10 CONSTRUCTION

This section discusses the issues concerning the construction stage for concrete panel walling.

Further details on concrete panel walling can be found in C&CAA publications: Tilt-Up Construction Notes; and AS 3850.

10.1 Planning / Programming

For all concrete panel walling types, planning is crucial to success. During this stage the entire design and construction process for the structure should be carefully planned. Time spent thoroughly planning will be regained many times over by a more productive and efficient construction stage. The various alternatives for each aspect of the project should be evaluated in the planning stage, as once construction is underway, proper evaluation may no longer be possible due to time constraints.

The walling system should be planned first, as each system raises its own set of design and construction issues. Determining whether you will use a cast off-site system or a cast on-site system will determine the set-out of the site, and the date that construction can begin. Panels that are cast off-site, freeing up site space, but requiring transport of the panels to the site. While, panels that are cast on-site, do away with the need for transport, but requiring site space for the casting beds.

Carefully assess the size of the workforce necessary to complete the project in the required time. This will depend (amongst other things) on the level of experience the workforce has with the walling system you've chosen. The learning period need not be long if there is a high level of standardisation in the panels, but allowance for learning time should be included in the overall time for the project.

Other important considerations in the planning of all concrete panel homes include:

Teamwork Planning should involve discussions between the main players in the building of the home: the Client (owner), the Builder, the Designers (Architect or Building Designer and Structural Engineer), the Panel Manufacturer and the Panel Erector. Cooperation should continue through to the completion of the project so as to ensure that the advantages of the panel system are fully exploited and that cost benefits are maximised.

It is important that each member of the team be aware of the limitations of the chosen panel system. Compromise may be necessary, so to achieve the best solution, all members should participate in all decision making. The casting and erection sequences are of particular importance, as are any changes that may occur during construction. Changes during construction should be made only after careful evaluation, since many will affect subsequent operations.

Design The structure must be designed specifically for the chosen panel system, so as to maximise the benefits of the system. For greatest cost-effectiveness:

- **Keep it simple**. Simple designs are most cost-effective.
- Optimise the panel size by balancing the maximum lifting capacity of the equipment against the benefits of on-site speed and mobility (as well as transport limitations, if the cast off-site panel system is being used).
- Standardise the panels as far as possible.
- Ensure that, if possible, the wall panels are loadbearing. Try to use the wall panel's load-bearing capacity so as to minimise the need for other structural elements.
- Make use of as many of the panels' attributes as possible (structural, acoustic, thermal, fire resistance, and so on. All are discussed in more detail in this handbook.)

There are two phases to the design: (1) structural design for in-service conditions, usually carried out by the structural consultant engineer, and (2) design for the conditions experienced during the handling, transportation and erection of the panels, carried out by either the structural consultant engineer or a design engineer employed by the panel manufacturer.

The design phase is discussed in more detail in Chapter 3, "General Design Considerations" and Chapter 8, section 8.2 – "Structural Performance (Construction, Dead, Wind and Seismic Loads)".

Layout The panel layout should be planned so as to facilitate quick erection and avoid unnecessary crane set-ups or double-handling of panels. When planning the layout, take all of the following into consideration:

- Location(s) for crane set-ups.
- Start of erection, and sequence of panel erection.
- Size and orientation of panels.
- Size and working radius of crane appropriate for the particular panels' weights. (For face-lifted panels, the true working radius of the crane should be assessed by adding a minimum of 1.5 m to the final panel position radius. This amount may need to be increased for taller panels.)
- Any overhead obstructions (like overhead power lines, or trees) that may restrict the crane's working radius.
- The site layout should allow for all-weather access to minimise any down-time in erection of panels after wet weather.
- The structural capacity of the site (footings, suspended slabs, and so on) to carry the concentrated loads of the crane and/or transport trailer while they are carrying panels.

For Cast On-Site Panels:

- If panels are to be cast on the ground floor slab, confirm the constructed dimensions, and level and finish the slab, before constructing the panels.
- Most panel types are cast with the external face down, but some surfaces need face-up casting.
- Location(s) for casting, and the sequence of panel casting, should be planned so that so that both ready-mix concrete mixers and erection cranes will have easy access.
- The option to 'stack-cast' panels (one on top of another) will provide extra casting space on site, if the type of surface finish allows for it. If this option is adopted, give careful consideration to the casting order and erection sequence so as to minimise double-handling of panels.

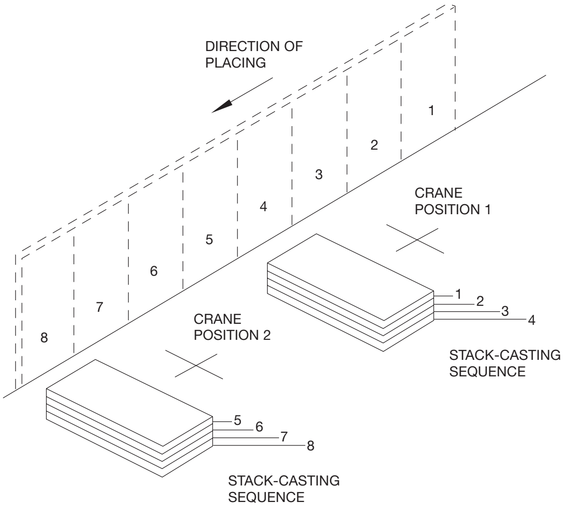

Figure 10.1 Stack-Casting Sequence

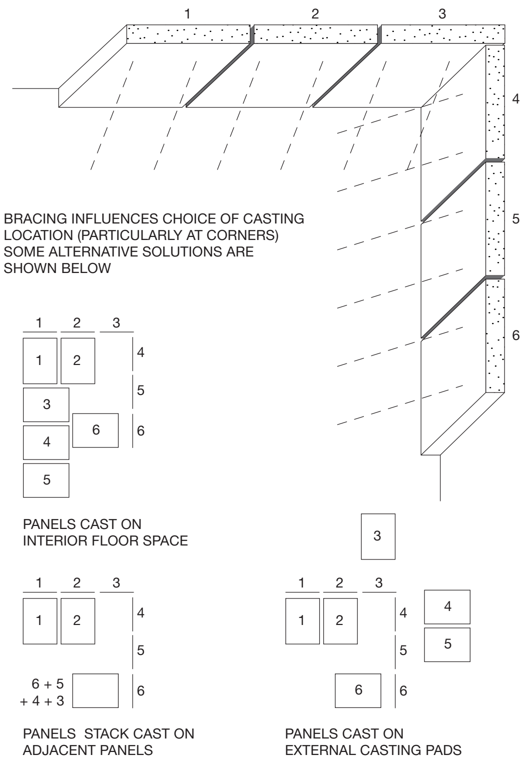

Figure 10.2 Influence of Bracing on Casting Layout

For Cast Off-Site Panels:

- Determine size and type of transportation required to bring the panels to the site.
- Plan the loading sequence and delivery sequence of panels so as to minimise double-handling of panels on-site.

Structural and Shop Drawings For effective concrete panel walling construction there must be good structural engineer's drawings of the structure's design (including the panel walling system design), as well as shop drawings of the individual panels, the layout elevations, and the connection details.

Structural drawings should be produced in accordance with Australian Standards AS 3850 and AS 3600, and contain sufficient information for detailed shop drawings to be prepared. Structural drawings should include at least:

- The project location.
- Elevations clearly indicating the structural framing and panel layout.
- The structural dimensions.
- Reinforcement for in-service loads.
- Framing connection locations and details.
- Panel supporting details (such as footing/pad).
- Design criteria affecting construction, including lifting inserts, bracing and strongback locations (if applicable).
- The fixing connections and reinforcement specifications.

Shop drawings of individual panels should include all information from the structural drawings relevant to the concrete panel walling system, and contain sufficient information to produce the individual panels. The drawings of the panels should include at least:

- The project location.
- The panel's dimensions, centre of gravity, weight, and concrete volume.
- The location of all reinforcing steel, cast-in inserts (connection, lifting and bracing), and embedded items (fixing plates, service conduits, blockouts, window or door frames).
- Edge details and panel sections.
- Architectural features and their locations (including panel surface finishes, grooves, and rebates).
- The reference number of the panel, and its location in the building plan, as well as references to the layout and elevation drawings (which should include enough information to erect the panel).

For further information on what must be included in shop drawings, refer to AS 3850.

Shop drawings should be approved by the builder, the structural engineer and architect prior to commencing panel manufacture.

10.1.1 Typical Cast On-Site Wall Panel Construction Programme

There are a variety of possible construction programmes for building with cast on-site panels that will depend on the on-site lead times, site preparation and restrictions, panel sizes/shapes, and numbers off. However, a typical programme could consist of the following steps:

- Structure is planned and designed, and walls are modularised into panels to suit the structure and construction restrictions.
- Site is levelled and any termite management systems installed.
- Foundations are dug and cast.
- Ground floor sub-base material is rolled, vapour barrier laid, and floor slab edge forms installed and accurately levelled.
- Floor slab is poured and finished by a power float.
- Once the slab has gained sufficient strength, panels are constructed on top, with either single layer or 'stack-cast' edge forms. Appropriate release agents or bond breakers are applied on formwork.
- Panel reinforcement and cast-in inserts are placed accurately within the moulds. Panels are concreted, finished and cured.
- After a curing period of up to seven days, panels are ready to be stripped. Braces and lifting devices are attached, and panels are gradually lifted and tilted up into an upright position. Flexure stresses during lifting reach a maximum when the panels reach an angle of approximately 30 degrees.
- Panels are then moved into position, and braces are fixed to the slab or bracing footings to temporarily restrain the panels until they are fully fixed and braced to the structure. The braces can be used to adjust the panels into their final position. Panels must not be detached from the lifting gear until they are securely braced.
- If required, suspended floors can be installed once a sufficient number of panels have been erected to support the floor.
- Roof framing can be added after all the main structural components of the house are installed.
- Servicing and fit-out work can commence within the building once it can be locked. Meanwhile, external finishing work can proceed, such as sealing of panel joints, painting, or application of other external surfaces.

