Australian Standard™

Tilt-up concrete construction

Standards Australia

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Australian Standard™

Tilt-up concrete construction

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PREFACE

This Standard was prepared by the Standards Australia Committee BD-066, Tilt-up Construction, to supersede AS 3850.1—1990, *Tilt-up concrete and precast concrete elements for use in buildings* Part 1: *Safety requirements*, AS 3850.2—1990, *Tilt-up concrete and precast concrete elements for use in buildings* Part 2: *Guide to design, casting and erection of tilt-up panels* and AS 3850.3—1992 *Tilt-up concrete and precast concrete elements for use in buildings* Part 3: *Guide to the erection of precast concrete members* in response to the call from industry to update them and regulatory authorities to expand the requirements relating to safety. The Standard is to be read in conjunction with AS 3600, *Concrete structures*.

Although the Standard has been written primarily to address the construction of concrete buildings using 'tilt-up' panels, the rules may be appropriate for other forms of precast concrete construction.

A 'Tilt-up' panel is defined as 'an essentially flat concrete panel; cast in a horizontal position, usually on-site; initially lifted by rotation about one edge until in a vertical or near-vertical position; transported and lifted into position if necessary; and then stabilized by bracing members until incorporated into the final structure'.

The terms 'normative' and 'informative' have been used in this Standard to define the application of the appendix to which they apply. A 'normative' appendix is an integral part of a Standard, whereas an 'informative' appendix is only for information and guidance.

In the Standard where the word 'shall' is used a mandatory requirement is implied and where the word 'should' is used the requirement is advisory.

> *This document includes commentary on some of the clauses of the Standard. The commentary directly follows the relevant clause, is designated by 'C' preceding the clause number and is printed in italics in a box. The commentary is for information and guidance and does not form part of the Standard.*

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SECTION 1 SCOPE AND GENERAL

1.1 SCOPE

This Standard sets out the requirements for the planning, design, casting, transportation and erection of tilt-up panels. Tilt-up panels are essentially flat concrete panels; cast in a horizontal position, usually on-site; initially lifted by rotation about one edge until in a vertical or near-vertical position; transported and lifted into position if necessary; and then stabilized by bracing members until incorporated into the final structure.

This Standard does not apply to other precast concrete members such as columns, beams, flooring panels and façade panels that are not rotated about one edge and/or temporarily braced before being incorporated into the final structure.

C1.1 *Tilt-up construction has traditionally involved casting flat concrete panels on-site adjacent to their final location in the permanent structure.*

Panels for these buildings can also be cast off-site in which case the design and erection requirements including those for cast-in lifting and fixing inserts apply.

It is, therefore, the intent of this document to cover all panels that are cast in a horizontal position and initially lifted by rotation about one edge and stabilized by bracing members until incorporated into the final structure. The operative words in this definition are 'essentially flat' and 'stabilized by bracing members'.

Tilt-up panels may include elements with textured finishes, tapered edges or return corners.

The Standard has been written assuming any task or function specified in this Standard will be carried out by, or under the supervision of, a suitably experienced and competent person.

This Standard is intended to be read in conjunction with AS 3600.

This form of construction is most vulnerable during the period when the panels are erected and are in the braced position before being incorporated into the final structure: this Standard provides specific recommendations aimed at minimising failure/collapse during this time.

1.2 REFERENCED DOCUMENTS

The following documents are referred to in this Standard:

AS

1100.501 Technical drawing—Structural engineering drawing

1012 Methods of testing concrete (all parts)

1110 ISO metric precision hexagon bolts and screws (all parts)

AS/NZS

1170	Structural design actions
1170.0	Part 0: General principles
1170.2	Part 2: Wind actions

AS

1199	Sampling procedures and tables for inspection by attributes
1379	Specification and supply of concrete
1397	Steel sheet and strip—Hot-dipped zinc-coated or aluminium/zinc-coated
1399	Guide to AS 1199—Sampling procedures and tables for inspection by attributes
1478	Chemical admixtures for concrete, mortar and grout
1478.1	Part 1: Admixtures for concrete
1544	Methods for impact tests on metals
1544.2	Part 2: Charpy V-notch
1544.5	Part 5: Assessment of fracture surface appearance of steel
1554	Structural steel welding
1554.3	Part 3: Welding of reinforcing steel
2550	Cranes—Safe use (all parts)
3600	Concrete structures
3610	Formwork for concrete
3799	Liquid membrane-forming curing compounds for concrete

AS/NZS

9001	Quality management systems—Requirements
9004	Quality management systems—Guidelines for performance improvements

ACI

318-02	Building Code Requirements for Reinforced Concrete

ASTM

D618	Standard Practice for Conditioning Plastics for Testing
D695	Standard Test Method for Compressive Properties of Rigid Plastics

HB

18.28	Guidelines for third-party certification and accreditation—Guide 28—General rules for a model third-party certification system for products

1.3 DEFINITIONS

For the purpose of this Standard, the definitions given in AS 3600 and those below apply.

1.3.1 Braces

Temporary elements providing stability in preventing a tilt-up element overturning. Both ends are fitted with a pinned foot, allowing a degree of freedom for variable fixing angles.

> ***C1.3.1*** *Braces are intended to resist any predictable loads that can destabilize the panel prior to its incorporation into the permanent structure. Some of the likely loads are wind loads and construction loads.*
>
> *Formwork props are not suitable elements to be used to resist horizontal loads on panels.*

1.3.2 Bracing feet or shoes

The elements that connect braces onto a panel or onto the bracing support via pinned connections and inserts.

1.3.3 Compatible

The coordinated use of two (or more) separate components without compromise to the working load limit (WLL) or utility of either component.

1.3.4 Competent person

A person who has acquired through training, qualification, or experience, or a combination of these, the knowledge and skills enabling that person to perform the required task.

1.3.5 Composite brace

A brace constructed from a combination of fixed or telescopic braces using proprietary coupling elements.

1.3.6 Edge-lifting

A method of lifting tilt-up panels with lifting inserts within the panel edge.

1.3.7 Erection platform (crane standing)

The base that supports the crane during erection of the panels.

1.3.8 Expansion anchors

Anchors placed in holes drilled in hardened concrete, which rely on expansion devices within the hole to prevent pullout under load. The two types of expansion anchors are:

(a) *Deformation-controlled*—anchors that are expanded only during installation. Application of load to the anchor does not increase the expansion forces.

NOTE: Deformation-controlled anchors are not be permitted in this type of construction

(b) *Load-controlled*—anchors that have a wedge and expansion-shield system where the wedge is directly connected to the applied load. Increases in load above the retained preload (obtained from initial torque) will increase the expansion force.

NOTE: Limitations are applied to the use of these anchors (see Clause 2.4.3).

1.3.9 Face-lifting

A method of lifting a tilt-up panel with lifting inserts within the panel face.

1.3.10 Insert

Any one of the following:

(a) *Bracing insert* A component or system cast or fixed into the panel, or into a supporting member, for later attachment of a brace.

(b) *Fixing insert* A component or system cast or fixed into the panel and subsequently used to tie the structure together or support other structural members.

(c) *Lifting insert* A component or system cast or fixed into the panel for later attachment of the lifting device.

1.3.11 Levelling pad

A bearing area or a mortar bed on the footing used to provide a level seating for a tilt-up panel or shims.

1.3.12 Lifting clutch

A quick-release device used to connect the crane rigging to the lifting insert.

1.3.13 LSF (limit state factor)

The sum of each of the appropriate load components multiplied by the appropriate load factors, divided by the sum of the unfactored load components.

1.3.14 Panel

Where the term panel is used it is intended to refer to a tilt-up panel.

1.3.15 Progressive collapse

A continuous sequence of failures initiated by the local failure of one part of the structure.

