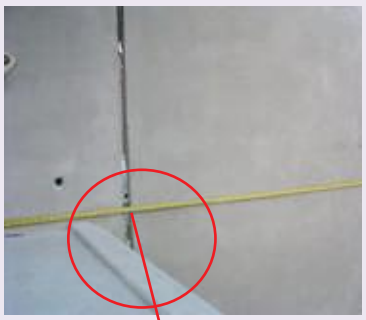
Remedial Measures

- Certain details such as missing starter bars / reinforcement and lifting hooks can be replaced by welding additional reinforcement bars/ lifting hooks to the existing reinforcement bars after hacking off the concrete at the affected area.
- Other items such as cast in-items, groove and blockout can be provided by chasing or chiseling out the face of the precast panels.

	Possible Causes	Recommendations
6. Strand slippage which exceed allowable design values (This item is applicable to prestressed elements only).  Slippages of prestressing strands can be detected by visual inspection.	a) Insufficient bond strength between the concrete and the prestressing strands. b) Poor compaction of concrete around prestressed strands. 	a) Required concrete strength of the precast elements should be attained and verified by cube test results before detensioning of strands. b) (i)Proper compaction method should be adopted and carried out during casting. (ii) Concrete mix design and workability should be reviewed and adjusted when needed. (iii)Provision of appropriate concrete vibrator to attain better compaction.

Remedial Measures

- It is not possible to rectify the elements from strand slippage.
- Design verification should be carried out to ascertain the reduced capacity of the elements due to slippage if adopted.

Common Defects	Possible Causes	Recommendations
7. Alignment   	a) Inaccurate setting out and positioning of precast elements during erection.    b) Deviation in the dimensions of the precast concrete element.	a) (i)Appropriate surveying and leveling equipment should be used to achieve better alignment.  (ii)Required alignment and level should be reconfirmed before permanent jointing.  b) Critical dimensions of precast concrete elements should be verified before installation. 

Remedial Measures

- Minor adjustment of the element / panel alignment can be done during installation. However, the effects on the final alignment and deviation of the building should be evaluated.
- For minor deviation, corrective measures such as surface grinding, trimming / hacking and skim coat application can be appropriately used to rectify the precast elements before installation.

Note :
Precast elements that are not within acceptable tolerance limits and have significant effects on the structural integrity or architectural performance should not be used.

Appendix A

Sample of Inspection and Test Plan (ITP)

Project:_____

Scope of Work: Fabrication of Precast Concrete Elements

S/No	Activity	Responsibility	Inspection Method	Requirement Reference	Acceptance Criteria	Stage/ Frequency	Records
1	**SUBMISSION**						
1.1	Submit shop drawings, joint detail drawings, method statements and mock up sample for approval	MC/ADOS	Review	Section 2 Section 3	Conform to specifications	Prior to start work For each type of precast concrete elements	Approved submissions
1.2	Submit design mix of concrete and constituents materials for approval	MC/ADOS	Review	Section 2	Conform to specifications	Prior to start work	Approved submissions
2	**INCOMING MATERIALS INSPECTION**						
2.1	Carry out inspection of moulds (dimensions, mould's profile, steel plate thickness etc)	MC/ADOS	Visual/ Measure	Section 3	Conform to drawings and allowable tolerances	Each delivery	Delivery document
2.2	Carry out inspection and tests of raw materials (cement, admixtures, aggregate contents, steel bars, wire meshes, prestressing tendons)	MC/ADOS	Visual/ Test	Section 2	Conform to specifications and code requirements	Prior to start work Each delivery	Delivery document
3	**IN-PROCESS INSPECTION**						
3.1	Check cleanliness & application of form release agent on mould	MC	Visual	Section 3	Mould surface clean and dry/Uniform coverage of form release agent	Upon completion	Checklist
3.2	Check mould assembly and condition	MC	Visual/ Measure	Section 3	Conform to drawings and allowable tolerances	Upon completion	Checklist
3.3	Check fixing of rebars, cast-in Items, prestressing tendons, other features, M & E services, fitting of side form and base mould level	MC/ADOS	Visual/ Measure	Section 3	Conform to drawings and specifications	Upon completion	Checklist
3.4	Carry out inspection on stressing techniques and operation (for prestressed precast element)	MC/ADOS	Visual/ Measure	Section 3	Conform to specifications	In process	Checklist