10.1.2 Typical Cast Off-Site Wall Panel Construction Programme

A typical programme for cast off-site construction is similar to one for cast on-site, with a few obvious differences:

- While on-site work is being performed, the manufacture of the panels can be occurring off-site in a casting factory, and the panels can stored off-site until required. Panels are produced in steel moulds to give them a higher level of off-form finish, and are stripped after only one or two days due to the use of higher early strength concrete and/or accelerated curing methods (such as steam curing).
- Once the footing or floor slab is constructed to support the panels, the wall panels can be transported to the site in erection sequence.
- Panels are then lifted directly from the trailer into position with a mobile crane. The programme is then the same as for cast on-site panels.

10.1.3 Sequencing Roof Installation

Roof installation is usually the last of the major construction processes, and occurs only after all wall panels have been erected. Ideally, the same erection crane is used for installing both the wall panels and the roof framework, to avoid access problems and to reduce costs.

10.2 Excavation and Earthworks

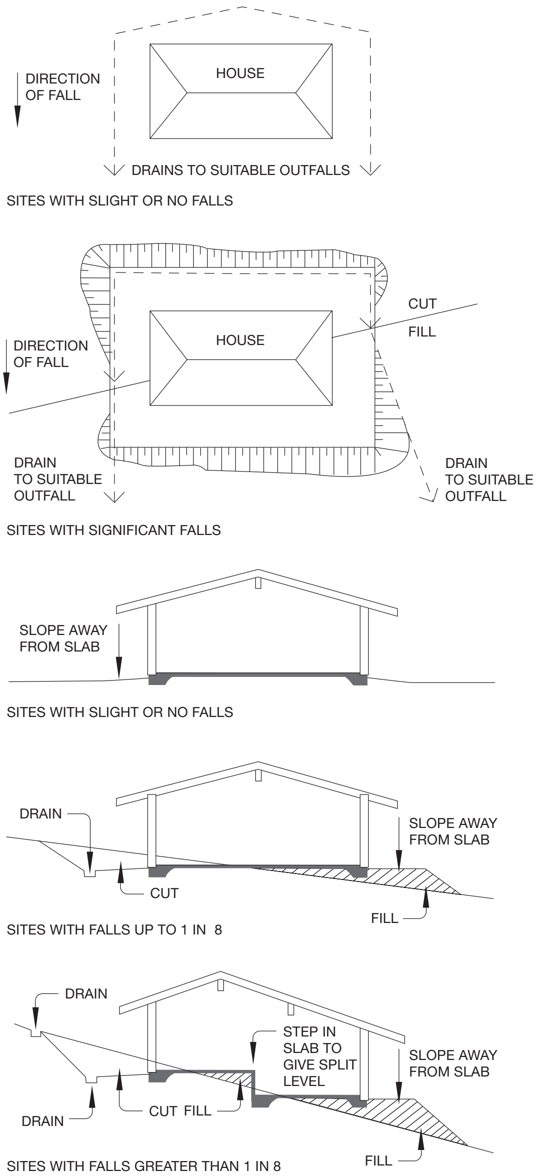

Figure 10.3 Typical Surface-Water Drainage Arrangements

Bulk excavations are best carried out by suitable earthmoving machinery. If imported fill is to be used, it is important to determine the type and makeup of the fill, and the most suitable compaction method. Various traditional compaction methods include:

- A rolling layered fill using bulk excavation machinery.
- A controlled fill using a fully-articulated or towed vibratory drum roller and/or a sheep's foot vibratory drum roller or vibrating plate.

In some cases, local authorities may require a *Sediment Control Plan*. This is a document indicating the measures to be taken to control soil and silt run-off from the building site.

For further details regarding the BCA requirements on earthworks and site drainage, refer to the BCA, Volume 2 – Class 1 and 10 Buildings, Housing Provisions, Parts 3.1.1 and 3.1.2. Further information on slab-on-ground construction can be found in this handbook in Chapter 4, "Structural Shell", and in the C&CAA publication, *"Residential Floors"*.

10.3 Formwork

An especially important process in concrete panel walling systems is the setting-up of the formwork or mould work that will determine the shape the panel.

The formwork must be in accordance with Australian Standards AS 3610, Formwork. Formwork often simply frames the perimeter of the panel-but the extent and sophistication of the formwork and formlining will depend on the amount of modelling and texturing required on the external surface. The choice of materials for the formwork, and the accuracy of its construction, play a vital part in ensuring that the erection process goes smoothly and efficiently.

The possibility of re-using formwork should be considered during design. Timber formwork is versatile, and cheaper than steel, but steel forms can be re-used more often, and may therefore end up being better value.

Currently, timber is most often used for cast on-site panel systems, while steel is preferred for cast off-site panels systems. If timber formwork is to be used, it should be sealed, and the timber should be of suitable quality to enable the forms to be reused.

The number of "square" edges should be minimised along the panel, as they are susceptible to damage. Chamfered or bevelled edges are more durable, and can easily be produced with a steel, timber or plastic triangular fillet strip fixed to the edge formwork.

To make vertical formwork easier to remove, it should have a 'stripping taper'. This is especially important for recesses, rebates or groove formers that are formed off the casting bed, which will be very difficult to remove from the face of the panel without stripping tapers on the vertical side faces of the formers.

Surface Finishes The panel surface finishes are influenced by the formwork surfaces: the concrete panel surface will reflect any imperfections or blemishes in the form it is cast on. Special care is therefore required to control the tolerances and finishes of all surfaces, especially the main faces of the panel.

If temporary bracing for the side forms are located on the casting surface, they should be positioned so that they don't mark the surface of the panel cast over them. Formwork that is to produce recessed areas in the panel face should be robust enough and be secured well and remain in place as the concrete is placed and compacted. (If a recess-former moves out of position, it's usually not noticed until the panel is cured and stripped from the mould.

For cast on-site panels:

- If panels are stack-cast (cast one on top of another), additional care needs to be taken with the top-steel floated surface of the panels, as any imperfections (like trowel marks, joint lines, uneven surfaces, or boney areas) will be reflected in the next panel cast on top.
- If openings (for pipes, utilities, and so on) must be left in a floor slab that is to double as a casting slab, then a form ply or a 20 mm coat of concrete on a sand fill can be used to close the opening temporarily. The infill can be knocked out after the panels have been erected.
- Check the tolerances on the floor slab to ensure that it is suitable to be used for the casting of panels.

Edge Formwork Wall panels are usually cast flat, so edge formwork is all that is required. Edge formwork can be made of timber or steel. Supports or bracing may be required to stiffen the side form to keep it straight enough to meet the required tolerances. Leave enough space between the bracing and the side forms of cast panels to avoid clashes with adjacent forms or panels during stripping and lifting.

As with all formwork, great care must be taken with the casting surface at joints, corners and edges of side forms. These areas are susceptible to damage, both to the panel and to the formwork. Special care also needs to be taken to ensure that the formwork is installed within specified tolerances to form a tight seal, and that joints in formwork-to-formwork and formwork-to-casting surfaces are sealed with a non-staining sealant. This initial care will reduce the likelihood of a leak of concrete slurry or mortar, which can lead to honeycombing or discolouration of the panel surface around the leak, and weakening of panel edges.

Blockouts and groove or rebate formers can be made from timber or steel, but plastic and high-density polystyrene can be used instead; these materials can be cheaper and maybe more practical (depending on the sizes, shapes, and number of reuses required).

Bond Breakers "Bond breakers" or "release agents" are coatings that prevent a bond from forming between panel surfaces, or between a panel and its formwork. They are critical to the manufacture of concrete wall panels: if a panel doesn't separate easily from its casting mould or formwork, it can delay the entire production schedule. The additional force needed to strip a stuck panel can damage both the panel and the formwork.

If panels are stack-cast, or cast on a concrete surface, the bond breaker acts as a water-repellent film that seals the concrete casting surface against the absorption of cement paste, preventing adhesion to the panel above.

In short, the functions of the bond breaker are:

- To enable a clean, complete separation of the panel from the casting surface.
- To minimise the dynamic loading caused by suction at time of separation.
- To function as a curing compound for the casting surface (in the case of panels being stack-cast, or cast on a concrete floor slab).

If the bond-breaker leaves a residue on the panel or the casting surface, it must not discolour it, or affect the adhesion or performance of any subsequent coatings or coverings that the panel is to receive.

Bond breakers are of various types:

- Film-forming bond breakers These form a waterproof coating on the concrete surface. Most also double as a curing compound if applied to the top surface of the concrete immediately after finishing. A second coat must be applied later. Using this type avoids any problems of incompatibility between curing compound and bond breaker. This type of bond breaker is usually used on panels that are cast on concrete surfaces (either on the floor slab or on top of another panel).

- Resin-based film-forming bond breakers These are designed so that the film will oxidise and break down over a period of time, depending on exposure to weather and sunlight. Wax-based compounds do not break down in this way, tending to leave a residue that can interfere with applied finishes, and so are not recommended. Resin-based compounds are generally used for cast on-site panel manufacture.

- Non-film-forming bond breakers These are also known as ‘release agents’ and can either be reactive or non-reactive. Reactive bond breakers work by combining with the alkalies in the concrete to produce a soapy layer which prevents bonding. Non-reactive bond breakers act as waterproofers. They do not react with the casting surface, but block its pores, repelling fresh cement paste and thus preventing bonding. These compounds usually do not function as curing compounds, and are primarily used in cast off-site panel manufacture where the concrete panels are rarely cast against other concrete surfaces. The release agent should be checked for compatibility with the curing compound and any other applied finishes and joint sealants.