1.3.16 Reinforcement

Any one of the following:

(a) *Structural* Reinforcement, including reinforcing steel and prestressing tendons, provided for crack control or to resist forces caused by in-service loading and thermal and shrinkage movements.

(b) *Additional* Reinforcement additional to the structural reinforcement, provided to resist forces caused by erection loads.

(c) *Component* Reinforcement placed in conjunction with lifting, bracing and fixing inserts so that they can attain their design capacities.

> ***C1.3.16(c)*** *Component reinforcement is normally specified by the insert supplier. It may not be shown in the shop drawings and is in addition to the structural reinforcement requirements for the panel.*

1.3.17 Reusable lifting equipment

A device that is directly connected to the lifting insert, for example a lifting clutch or bolt-on bracket.

1.3.18 Shear cone failure

The type of failure achieved when tension is applied to an insert embedded in concrete until tensile failure of the concrete occurs and a ‘cone’ of concrete is pulled from the main body of the member, together with the insert.

1.3.19 Stack casting

Casting one panel on top of another.

1.3.20 Strongback

A temporary member used to provide localized strengthening of the panel during erection.

1.3.21 Tilt-up panel

An essentially flat concrete panel; cast in a horizontal position, usually on-site; initially lifted by rotation about one edge until in a vertical or near-vertical position; transported and lifted into position if necessary; and then stabilized by bracing members until incorporated into the final structure.

1.3.22 WLL (working load limit)

The maximum unfactored load that may be applied to an item, component or system.

1.4 NOTATION

For the purpose of this Standard, the symbols given in AS 3600 and those below apply.

f_{cm} = the mean value of the compressive strength of concrete at the time being considered

k_s = the sampling factor (see Appendix A)

n = the accumulated sample size or total number of components tested to destruction

R_u = the characteristic strength of a member or assemblage

s = the standard deviation of a finite population of components tested to destruction

S_t = the test load

S^* = the strength limit state load

V = the coefficient of variation

x = the mean value of the test results of the accumulated sample of components

x_i = the test result of each individual component of the sample

ϕ = the capacity reduction factor

1.5 USE OF LIMIT STATES DESIGN

Tilt-up panels shall be designed for all phases of their design life, from casting to their service in the final structure. Where these aspects are covered by AS 3600, the design shall be carried out using limit states design (LSD) procedures. The design of other aspects shall be carried out using a mixture of either limit states design and working stress design methods as appropriate given design data available.

C1.5 *Limit states design at this stage is under investigation and the committee is not in a position to recommend limit state procedures for insert design and erection stresses in panels. There is information currently available for the limit states design of inserts which is being reviewed by BD-002, Concrete Structures, and can be found in ACI 318-02.*

The design of the panel in the final structure should conform to AS 3600.

SECTION 2 MATERIALS, COMPONENTS AND EQUIPMENT

2.1 GENERAL

All materials, components and equipment shall comply with the relevant Australian Standards and the requirements set out below.

The requirements and appropriate factors for materials, components and equipment are set out in the Clauses below. Verification that the various systems and items comply with these requirements shall be either —

(a) by calculation; or

(b) by testing in accordance with Appendix A.

Where limit state procedures are used either in the calculation or as required by Appendix A, the capacity of the component or device (ϕR_u) shall be sufficient to carry the appropriate load combinations set out in AS/NZS 1170.0. Where design situations occur for which load combinations are not given, conservative estimates of the proportions of the various load components shall be made, taking into account specific requirements such as fatigue.

For load-bearing proprietary products, the WLL shall be stated in the product documentation.

All components to be used on site within the system shall be compatible and different proprietary components shall not be mixed without verification of compatibility.