Prepared by _____ Verified by _____ Approved by _____

Date _____ Date _____ Date _____

LEGEND **MC – Main contractor/ Fabricator** **ADOS – Architect/ Designer/ Owner/ Supervisory Personnel**

Appendix A

Sample of Inspection and Test Plan (ITP) (cont'd)

Project:_____

Scope of Work: Fabrication of Precast Concrete Elements

S/No	Activity	Responsibility	Inspection Method	Requirement Reference	Acceptance Criteria	Stage/ Frequency	Records
3	**IN-PROCESS INSPECTION (CONT'D)**						
3.5	Carry out inspection of the ready-mix concrete or factory-mix concrete, concrete workability and compaction	MC/ADOS	Visual/ Test	Section 3	Conform to specifications and approved design mix	Each delivery Before and during casting operation	Delivery document Checklist
3.6	Check concrete strength using cube test before demoulding and detensioning (for prestressed element)	MC/ADOS	Visual/ Test	Section 3	Conform to specifications	Before demoulding Each delivery	Checklist
4	**FINAL INSPECTION**						
4.1	Check for any defective works or cracks on finished surface	MC/ADOS	Visual	Section 6 Section 7	Conform to specifications	After demoulding	Checklist
4.2	Check dimensions, reinforcement details and protrusions, other features and identification markings before storage	MC/ADOS	Visual/ Measurement	Section 3 Section 6	Within allowable tolerances	After demoulding	Checklist
4.3	Check load test results for hollow core slab and prestressed concrete panels	MC/ADOS	Visual	-	Satisfy the design load criteria	As per required Upon completion	Test Records
4.4	Check finishing and repair work	MC/ADOS	Visual	Section 3 Section 7	Conform to specifications	As per required Upon completion	Checklist
4.5	Check concrete strength using cube test before delivery	MC/ADOS	Visual/ Test	Section 3	Conform to specifications	Before delivery	Checklist
4.6	Check protection works	MC	Visual	Section 4	Conform to specifications	Each delivery	Checklist

Prepared by _____ Verified by _____ Approved by _____

Date _____ Date _____ Date _____

LEGEND **MC – Main contractor/ Fabricator** **ADOS – Architect/ Designer/ Owner/ Supervisory Personnel**

Appendix A

Sample of Inspection and Test Plan (ITP)

Project:_____

Scope of Work: Installation of Precast Concrete Elements

S/No	Activity	Responsibility	Inspection Method	Requirement Reference	Acceptance Criteria	Stage/ Frequency	Records
1	**SUBMISSION**						
1.1	Submit precast layout plans, shop drawings, joint detail drawings, site storage plan, method and sequence of assembly, erection and temporary support for approval	MC/ADOS	Review	Section 2 Section 3	Conform to specifications	Prior to start work For each type of precast concrete elements	Approved submissions
1.2	Submit specifications/ samples of materials such as grout, backer rod and sealant for approval	MC/ADOS	Review	-	Conform to specifications/ Manufacturer's Data Sheet	Prior to start work For each type of materials	Approved submissions
2	**INCOMING MATERIALS INSPECTION**						
2.1	Carry out inspection of precast concrete elements (good conditions, dimensions, lifting hook conditions and other connections)	MC/ADOS	Visual	Section 5 Section 6	Conform to specifications	Each delivery Before hoisting	Delivery document
2.2	Carry out inspection of materials used for jointing and grouting works (type of grout, sealant, backer rod etc)	MC/ADOS	Visual	-	Conform to specifications As per approved samples	Each delivery	Delivery document