The compound must be applied to the casting surfaces in accordance with the manufacturer’s instructions. Keep the following points in mind when using bond breakers and release agents:

- Before application, the surfaces should be free of dirt and foreign materials.
- Application should be in two coats, each application at right angles to the other so that the compound doesn’t pond on the casting surface. For best results, application should be uniform and cover the entire surface.
- If the compound is designed to cure the concrete, it should be applied directly to the top surface as soon as it begins to harden, just after finishing the surface.
- The application rate of the compound should never be lower that that recommended by the manufacturer. On porous or high textured surfaces, a higher-than-recommended rate may be required.
- Application should happen before reinforcement is placed to ensure complete coverage of surfaces in corners, rebates, reveals and grooves.
- If there are lengthy delays in the casting due to weather or other circumstances, the coating should be re-examined afterward to ensure that it is still intact, and that the reactive compounds have not broken down (if they are being used). The coating may need to be reapplied. If the surface is excessively wet from rain, then the water should be removed before casting.

Freeing “Captive” Panels If a panel does not readily come free of the casting mould or surface, it’s dangerous to try to pull it free with the crane: the sudden release of tension when it does spring free can damage the panel, the formwork, and possibly the crane itself.

If the panel is not too strongly bonded to the casting surface, it can be separated by driving wedges between the panel and casting surface, along the lifting edge of the panel in line with the lifting inserts, while slowly lifting the panel in an effort to peel it off. Wooden wedges are better than steel ones, as they are less likely to damage the panel.

10.4 Steel Reinforcement

The steel reinforcement for all concrete wall panels is designed to resist handling, installation, and in-service loads. It also controls cracking caused by temperatures and shrinkage stresses.

The type of reinforcement must comply with the relevant Australian Standards (AS 1302 for reinforcement bar and AS 1304 for fabric reinforcement).

There are three categories of reinforcement, as defined in AS 3850:

Structural Reinforcement includes reinforcing and prestressing steel that resists in-service loads, and controls cracking from thermal and shrinkage stresses.

Additional Reinforcement is reinforcement for resisting the additional loads created during stripping, handling and erection.

Component Reinforcement is reinforcement associated with cast-in lifting, fixing and bracing inserts, to enable them to attain their design capacities and to ensure that their failure mode is ductile rather than brittle. Structural and additional reinforcement must be shown on shop drawings, but component reinforcement can be specified as part of an insert assembly and therefore does not need to appear in the drawings.

The reinforcement ‘cage’ is usually in the form of one or two layers of reinforcement. If possible, the reinforcement should consist of fabric or mesh, with supplemental reinforcement bars to achieve the required area of steel in the panel’s cross section. (Using fabric or mesh instead of loose reinforcement bars eliminates the time and expense of fixing the loose bars.) Reinforcement can be fabricated in one or two completed pieces and lifted directly into the casting mould, so there are minimal delays. Additional reinforcement bars are provided around the edges and any openings in the panel to strengthen corners and control cracking.

The reinforcement is usually located centrally in the cross section of the panel, but there are cases (such as panels thicker than 180mm, odd-shaped panels, or panels that will bear excessive loads) that require two layers of reinforcement. Sandwich panels need a layer of reinforcement in each leaf of concrete enclosing the insulation board. The reinforcement should always be placed accurately relative to the side forms and casting surface, using bar chairs and/or spacers of the correct size to ensure that the reinforcement has the required cover. If possible, reinforcement should be secured to keep it from moving during the pouring of the concrete. Lapped reinforcement should also be tied to avoid movement.

Finally, the whole panel must be checked to ensure that the all reinforcement is of the correct size and in the right place. Particular attention should be paid to ensuring correct and uniform cover at the corners and along reveals.

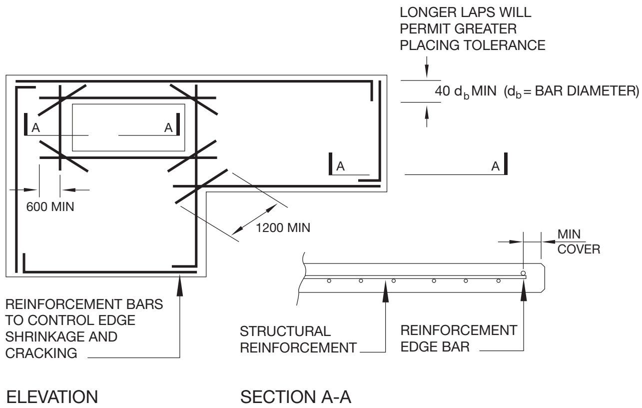

Figure 10.4 Typical Structural Reinforcement

In sandwich panels, the reinforcement for the second concrete leaf (the one poured on top the insulation board) is laid in the same way as for solid panels, except that special chairs are needed to support the reinforcement without punching through the insulation.

10.5 Fitments / Embedments

Besides reinforcement, there are numerous other elements that may need to be cast into the panel, such as:

- Lifting inserts and lifting devices.
- Bracing inserts.
- Connection or fixing inserts, fixing plates, brackets, and so on.
- Insulation board and tie inserts (for concrete insulated sandwich panels).

10.5.1 Lifting Inserts and Devices

Australia has a number of specialist manufacturers and suppliers of proprietary concrete panel lifting systems for safely handling wall panels during stripping, transport and installation. The inserts and associated lifting devices must comply with Australian Standard AS 3850, which details the correct procedures and necessary certification.

Lifting systems are comprised of inserts (specially-designed components cast into the concrete panel) and an associated lifting 'clutch' that can connect to the inserts. Lifting systems are available in a variety of types and sizes to accommodate different kinds of lifting and sizes of loads. (All lifting systems, though, should have a corrosion protective coating such as hot-dipped galvanising.)

There are two types of lifting systems: face-lifting systems and edge-lifting systems. *The inserts for one system cannot simply be used for the other*. In fact, it's extremely important that all components used for lifting be compatible with each other. For this reason, all cast-in inserts and their associated hardware should be obtained from a single manufacturer. If possible, the same size and type of lifting system should be used for the entire project, to reduce the possibility of the wrong size or type of lifting hardware being used on a lifting insert.

Face-Lifting Systems are comprised of a forged steel anchor that is cast into the face of the panel in a specially-formed recess. The head of the anchor can then be connected to the lifting clutch. If the cast-in end consists of an 'eye', a Y12 to Y20 deformed bar (of a length specified by the proprietary system) must be threaded through the eye and lapped behind the panel's main reinforcement. If the cast-in end consists of a 'foot', then no additional reinforcement maybe required. (Other types of anchors are available as well, such as plates with a splayed tail, or with an eye for an additional reinforcement bar.)

For face-lifting systems to be effective, the panel must have a large surface area on the main panel face, so as to facilitate a failure cone large enough to provide a suitable "pull-out" capacity of the anchor. Face lifting systems are available for lifting typically 1.3, 2.5, 5.0 and 10.0 tonnes. A minimum of two anchors are cast into a panel to provide for a controlled and balanced lift.

This type of lifting system is usually the least expensive of the two.

Edge-Lifting Systems are comprised of a forged steel plate anchor with a corrugated edge profile that is cast into the edge of the panel in a specially-formed recess. The head of the anchor can then be connected to the lifting clutch. Edge-lifting anchors are usually longer than face-lifting anchors, and so require additional reinforcement with Y12 to Y20 deformed bars. The bars lap around the anchor to increase the diameter of the failure cone.

Edge lifting systems are available for lifting typically 2.5, 5.0, 10.0 and 20.0 tonnes. A minimum of two lifters are cast into a panel to provide for a controlled and balance lift.

Lifting Inserts When deciding the type and number of cast-in lifting insert to use, and where to put them, all the following should be taken into consideration:

- Method of lifting (face or edge).
- Mass of the panel.
- Size and shape of the panel, taking into account any openings.
- Structural capacity of panel section.
- Concrete strength at the time of lifting.
- Capacity of the lifting insert, taking into account edge effects and embedment depths.

If wall panels will be lifted and tilted about an edge, anchors are cast into the face of the panel, but above its centre of gravity, so that the panel hangs off the vertical. (Panels lifted in this manner should be designed to hang no more than about 10º off the vertical. If this is not possible, consider using a combination of face-lifters and edge-lifters.)

Australian Standard AS 3850 requires that lifting inserts be designed, manufactured and installed such that the Working Load Limit (factor of safety) is at least 2.5 against failure. A minimum dynamic and impact factor of 20% of the dead load of the panel must also be incorporated into the design.

The lifting inserts should be marked (in a place that will remain visible after casting) with the following information, which should be checked both during and after manufacture of the panels:

- The manufacturer's symbol and name.
- The lifting capacity of the insert.
- The insert length.

Lifting Clutches With all types of cast-in lifting inserts, a purpose-made, quick-release lifting clutch is used to enable the erector to quickly and safety connect, lift and release the rigging from the panel during installation.

It is essential that lifting clutches be compatible with the lifting inserts they're connected to, both in type and in lifting capacity. It's recommended that all the items be from the same manufacturer.

The lifting clutches must be designed and manufactured with a safety factor in accordance with Australian Standards.