Prepared by _____

Date _____

Verified by _____

Date _____

Approved by _____

Date _____

LEGEND **MC – Main contractor/ Fabricator** **ADOS – Architect/ Designer/ Owner/ Supervisory Personnel**

Appendix A

Sample of Inspection and Test Plan (ITP) (cont'd)

Project:_____

Scope of Work: Installation of Precast Concrete Elements

S/No	Activity	Responsibility	Inspection Method	Requirement Reference	Acceptance Criteria	Stage/ Frequency	Records
3	**PRE-ERECTION**						
3.1	Check availability of tools, equipment and necessary accessories including the temporary props for erection	MC	Visual	-	Conform to specifications/ method statement	Prior to erection	Checklist
3.2	Check element type received and erection sequence	MC	Visual	Section 5	Conform to specifications/ method statement	For each location	Checklist
3.3	Check accuracy of setting out for the reference and datum levels	MC/ADOS	Visual/ Measure	Section 5	Conform to specifications/ drawings	For each location	Checklist
3.4	Check fixing of compressible waterproofing strip/ backer rods (for external elements)	MC	Visual	Section 5	Conform to specifications/ method statement	For each location	Checklist
4	**INSTALLATION**						
4.1	Check hoisting condition and position of precast elements	MC/ADOS	Visual	Section 5	Conform to specifications/ method statement	In process	Checklist
4.2	Check adequacy of temporary supports in securing the elements before releasing hoisting cable	MC/ADOS	Visual	Section 5	Conform to specifications/ method statement	In process	Checklist
4.3	Check on the alignment, verticality and level of elements	MC/ADOS	Visual/ Measure	Section 5	Conform to specifications/ drawings	In process	Checklist
4.4	Check rebar connections between precast elements and with other building elements	MC/ADOS	Visual/ Measure	Section 5	Conform to specifications/ drawings	In process	Checklist

Prepared by _____

Date _____

Verified by _____

Date _____

Approved by _____

Date _____

LEGEND **MC – Main contractor/ Fabricator** **ADOS – Architect/ Designer/ Owner/ Supervisory Personnel**

Appendix A

Sample of Inspection and Test Plan (ITP) (cont'd)

Project:_____

Scope of Work: Installation of Precast Concrete Elements

S/No	Activity	Responsibility	Inspection Method	Requirement Reference	Acceptance Criteria	Stage/ Frequency	Records
4	**INSTALLATION (CONT'D)**						
4.5	Re-check and confirm the overall alignment verticality and level of the erected elements before proceeding with the grouting and casting of joints	MC/ADOS	Visual/Measure	Section 5	Conform to specifications/ drawing/method statement	Before joint casting For each location	Checklist
4.6	Check application of grout for joints and connection / installation of waterproofing system	MC/ADOS	Visual/Measure	Section 5	Conform to specifications/ drawing	For each location	Checklist
5	**FINAL INSPECTION**						
5.1	Check for any cracks on finished surface	MC/ADOS	Visual	Section 6 Section 7	Conform to specifications	At completion	Checklist
5.2	Check watertightness test results for - External wall panels - Joints between external wall and window frame	MC/ADOS	Visual	-	No dampness and leakage	As per required	Test Records

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Date _____ Date _____ Date _____

LEGEND **MC – Main contractor/ Fabricator** **ADOS – Architect/ Designer/ Owner/ Supervisory Personnel**

Sample Checklist for Fabrication of Precast Concrete Elements

Project: _____

Location: _____

Checklist	Inspection			Remarks
	Date	Result	Sign	
MOULD INSPECTION				
1. Critical dimensions (within tolerance) • Length • Width • Height • Squareness • Openings				
2. Mould condition • Plate thickness • Base mould support • No twisting or unevenness • Fitting				
3. Provision for bar protrusion and openings				
4. Level and anchorage				
5. Mould cleanliness				
6. Form release agent				
REINFORCEMENT & CONNECTION				
7. No.,size and position				
8. Lifting hooks and inserts				
9. Corrugated pipes				
10. Starter bars				
11. Anchorage, and lapping				
12. Cover				
PRESTRESSING TENDONS				
13. No. size and profiles of strands/tendons				
14. Stressing pressure				
15. Elongation				
M & E SERVICES				
16. Recesses or blockouts and openings • Electrical services – power points, telephone SCV points, cast in switches • Plumbing services – grooves lines, waste pipes, water pipe • Gas pipes and Aircon ducts				

Sample Checklist for Fabrication of Precast Concrete Elements (Cont'd)

Project: _____

Location: _____

Checklist	Inspection			Remarks
	Date	Result	Sign	
OTHER FEATURES				
17. Provisions for groove line, water drip line and fittings				
CONCRETING				
18. Concrete slump and cube sampling				
19. Compaction and curing condition				
20. Demoulding strength				
FINAL INSPECTION				
21. Surface condition • No honeycomb • No crack • No chipping • Edge straight • No excessive pinholes • Flatness or evenness				
22. Element markings				
23. Dimension checks on elements				
24. Recess, groove line, water drip line				
25. Reinforcement, links, bar protrusion, fitting and prestressing strands (if any)				
26. Storage condition and stacking method				
27. Finishing and repair works				
28. Load test for hollow core slab and prestressed concrete panels				
29. Concrete strength before delivery				
30. Protection works for delivery				

Sample Checklist for Installation of Precast Concrete Elements

Project: _____

Location: _____

Checklist	Inspection			Remarks
	Date	Result	Sign	
ELEMENT INSPECTION				
1. Correct element type				
2. Critical dimensions (within tolerance) • Length • Width • Height or thickness • Squareness				
3. Surface condition • No honeycomb • No crack • No chipping • Edge straight • No excessive pinholes • Flatness or evenness				
4. Lifting points / inserts • Location • Physical condition				
5. Sleeve system / Connections • Starter bar (length, size and spacing) • Loop and lapping bars (length, size) • Corrugated sleeve (location and cleanliness)				
6. M & E services • Location • Physical condition				
7. Storage and loading points • Condition • Stacking method				
PRE-ERECTION				
8. Tools, equipment (drills, auto-level, theodolite, brackets, bolts) and temporary props and bracings				
9. Precast elements to be erected are delivered to storage or loading points				
10. Survey reference lines and level marks				
11. Starter bars of lower units (number, spacing, size and length) for vertical components such as wall and column units				
12. Location and conditions of corrugated pipe sleeves				
13. Shim plate level				
14. Backer rods and waterproofing strip position				

Sample Checklist for Installation of Precast Concrete Elements (Cont'd)

Project: _____

Location: _____

Checklist	Inspection			Remarks
	Date	Result	Sign	
INSTALLATION				
15. Setting out and position of elements • Verticality • Alignment • Level				
16. Adequacy of temporary supports				
17. Grouting work (check mix ratio) • Horizontal joints • Corrugated pipe sleeve connection				
18. Joint and connection details • Rebar connections • Weld connection • Cast in-situ joint connection				
FINAL INSPECTION				
19. No visible crack or damage				
20. Watertightness test on - External wall panels and - Joints between external wall and window frame				

References

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   Code of Practice for Structural Use of Concrete – Design and Construction

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   Code of Practice for Precast Concrete Slab and Wall Panels .

4. CP 82:1999
   Code of Practice for Waterproofing of Reinforced Concrete Buildings

5. Singapore Standard SS 289
   Concrete

6. Singapore Standard SS 26
   Ordinary Portland Cement

7. Singapore Standard SS 31
   Aggregates from Natural Sources for Concrete

8. Singapore Standard SS 320
   Concrete Admixtures

9. Singapore Standard SS 32
   Welded Steel Fabric for the Reinforcement of Concrete

10. Singapore Standard SS 2
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11. Singapore Standard SS 475
    Steel for the Prestressing of Concrete

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