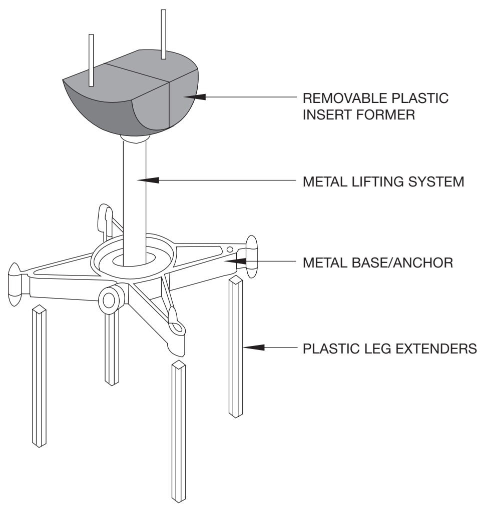

Figure 10.5 Typical Face-Lifting Insert

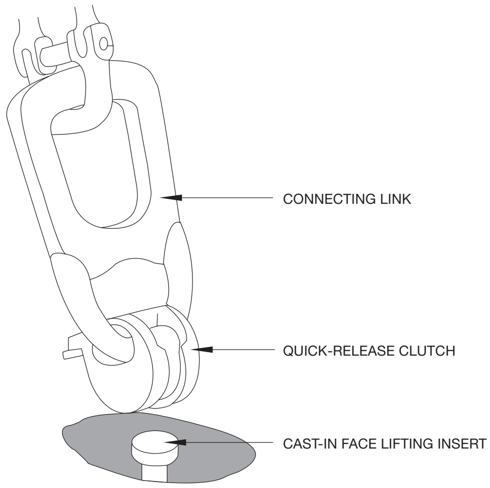

Figure 10.6 Typical Quick-Release Lifting Clutch

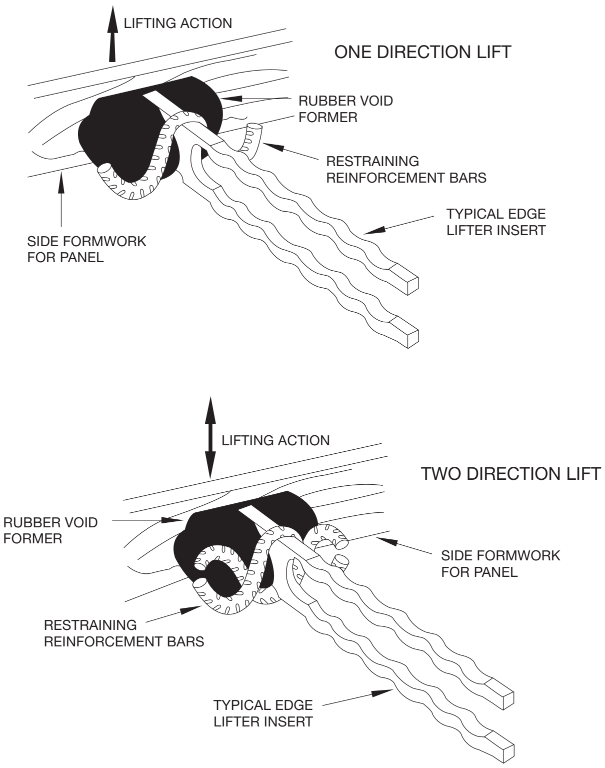

Figure 10.7 Typical Edge Lifting Inserts for One-Direction and Two-Direction Lifts. From Reid Swiftlift Concrete Lifting Systems – Design Manual.

Quick-release lifting clutches, if used properly, offer the following advantages:

- Easy positive connection to the lifting insert.
- Safe operation, as the clutch cannot be released until the tension on the lifting rigging is released.
- Easy installation and release from ground level, once panel is secured in the correct position.
- Proven and documented capacity of the lifting gear.
- Certification by State authorities.

10.5.2 Bracing Inserts and Braces

Bracing inserts are either threaded inserts (like connection and fixing inserts, discussed below), or coil-like sockets similar to the coil threads used in formwork systems.

It can be quite difficult to cast bracing inserts into ground slabs or pad footings because of the difficulties of controlling the accuracy and quality of installation on ground. In this case, another option is to use drill-in fixing anchors once the slab or footings are cast, just before installation of the panels. There are various types of drill-in anchors available, all of which must be installed in accordance with AS 3850 and the manufacturer's recommendations:

Mechanical Anchors are either installed into specially prepared undercuts in the slab, or drilled completely through and locked under the slab.

Chemical Anchors rely entirely on the chemical bond between the resins and the concrete they are drilled into and embedded in. They are very susceptible to variations in operating conditions, so AS 3850 allows them only if each anchor is individually proof-tested. Because of this restriction, and because of the delay as the resin sets, chemical anchors are not widely used.

Expansion Anchors are the most commonly-used type of drill-in anchor for fixing braces in ground slabs and footings. They are comprised of a bolt attached to one or more conical wedges enclosed in an expansion sleeve; the assembly is inserted into a hole drilled in the concrete, and as the bolt is tightened, the wedge is drawn into the sleeve and progressively expands.

Expansion anchors must be tightened to a specified torque to induce a preload in the bolt. This preload must be maintained for the load-controlled anchor to perform adequately: unless it exceeds the specified working-load limit, the bolt will eventually fail by creep pullout.

The use of any of the above anchor types should be approved by the consultant or design engineer for the project, prior to their use.

10.5.3 Connection/Fixing Inserts and Fixing Plates/Brackets

A connection or fixing insert is a ferrule, either purpose-made or a standard proprietary one, that is cast into the panel to enable it to be connected to other structural members, fixing plates, brackets and the like, with the purpose of permanently restraining the panel in its final position. The insert usually consists of an internally-threaded steel bar or tube, a base plate, and an anchor bar.

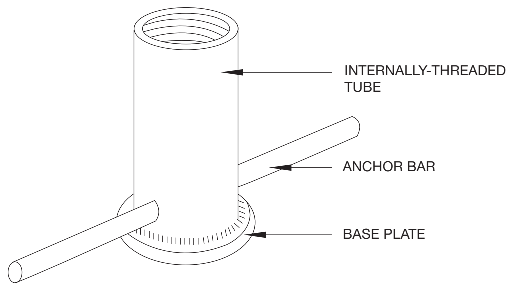

Figure 10.8 Typical Cast-In Ferrule

Inserts should be hot-dipped galvanised, or have some other protective coating, so as to resist corrosion. The positions of all inserts should be determined during the designing and detailing stages and be included on all panel shop drawings. The fixing inserts themselves must comply with AS 1110.

To remain within specified tolerances for connecting adjacent building elements, connection inserts must be placed accurately. Mistakes will mean expensive delays as the fixings are modified.

Weld plates usually have reinforcement bars protruding from the bracket that are cast into the panel. Care must be taken during the detailing of the cast-in component and the surrounding reinforcement so that they don't clash with each other, and so that the component is placed accurately and has the required cover.

10.5.4 Sandwich Panel Insulation (Board and Tie) Inserts

With concrete sandwich wall panels, rigid or semi-rigid insulation boards are normally cast into the panel, however fixing onto the panel after casting (usually after installation on site) is also an option.

The interior leaf of concrete is usually load-bearing, carrying vertical loads down to the footings. The exterior concrete leaf can be designed to carry a proportion of the lateral wind loads, though. Freedom of movement of the inner and outer leaves is important, so as to avoid induced stresses due to creep, shrinkage and temperature.

The ties that are used to connect the two concrete leaves through the insulation boards can be made from:

- Stainless steel
- Composite fibre rods
- Other non-corrodible materials

These ties transfer the lateral loads from the exterior leaf to the interior leaf, while allowing the exterior leaf to move independently in response to temperature changes. The type of tie is usually determined by the proprietary insulation system chosen.

Stainless Steel Ties These ties come in a variety of shapes, such as looped pin ties, round or sleeve connector anchors, or flat plate anchors. The ties or anchors are made from either 304 or 316 grade stainless steel. They connect both inner and outer concrete leaves through the insulation boards to produce an integrated unit that effectively behaves as a monolithic concrete panel. The setout and spacing of the ties and/or connectors will vary depending on the particular design and system used, but the typical spacing for these ties and anchors is at intervals of 1100 to 1200 mm, with an edge distance of 100 mm.

Composite Fibre Connectors The composite fibre connector system is the most commonly-used insulation system and is often the simplest to install. The connectors are usually made from a glass fibre composite material and are extremely resistant to corrosion. They can have up to three times the elasticity and twice the tensile strength of mild steel, and cause minimal heat loss through thermal bridging.

Composite fibre connectors usually come in the form of stubby cylindrical ties that have wedged ends to lock the ties into the concrete. Like stainless steel ties or anchors, they are cast into the bottom leaf of concrete, and the insulation board is laid on top. The spacing of the connectors will vary depending on the proprietary system used, but can range from 400 mm to 1000 mm.

The type of proprietary thermal insulation system you use will determine the type of ties and thickness of the insulation board. It is strongly recommended that you consult with the manufacturer as to the most suitable system for your project, so that you end up with the most efficient design possible.

10.6 Concrete Requirements

Concrete to be used in concrete wall panels should have the appropriate strength, workability and durability.

10.6.1 Strength (High-Early Strength)

The strength of concrete for concrete wall panel projects has to satisfy two design criteria:

- It must enable the panel to function in its final position as part of the complete structure.
- It must enable the panel to resist the forces to which it is subjected during erection and bracing.

The panels frequently experience their greatest stresses during stripping and lifting, when the concrete is still relatively "green" (weak in strength). The concrete must have sufficient tensile strength at time of stripping to resist stresses caused by:

- Its own weight.
- The lifting point configuration.
- Suction forces between the panel and casting surface.
- Dynamic factors (such as lifting speed, sudden movement, and so on).

Correctly determining the panel thickness, lifting point configuration, and concrete strength will enable the designer to ensure that tensile stresses do not exceed allowable limits during the lifting process.

As the panels are stripped at early age, it's important to specify the concrete's strength at time of stripping. (A concrete with a compressive strength of 32 MPa or higher is usually needed to achieve the necessary early strength.)

10.6.2 Workability

Usual good work practices for placing, compacting, finishing and curing concrete should be employed. These processes should be completed as quickly as practically possible.

The most efficient method of compacting concrete is to use a double-beam vibrating screed (if possible) in combination with conventional poker vibrators. The poker vibrators should be used to ensure full compaction at the edges, blockouts, penetrations in the panel and around the lifting and bracing inserts. The vibrating screed supported from the edge formwork will produce a flat, well compacted surface that will require minimal finishing.

Concrete suitable for mechanical compaction and finishing should have a slump of not more than 100 mm. An 80 mm slump is usually be appropriate.

10.6.3 Durability

AS 3600 gives the grades of concrete to be used in various exposure conditions. The Standard also nominates the minimum cover to reinforcement for different exposure conditions. The table below gives these values.

Note that concrete grades less that 32 MPa have be listed for some exposure conditions, but lifting stresses during stripping usually necessitate grade 32 or greater.

Table 10.1 Concrete Grade and Reinforcement Cover for Various Exposure Conditions (extracted from AS 3600, Tables 4.3 and 4.10.3.2)

Exposure condition of either surface[1]	Concrete strength (MPa)	Min. cover to reinforcing steel[3] (mm)
Fully enclosed inside a building:	20	20
Inside a building subjected to repeated wetting and drying:	32	40
Above ground in exterior environments[2] and in...		
• in a non-industrial zone with...		
– an arid climate:	20	20
– a temperate climate:	25	30
– a tropical climate:	32	40
• in an industrial zone:	32	40
• between 1km and 50 km from coastline:	32	40
• up to 1 km from coastline, but not in a tidal or spray zone:	40	45
In contact with ground[4]	25	30

Notes:

[1] Exposure conditions other than those specified in the table may have to meet with additional requirements for protection of both concrete and reinforcing steel.

[2] An exterior wall can have internal and external exposure. Only the higher concrete grade should be used, but reinforcement cover may vary according to the exposure of the particular surface.

[3] Protective surface coatings can be included in the depth of cover, but their performance should be established before reducing cover below the value shown in the table. For details, refer to AS 3600, clause 4.3.1(c), note.

[4] Applies to non-aggressive soils only. Refer to AS 3600 for information on contact with aggressive soils.

10.6.3.1 During Construction

The construction processes necessary to produce a sound and watertight concrete wall panel fall into three main groups: compaction of the concrete; formwork selection and design; and curing techniques.

- *The concrete must be compacted* thoroughly to make it sound and watertight. It should be compacted using immersion vibrators (such as a stick vibrator) or external vibrators attached to the outside of the mould base or formwork to reduce the occurrence of voids and honeycombing in the panel that can lead to water penetration. Prolonged vibration should be avoided, since it can cause segregation and excessive bleeding, thus leading to areas of weak mortar at the surface.
- *Formwork selection and design* can affect the watertightness of the surface of a concrete panel. The formwork should be:
  - Able to produce a smooth, tightly compacted concrete surface finish.
  - Constructed with tight joints for good surface alignment.
  - Sealed to prevent leakage of slurry while the concrete is still plastic.
  - Coated with a surface release agent to enable easy disengagement of the forms from the concrete at time of stripping.
- Using the proper *techniques for curing concrete* enhances the strength and permeability of the concrete surface and reduces the risk of cracking. Concrete wall panels should be cured continuously for at least seven days using normal curing processes (such as moist curing, covering with an impermeable plastic sheeting, or spraying with a liquid membrane curing compound). The curing compound should have a water retention efficiency index of not less than 90% when tested in accordance with AS 3799 – Appendix B.

With all curing methods, it is vital that they be implemented immediately after the finishing operations, before the concrete surface has had a chance to dry out. In hot weather, moist curing should be continued for at least the first 24 hours, after which the concrete should be covered with plastic sheeting or liquid membrane curing compound for a further six days.

10.6.4 Summary

As a rule, the concrete for concrete wall panels should be:

- Normal Class (or Special Class if coloured or other special concrete is used)
- Grade 32
- Slump of 80 mm
- Maximum aggregate size of 20 mm

Higher early-strength grades may be required if the panels must be lifted (or exposed to harsh conditions) soon after casting.

Project testing may be required to confirm early strengths.

10.7 Transportation / Delivery

10.7.1 Loading and Transport

Planning In the planning for the transportation of the wall panels to and around the site, take all of the following into consideration:

- Before the panel design is complete, confirm that all panels will be able to be transported to the site and erected. (It is the responsibility of the panel manufacturer to ensure that the panels are sufficiently strong enough to withstand the stresses of transport and erection.)
- It is the responsibility of the transporter to ensure that all panels are appropriately secured during transport so as to prevent damage or injury. Unusually heavy panels, or panels with unusual shapes and sizes, should be fitted with additional restraints or support frames during transportation.
- Road regulations along the transport route may limit the overall weight, length or height of a loaded transport vehicle. Panels that fall outside these parameters may require additional permits, need special escorts, or be restricted to special haulage times. This will raise the cost.
- The route to the site should be examined, and possible obstacles noted, such as over-head power lines, tramlines, train lines, OD routes (recognised truck routes), roundabouts, over-head bridges, or reverse-cambers in the road.

- The panels should be loaded onto the transport in the reverse of the erection sequence, so that the last panel loaded is the first to be erected. Most transport trailers carry more than one panel per load, so if the panels are of different shapes or sizes, loading them in reverse erection sequence can result in an unbalanced load. Panels should be as evenly distributed as possible along the centreline of the vehicle, and their centres of gravity should be as low as possible.
- The panels should be loaded so that their identification markings are visible during unloading.
- Ensure that the delivery vehicle will have all-weather access to and around the site.
- Determine whether panels will need to be temporarily stored off-site (or on-site). This may be necessary to minimise the number transport loads, but may result in panels being delivered to site before they're needed.
- The lift points on each panel should be checked and clearly marked before loading and unloading, so that they can easily be located during lifting.
- It is most cost-efficient if panels are lifted directly from the transport vehicle into their final positions. Every effort should be made to ensure this happens so as to avoid the cost of double-handling panels.

Support Frames These frames are the main support for the panels, and are usually in an A-frame configuration. They support the panels in an out-of-vertical position (up to 10º off vertical) on the transport trailer, and allow for more than one panel (usually two or three, but more if the panels are small) to be transported at once. The frame must be able to withstand not only the panel weights, but also the induced dynamic loads that will be generated by the panels while the transport vehicle is in motion.

Panel Protection Places where the panel comes in contact with support frames, restraints, and other panels should be protected from damage and staining. Damage can occur during loading, transport and unloading. Staining or marking can be caused by dirty strap restraints, or even by the timber in the hardwood blocks used to support or space the panels (if the blocks get wet). If there is a danger of this, then plastic or non-marking rubber should be placed between the contact surfaces.

Concrete wall panels that are transported horizontally should be stacked so that all panel supports are directly above the panel supports below them, so that the panel loads are transferred directly from one support to another without creating any additional stresses on the panels. For rectangular panels, supports should be placed 1/5 the length of the panel from each end.

Delivery There must be an authorised traffic management plan in place on the site before any panels are delivered. It is usually the responsibility of the builder to create this plan. It may necessitate flagmen, barricades and road closure permits to allow unimpeded access to and around site for both transport vehicles and crane. Drivers of the transport vehicles should be well informed of the travel route, and they should know how to enter the site and where to bring each of the panel loads.

It is the responsibility of the driver to ensure that the load is appropriately secure at all times while it is on the transport vehicle, even during unloading.

10.8 Cranage

10.8.1 Planning

The following issues should all be taken into consideration before choosing a crane or finalising construction plans, erection sequences or panel design:

- On-site and public safety (including written procedures, training and induction schemes, requirement of safety equipment, and emergency procedures).
- Local street access, and when it will have to be restricted for unloading and erection.
- Panel sizes, weights, and on-site locations.
- Panel bracing details.
- Maximum reach of crane from set-up position to final position of erected panels. As a rough guide, crane capacity should be two to three times the maximum panel weight. Consideration should be given for extra reach from any additional lifting rigging required to lift the panels (such as spreader beams or equalising sheaves). For panels that are 'face-lifted', the true working reach of the crane may be up to 1.5 m or more than the final position of the panel, as the panel is not lifted in a true vertical position.
- Any site limitations (such as limited access due to nearby buildings or power lines).
- Capacity of floors or other areas that may need to bear the crane. Crawler mounted cranes impose higher loads than mobile cranes, as they are able to distribute the load onto a greater area.
- Required number of crane set-ups. Dismantling and setting up the crane takes a considerable amount of time, so crane set-ups should be restricted to a minimum. The more panels that can be lifted from a single position, the more efficient the process.
- If a 'dual lift' is planned, the required capacities of the cranes should be carefully assessed. The capacity of either crane should not be less than 70% of the mass of the panel.

10.8.2 Crane Position

The crane should be carefully positioned on-site to make the most of its capabilities and to minimise the erection period. If possible the crane should be always located so that the rigging and braces are visible by the crane operator. 'Blind' lifting, where the rigging is on the side opposite the crane, should be avoided, as the crane operator will not be able to check on the rigging during lifting, and if there is a failure, the panel will fall towards the crane. Care should be taken to ensure that bracing doesn't foul the rigging.

10.8.3 Operation near Power Lines

Crane operations near power lines certainly require pre-planning, so that the power will be isolated when the crane is working. Electric Supply Authorities can usually isolate any power line, if given sufficient notice. If power lines are isolated, the Electric Supply Authority's access permit must be obtained and kept by the crane operators during their operations.

If there is no access permit, the power lines must be treated as live. Compliance with individual state's minimum requirements for operations near live power lines must be met.

10.8.4 Rigging

Proper crane rigging is essential for successful wall panel construction. The selection and configuration of the rigging system connecting the concrete panel to the crane should be discussed and approved by the panel manufacturers and erectors. The configuration will depend on the number and location of lifting inserts, and must ensure that all inserts are loaded equally. Care during rigging is crucial for preventing accidents. Typical terminology and layouts for rigging systems are shown in Figure 10.9.

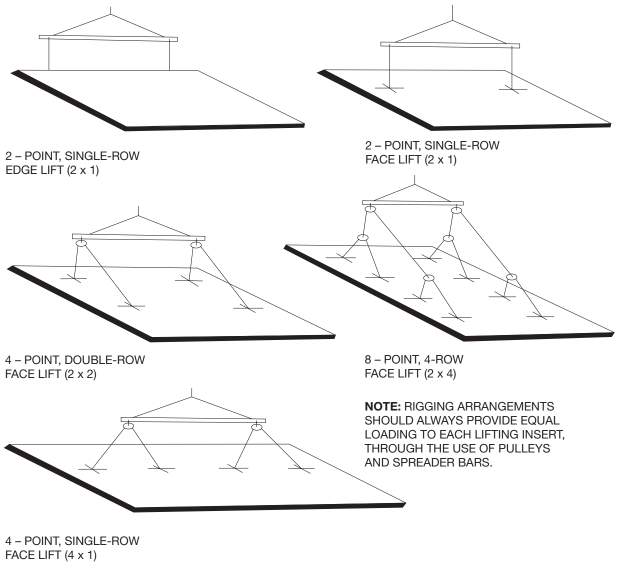

Figure 10.9 Typical Rigging Systems/Layouts

It is important to determine the proper sling length (or chain length) of the rigging for a particular lifting point configuration, especially if two lifters are connected by a single sling. Short slings can overload the lifting inserts because of sideways drag. If the slings are connected to equalising sheaves, spreader or lifting beams can be used to determine the length of slings. Single, double or even four-leg slings are commonly used. (The angle between slings at reeving points should not exceed 120 degrees.) The use of three rows of lifting inserts should be avoided if possible due to the complex rigging configurations required.

Re-useable, “quick-release” lifting devices (lifting clutches) are commonly used to enable the crane to be freed from the panel as soon as the temporary bracing has been fixed, thus speeding up erection.

Temporary bracing must be positioned clear of the lifting inserts and rigging. If possible, braces should be attached to the panel before lifting. The use of purpose-made adjustable braces speeds up the erection process. Final plumbing of the panels can be performed using these braces.

If panels need to be rotated with a tailing lifter (that is, if tall narrow panels need to be transported on their sides and rotated into vertical position), the capacity of the crane winch that is being used to rotate a panel must be approximately 70% of the mass of the panel.

10.8.5 Strongbacks

Concrete wall panels that are odd-shaped or elongated, or have large or awkwardly located openings, can be strengthened for lifting by the addition of strongbacks. Strongbacks can be formed from steel angles, channels, or even timber beams, and are fixed to the back of the panel with either cast-in inserts or temporary fixed mechanical anchors. Strongbacks should be designed by a qualified engineer and be produced and installed in accordance with design details and shop drawings.

If the panels are cast off site, strongbacks should be attached to the panels before they reach the site to avoid the crane sitting idle while this is being done.

The designer of the strongbacks should plan their shapes and sizes carefully, to ensure they do not clash with the roof, suspended floors, support angles, braces or rigging.

The mass of the strongback must be included when assessing the load on the crane. Any changes to the specified strongback system should be re-approved by the designer before being implemented.

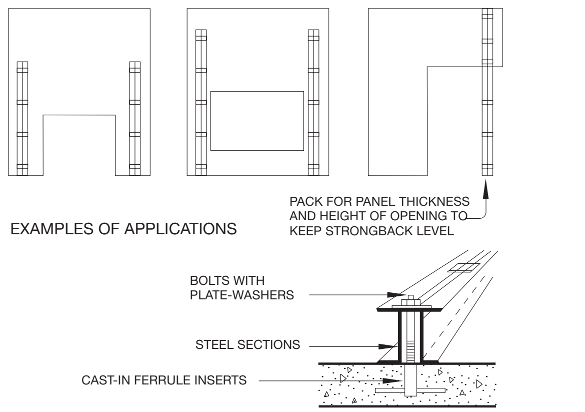

Figure 10.10 Use of Strongbacks to Strengthen Panels During Erection

10.9 Lifting and Erection

Panels must be lifted smoothly at all times. Any sudden movement can damage the panel or even the crane.

Accurate placement of the first few panels is critical for ensuring the straightforward placement of succeeding panels. Extra time should be spent on the first few panels so the erection crew can become familiar with the erection procedure.

Lifting should be carried out so that the panels are rotated about their bottom edges, which shall limit possible damage to the bottom edge. Any damage that does occur to the bottom edge can either be concealed below ground level or easily repaired. Care should be taken to avoid sliding or dragging the panel across the trailer floor, other panels, casting slabs, or the site floor, as this can damage both the panel and the surface it’s on.

Slenderness Effects Buckling and instability can occur during lifting and erection of long slender panels. Lifting inserts should be located to ensure that compression flange buckling (as in a long slender beam) cannot occur, particularly during rotation of long wall panels. The span/thickness ratio of the element between lifting points should be limited to a maximum of 60.

No one should be inside the drop zone when the panel is being lifted, tilted or rotated from the horizontal to the vertical. **At no time should anyone be underneath a panel.**

During strong winds, no attempt should be made to lift or erect a panel if there is a possibility that control of the panel may be lost. It is the responsibility of the erection crew to determine whether conditions are suitable or not.

In no case must there ever be fewer than two connections supporting a panel before the lifting equipment is released.

10.9.1 Levelling Shims / Packers

To meet tolerances in the panel's size and in the footing or foundation levels, levelling shims are usually required. They carry the vertical loads from the panel into the foundations.

The shims must be made out of a durable material and be manufactured to meet the requirements of AS 3850. The most commonly-used materials are compressive fibre sheets or P.V.C. Steel shims should not be used.

Shimming should be limited to a maximum height of 40 mm, and a minimum width of 100 to 300 mm, depending on the size of the panel. Shims should be located a minimum of 300 mm from the ends of the panel (particularly with thinner panels). There should only be two shimmed-up bearing supports per panel. Three or more supports may result in an uneven distribution on each support, and the resulting stresses can crack the panel.

Direct concrete-to-concrete or concrete-to-steel bearing should be avoided, as edge spalling and cracking may occur due to uneven bearing.

The gap between the bottom of the wall panel and the footing should be grouted or dry-packed to distribute the load throughout the footings.

10.9.2 Missing and Unusable Lifting Points

Sometimes, during the installation of the wall panels, a lifting point is incorrectly located, faulty, or even missing. If this happens, the lifting point should be identified, and the panel designer should be contacted so that he or she can establish a suitable solution to the problem.

Such a solution might include:

- Using a temporary fixing plate with undercut anchors.
- Drilling through the panel and attaching lifting plates or through-bolts.
- Placing slings or straps around the panel (if the panel is small enough to allow it).

Whatever the solution, the working load capacity must be calculated using a working load limit (or factor of safety) of greater than 2.5 against failure.

Expansion inserts should not be used as lifting points, as failures are sudden and can occur without any warning.

10.9.3 Bracing

Braces or props are temporary supports that stabilise wall panels while they ae being erected. The braces usually stay in place until the wall panels are connected together to form a self-supporting structure.

All panels should be braced in accordance with the requirements of the structural design. Shop and panel layout drawings should be followed detailing locations and types of braces to be used, as well as any requirements for the brace footings or floor slab. It is especially important that the concrete strength, and the size of footings and floor slab, be large enough to resist the anticipated loads. Refer to the figure below for a typical example of a brace set-up from which the required propping forces can be determined.

The typical setout of braces on a typical small rectangular wall panel is as follows:

- A brace is located approximately one-fifth the width of the panel from each side.
- The cast-in bracing inserts are located two-thirds the height of the panel from the base.
- The braces form an angle of approximately 60º with the ground slab or footing.

As panel shapes and sizes vary, though, each panel's bracing should be individually reviewed and, if necessary, individually designed.

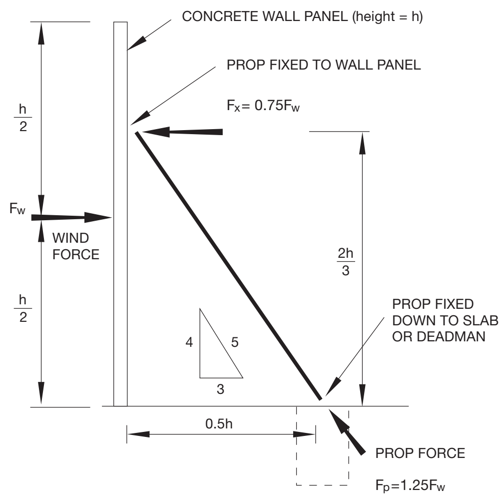

Figure 10.11 Typical Bracing Set-Up

The braces should have a permanent name plate displaying:

- The supplier's or manufacturer's name.
- The model type or designation.
- The maximum safe working loads for minimum and maximum extensions.

Adjustable braces must have stops on the threads so as to prevent over extension.

Wherever possible the bracing should be fixed to the panel before lifting. During lifting the erection crew should adjust the extension of the braces (if necessary) to ensure that the braces do not hang below the base level of the panel. In the case of face-lifted panels, both lifting inserts and bracing inserts should be installed on the same face of the panel so that the crane operator is able to observe both lifters and braces during the lift.

If braces must be attached to the panel after it has been lifted into place, the panel should be hung just past the vertical while the braces are being installed. No personnel should ever work on a panel that is leaning towards them until the panel is secured.

A minimum of two braces should be used to stabilise a wall panel (though this may not be necessary if other fixing brackets or permanent connections are present).

After erection of the panels, the braces and their associated components should be checked at regular intervals to ensure their integrity. If there is a requirement to service the braces, it should be done by the bracing installer or supplier.

Before the bracing is removed, the structure created by the panels must be secure and stable. It is usually the responsibility of the design and/or consultant engineer to ensure that this is so. Braces should be removed only upon written instruction.

10.10 Tolerances for Construction

In all concrete panel construction, suitable construction tolerances must be catered for in the building structure. It is especially important that specified panel and joint tolerances be realistic. Once they are established, they must be assiduously maintained, or finished walls will not be the right length.

Depending on the size of the tolerances, joints can be used to absorb any variations, either progressively at each joint or collectively at one location. If panels are being erected in conjunction with in-situ construction, then the tolerances for the panels should not be used to compensate for construction errors in the in-situ work.

Joint Tolerances Joint tolerances are important for the performance of the joint sealant (most of which have a movement capability of around +25 %), and therefore are critical to weatherproofing. It's best to maintain joints at their specified widths, and to take up any variations at doorways (or oversail corners, if applicable).

Panel Tolerances The panel tolerances can have a marked effect on all aspects of the construction: the tighter the tolerances, the greater the expense required to achieve them. If panels are carefully formed and thoroughly checked before and after manufacture, though, and if their footings are checked as well, then the tolerances listed in the following table are both achievable and cost-effective:

Table 10.2 Recommended Tolerances on As-Cast Panels (Table 3.11(A) of AS 3850)

Panel Height (m)	Tolerances (mm)						
	Linear			Angular	Profile		
	Width	Height	Thickness	Squareness[1]	Twist[2]	Warp[3]	Straightness of Edges and Flatness of Surfaces
<3	+0,-6	±3	±3	±4	±3	±3	± Length / 1000
≥3 <6	+0,-6	±6	±3	±5	±3	±3	± Length / 1000
≥6 <10	+0,-6	±6	±3	±6	±3	±3	± Length / 1000
≥ 10	+0,-6	±6	±3	±8	±3	±3	± Length / 1000

Notes:

[1] Expressed in terms of the distance by which a shorter side of the panel deviates from a straight line perpendicular to the longer side and passing through the corner of the panel.

[2] Per metre width in 3 metre length.

[3] Per metre width.

Table 10.3 Recommended Panel and Erection Tolerances

Type of Tolerance	Item	Details	Tolerance (mm)
Casting	Thickness[4] of panel		±5
	Skew of panel or opening[5]	Per 1.8 m	±3
		Maximum difference	±12
	Openings cast into panel	Size of openings	±6
		Location of openings	±6
	Location/placement of embedded items	Fixing inserts	±5
		Face-lifting inserts	±20
		Edge-lifting inserts – longitudinal	±20
		Edge-lifting inserts – thickness	±5
		Bracing inserts	±50
		Strongback inserts	±5
Erection	Joint width variation[6]	Panels up to 6 m tall	±6
		Each additional 3 m height	±3
	Joint taper[7]	Maximum for entire length	±10
		Panels up to 6 m tall	±6
		Each additional 3 m height	±3
	Panel Location	Deviation from specified final position of panel (but will not reduce specified joint width by more than 33%)	±5

Notes:

[4] The average variation of panel thickness through any horizontal or vertical cross-section of the panel.

[5] The measured difference in length between the two diagonals.

[6] Measured between panels at the exterior face of the panels at the joint.

[7] The measured differences in joint width indicating panel edges are not parallel.

10.11 Quality Assurance / Control

10.11.1 Quality of Workmanship

If the final product is to satisfy all the requirements of the project, all aspects of construction must be a planned and systematically checked. A quality management system will provide the necessary structure, but it will succeed only if individual workers take responsibility for checking the quality of own tasks before handing off their work to someone else. *Quality can be assured only if it is* ***built into*** *the work as it progresses.*

10.11.2 Guiding Principles for Quality

To ensure that the job is done properly, everyone involved must:

Principles	Actions
Know what to do	Have the correct specifications and drawings
Know how to do it	Be properly experienced or trained, know the appropriate procedures and have ready access to any necessary instructions
Be able to do it	Possess the resources, plant and materials required
Know if it is done properly	Check, measure or test items as appropriate
Be able to effect it	Obtain feedback and undertake any corrective action needed
Want to do it	Be properly motivated
Record it	Keep proper records, obtain any certification specified and undertake or participate in audits.

Quality Control means *the techniques and processes for achieving and sustaining a quality of goods or services that will satisfy the specified requirements*.

In other words, quality control is a set of control and monitoring procedures (prescribed by a quality assurance system) for ensuring that the product or service stays within the specified limits.

A functioning and effective total quality management system involves both quality control and quality assurance at every step in the production of concrete panel housing.

10.12 Occupational Health and Safety

The object of the Occupational Health and Safety Act is to prevent harm to employees at work. Under the OH&S Act, employers must provide, "such information, instruction, training and supervision to employees as necessary to enable the employees to perform their work in a manner that is safe and without risk to health". This covers both independent contractors and general employees at the workplace.

It is imperative that a structured system of education and training be maintained in the concrete walling industry to enable identification and management of risks.

10.12.1 Safety Issues

Concrete wall panel construction methods are relatively safe, but the erection phase of construction is the period where there is most scope for accidents. During erection, safety is of prime importance. As concrete panel construction involves the handling of large, heavy concrete panels, good work practices must prevail at all times to maintain a safe working environment.

It is imperative that the lifting sequence be well planned, and that the site team communicate well and know how each sequence of work is to proceed. Among the requirements for keeping the site safe are these:

- Personnel should stand clear of panel edges in case of slew.
- Personnel should never work below or reach under a panel being lifted.
- Panels should not be lifted in high winds.
- Braces should always be of the right size and capacity, and be connected properly at each end before releasing the panel from the crane.
- Always use the right size and number of lifting points and the proper kind of lifting equipment. The maximum capacity of the lifting equipment must never be exceeded.
- The crane operator should never leave the crane while a panel is connected.
- If possible, avoid "blind" lifting, where the crane operator cannot see the lifting attachments.
- The site should be kept as clean, orderly, and free of debris as possible at all times.
- Sites should be closely supervised, and common sense should always be the rule.

The following table lists some of the safety-related responsibilities of each of the main parties.

Party	Safety-Related Responsibilities
Consultant Engineer and/or Panel Design Engineer	• Overall building stability • Panel lift design • Insert selection and location • Bracing design and type • Panel design (including panel size, shape, concrete strength and reinforcement) • Design for fire • Lifting procedures • Load design on floor/pavement (if applicable) • Communication of all aspects to the builder via drawings and other documentation
Panel Manufacturer (Contractor)	• Panel size, shape and construction tolerances • Access for cranes/transporters • Preparation of floor/pavement (if applicable) • Insert selection • Fixings and fittings (including bolts, brackets, strongbacks, etc.) • Bond breakers/release agents, type selection and application • Concrete quality, its compaction, curing • Casting sequence • Erection sequence • Essential forms of communication
Erection Crew	• Safe working environment and procedures • Crane access and positions • Erection sequence and procedures • Rigging gear • Correct lifting gear ('quick-release' clutches, spreader beams, etc.) • Fixing bracing

A site safety meeting before the start of any lifting is strongly recommended, so that safety issues can be discussed. Issues covered should include at least the following:

- Proper on-site attire (hardhats, safety boots, and so on).
- The function and responsibility of each person in the erection crew.
- Any requirements for documentation before on-site work can start (work method statements, insurance documents, erection crew qualification certificates, and so on).
- Emergency and accident procedures (location of first aid kits, emergency contacts, and so on).
- On-site hazards that the erection crew may be exposed to.
- A safety checklist, and an assurance that all parties are aware of and understand each item in the list.

10.12.2 Temporary Access

Temporary access is usually required to the panel during erection, initially to brace it, and finally to fix it into its final position with fixing brackets, plates, dowels, and so on. Access to the panel at ground level is quite simple, but most fixings on the panels are located above ground level, where access is more difficult.

Ladders, platforms, scaffolding, mobile towers or boom-lifts (cherry-pickers) can be used during and after erection, but must comply with the applicable provisions of the Occupational Health and Safety Act.

Ladders should only be used as access for short-duration work (like fixing anchor points). The use of lightweight mobile scaffold towers and alternative working platforms should be considered, especially if they might be useful over the long term. In most cases, these options should prove sufficient for concrete panel homes that are relatively small. But if overhead access becomes difficult due to extreme height or reach, mobile boom-lifts (cherry-pickers) may be suitable (though they are more expensive).

The use of safety harnesses, static lines or anchor points can be a good idea if work is in high or awkward areas.

Safety Harnesses Safety harnesses are used to limit the distance of a fall, and thereby minimise the risk of injury. They provide valuable protection, but are not a substitute for effective prevention. For a safety harness to be effective, it must be securely fastened to a point where the lanyard length will prevent a fall to the ground. The use of an inertia reel adds to the range of movement while still preventing a full fall, though its load limitations must be carefully assessed.

10.12.3 Hazard Management

An effective method for identifying hazards on-site should be implemented to determine whether there are significant hazards that require further action. (A hazard is an “existing, new, or potential situation or event that could jeopardise the safe working environment”.)

In concrete panel construction, risk is always present when handling, transporting and erecting panels. Under no circumstances should personnel ever stand below or work on a panel that is leaning towards them. Although component failure is rare, the consequences are always significant.

An assessment of the risks from hazards must be carried out by the builder in conjunction with the contractor involved in the work. A Job Safety Analysis that lists the hazards and suggests safety procedures should be prepared. At a minimum, this Job Safety Analysis should include:

- An identification of the hazards.
- An assessment of the risks from the hazards identified.
- The control measures required to minimise the risks from the hazards.
- The name of the person responsible for implementing and monitoring the control measures.

If possible, each risk should be reduced by changing the proposed work method, construction procedure, or equipment.

If a hazard cannot be eliminated, control measures must be implemented to isolate it and minimise the risk to workers on site. This may involve the implementation of specific safety training and work instructions, the use of protective equipment, the posting of warning signs, or the fencing off of the hazardous area. Such measures should be discussed with personnel, and evaluated to ensure that they are effective and do not create hazards themselves.

Planning to prevent injury means identifying, assessing, and controlling risk.

10.13 Training / Education On-Site

All workers on a building site, including independent contractors, need to work in a safe environment. Training, including instructions in safety and work practices, are essential for providing such an environment.

The workers must be sufficiently experienced to carry out their tasks safely, or must be supervised by an appropriately experienced person.

Training programs should emphasise occupational health and safety, and provide opportunities for individuals to have their existing skills recognised and to develop new knowledge and skills. Education and training programs should be structured, lead to nationally recognised qualifications, and be delivered by a Registered Training Organisation. Such training should be in addition to, not a replacement for, the required site-specific induction training.

Training and instruction programs should include:

- Instruction in relevant industry standards and codes of practices.
- OH&S training to the industry-competency standard established by the National Building and Construction Industry Training Board, Construction Training Australia.
- First-aid training to the minimum requirements of the Code of Practice, First Aid.
- Supervised practical experience programs relevant to the tasks being performed by the worker. Such training should be part of a program that leads to a national qualification (if applicable).
- Identification of hazards associated with the safe use of plant and equipment on site.
- Correct use of protective clothing and equipment.

10.14 Cost Advantages

There are significant benefits of concrete panel construction that can relate back to cost-effectiveness. This benefit can be realised in several ways:

- Speed of Construction – This is the primary way in which the cost-effectiveness of concrete panel construction is realised. Concrete panel construction is very fast; buildings seem to go up almost overnight. The costs of non-occupancy (such as lost rent) are reduced.

  Cast off-site panel construction is fast because the panels are manufactured off-site while work continues uninterrupted on-site. Cast on-site construction, panels are produced on site, can be poured on a separate casting slab so that work can still continue on the building. Panel sizes are usually larger for cast on-site panels, so there are fewer panels to cast, lift and erect.

  Once foundations and floor slabs are completed, and wall panels have been poured, a typical detached house can be erected within a few days if planned well. (Large, complex homes with suspended floors and multiple levels of wall panels might take as much as two or three weeks.)

- Reduction in On-Site Labour – This is especially true for cast off-site panel construction, as panels are made off-site; a small erection crew are the only personnel required to erect the entire wall system for the house. For cast on-site construction, a small crew of concretors are required to produce the wall panels, together with the same small erection crew. With both construction methods, a relatively small number of on-site personnel are required to construct the house. Costs are saved on materials and labour.

- Design Freedom and Flexibility – A variety of wall panel sizes, shapes and finishes are available to afford the designer a great deal of latitude. (This benefit needs balancing, though, against the cost-effectiveness of repetition and simplicity in the design.)

- Durability and Solid Construction – The durability and solidity of concrete panel construction means a structurally sound and long-lasting home that will retain its value better and longer than homes made with more conventional building methods. Maintenance is greatly reduced, as the materials are longer-lasting.

- Structural Performance and Load-Bearing Capacity – Because concrete wall panels can be load-bearing, they can be designed to support themselves, other panels, suspended floors, roof structures and even balconies, making other structural support (such as columns and beams) unnecessary. Ensure that the wall panel designer takes full advantage of the load-bearing capabilities of the panels. This could reduce the need for other structural support member (ie. columns & beams), reducing costs and increasing clear open areas internally.

10.15 Construction Checklist

Checklist Item	**Issues**
Safety	• A preliminary safety meeting involving all personnel is essential. • Note on-site hazards such as overhead and underground wires. • Remove all debris and obstacles from the work area. • Inform surrounding neighbours of time of lifting and its local impact. • Strict discipline must be maintained during the lift. Remain alert at all times, and watch out for fellow workers. • The rigging foreman is the only person who should signal the crane operator. • Always stand at a safe distance from the panel while it is being lifted, tilted and erected. • Always keep clear of panel edges during lifting, in case of slews. • Never stand under or place hands under an inclined panel or behind a panel being lifted. • Panels should not be lifted in high winds. • Bracing must be complete (properly fixed) before releasing a panel from the crane. • Keep well clear of any panel being lifted.
Shop Drawings	• Are the shop drawings being used correct, signed off for construction, and are they the current issue? • Shop drawings must be available for each panel, and conform to the requirements of AS 3850, including clear details of reinforcement, type and location of inserts, mass, dimensions, concrete strength, and concrete strength at time of lifting.
Panel Mould	• Ensure that all panel moulds or setouts of the formwork are inspected for correct dimensions, position and type, and are in accordance with panel shop drawings. • Ensure edge details are correct (such as chamfer and bevel details). • Ensure that the mould or formwork has been properly coated with release agents or bond breakers. • All inspections should be performed before the pouring of the panel. Ensure that enough time is available between inspection and pouring so that any modifications or rectifications can be performed to the mould without delaying the pour. Delays will reduce workability times and delay subsequent pours.
Reinforcement	• Ensure that reinforcement bars of the correct size and length are used, and are in accordance with the panel shop drawings. • Check that the cover and location of all reinforcement complies with panel shop drawings.
Inserts and Ferrules	• All inserts should be visually inspected to ensure that the types and strengths are correct and in accordance with panel shop drawings. • Check that shear reinforcement is correctly placed for each insert in accordance with panel shop drawings. This reinforcement is critical to the performance of the insert, and must be correctly positioned. • Only proprietary inserts and ferrules rated for the particular application should be used. (For example, do not use a face-lift insert in lieu of an edge-lift insert.)

Anchors	• Know when chemical anchors can and cannot be used. (Refer to Section 10.5, “Fitments and Embedments” or to AS 3850.) • Only load-controlled (torque-controlled) expansion anchors comply with the standard; other types of expansion anchors should never be used. • Ensure that the anchor has been embedded to the proper depth before loading it.
Concrete Standard	• Ensure that the concrete complies with design requirements and with AS 1379: The Specification and Manufacture of Concrete. If the concrete is being supplied, insist that the concrete supplier provide certification for the concrete. The concrete strength is critical to the performance of the panels, and must be assured. • The concrete supplier’s certificate should include a statement that the concrete supplied is compliant with AS 1379, or that the supplier is a member of the APMCA. • Good concrete practice applies to concrete wall paneling. For instance, it is important not to add additional water to the mix; it is important to have proper curing procedures in place; and so on.
Rigging and Lifting	• It is very important that the erection crew, especially the crane operator, be experienced at lifting and erecting concrete panels. Do not choose the crew solely on the basis of cost. • Panels should never be lifted in high winds. • Personnel should keep well clear of panels being lifted. No one should work under a lifted panel. • It is important that any water around the panel be swept away before the panel is lifted, so the water will not create additional suction that will stress the panel.
Temporary and Permanent Fixings	• Panels should not be leaned or braced against other panels unless they have been designed to take the loads. • All panels must be restrained with appropriate fixings as detailed on shop drawings, • The fixings must be attached to the panels in the correct positions. • All roof bracing must be complete. • Grouting of dowels and under panels must be complete. • All permanent fixings should be inspected by the panel designer and/or consultant engineer and signed off before the removal of the temporary bracing or fixings.
Bracing	• The builder should prepare a checklist to ensure that the bracing system is installed correctly, and that maintenance inspections are performed. • Visually verify that brace types are correct, and that anchors are ready for panel erection and are correctly sequenced and installed. • There should be a minimum of two braces per panel unless specified otherwise in the design. • Bent braces must not be used. • Telescopic braces must be used correctly. Proper restraining pins must be used; nothing should be substituted for them. • Bracing corner panels can be a problem if corner panel braces clash with each other. The problem can be prevented if the braces for the first corner panel erected are positioned lower than the braces for subsequent corner panels.

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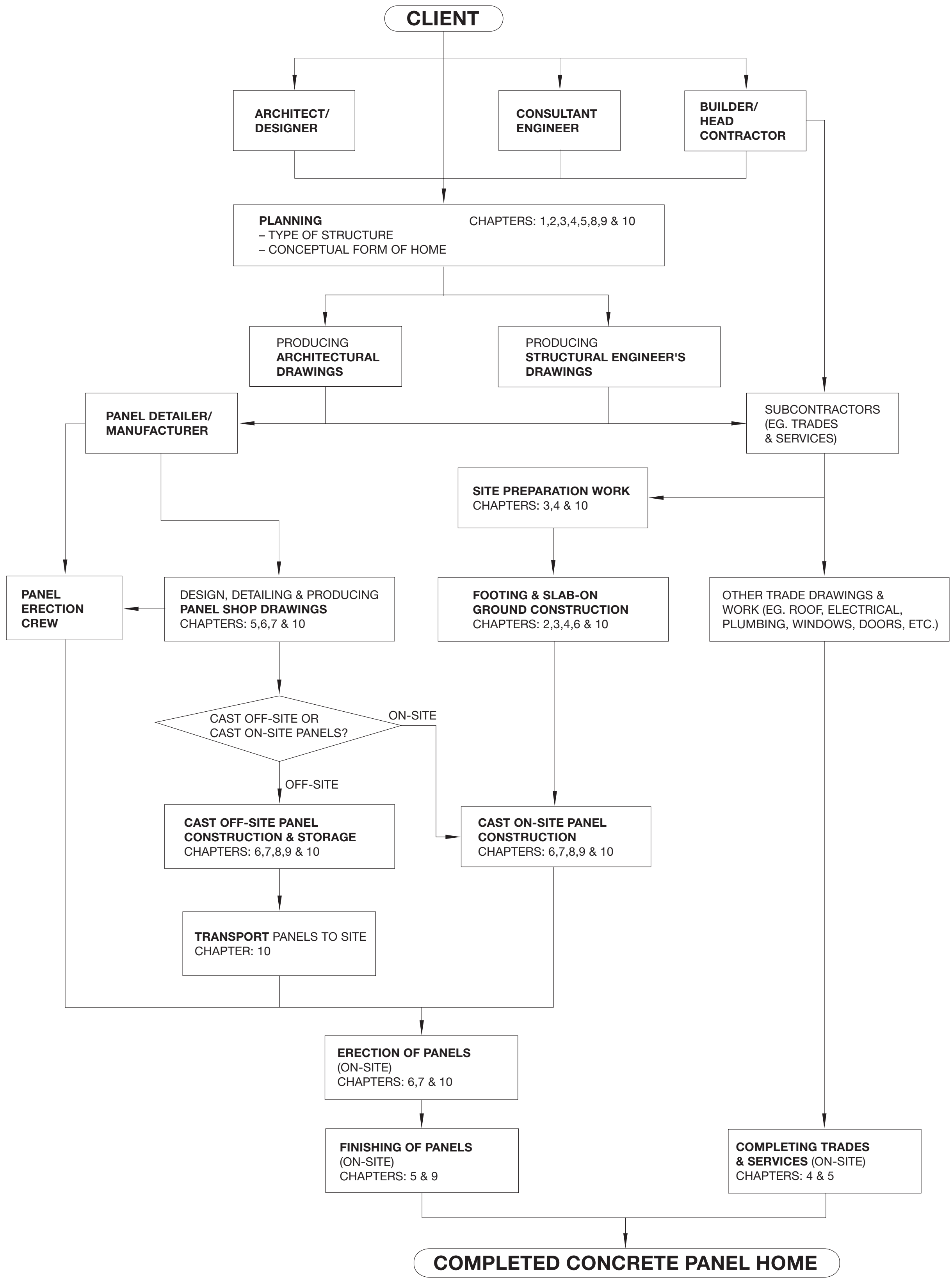
12 APPENDICES

12.1 Process Flowchart



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