> ***C2.1*** *Incompatibility of different types of inserts or sizes may lead to failure. This is particularly relevant to lifting inserts, lifting clutches, bolts and ferrules. It should be ensured that all components within a system are compatible. Verification of compatibility may be obtainable from the suppliers and the designer of any other equipment to be used.*

2.2 WORKING LOAD LIMIT (WLL)

The WLL shall be derived from one of the following, as appropriate:

(a) The relevant Australian Standard.

(b) By dividing ϕR_u, obtained from the relevant Australian Standard, by the limit state factor (LSF).

(c) By dividing the multiple of the mean value of the test results (x) (see Appendix A) and the capacity reduction factor (ϕ), by the limit state factor (LSF) and the sampling factor, k_s, i.e.

$$\mathrm{WLL} = \frac{\phi x}{k_s\ (LSF)}\text{; or}$$

the value of ϕ shall be chosen from the appropriate Australian Standard.

For the pull-out of a lifting insert, or cast-in ferrule, from concrete, the value of ϕ shall not be greater than 0.6.

> ***C2.2*** *The term working load limit (WLL) has replaced the term safe working load (SWL). The WLL of a system will need to be assessed by a suitably experienced and competent person. It should be noted that the manufacturer of a device cannot determine the WLL of the device for each and every configuration that may be involved in a given system.*

The designer should note that minimum values for k_s(LSF)/ϕ are given in Clauses 2.4.3 and 2.6.1.

2.3 MATERIALS

2.3.1 Concrete and reinforcement

Cement, aggregate, additives, reinforcement and tendons shall comply with the appropriate Clauses of AS 3600.

C2.3.1 Concrete and reinforcement

Additives should comply with the requirements of AS 1379. Calcium chloride should not be used as an additive in its own right to increase the rate of strength gain of the panel concrete, except as permitted in AS 1478.1.

2.3.2 Curing compounds and release agents

Curing compounds and release agents shall comply with AS 3799.

The curing compound and the release agent used on the casting bed and the panels shall not compromise the effectiveness of each to perform their respective functions.

C2.3.2 Curing compounds and release agents

The strength, permeability and durability of concrete are dependent on it being adequately cured. In addition, the principle of tilt-up construction requires that the 'suction' between the panel and the casting bed is kept to a minimum to reduce the stresses on the panel.

When selecting curing compounds and release agents, considerations should include the following:

(a) The effectiveness of the release agent and the curing compound should not be compromised by either compound. In the absence of previous experience, testing is highly recommended.

(b) Tests—Simple tests should be available to check the effectiveness of the release agent. Such tests should normally be available from the manufacturer of the release agent.

(c) Solubility—The products should not be washed off by rain.

(d) Discolouration—Where a pigmented product is used, the pigmentation should weather off within a reasonable time.

(e) Temperature effects—The product should be suitable for the climate at the project location, e.g., extreme temperatures may blister the product and cause it to lose its properties.

(f) Effect on finishes—The adherence of applied finishes, including joint sealants, should not be affected.

Products should be used in accordance with the manufacturer's instructions.

2.4 LIFTING, BRACING AND FIXING INSERTS

2.4.1 General

All lifting, bracing and fixing inserts shall be manufactured from ductile materials. Site welding of reinforcement to lifting, bracing or fixing inserts (other than weld plates) shall not be carried out.

For proprietary items, technical specifications including make, type and WLL shall be provided by the supplier and a copy shall be held available on the project site. The insert assembly, which includes the void former, shall be marked with the manufacturer's name or symbol.

All non-proprietary inserts shall be designed to be compatible with the other parts of the system with which they are to be used. All inserts that are not verified by testing shall be designed in accordance with the appropriate Australian Standards.

Lifting, bracing and fixing inserts shall be specified on the design drawings as to the type (for example cast-in or drilled) and the capacity. They shall not be changed without prior approval from the panel designer. Lifting and bracing inserts within the panel shall be specified as cast-in inserts. Where cast-in inserts are omitted or after casting are found to be unusable then approval from the panel designer to use other types shall be obtained before installation.

The washers used for all fixings shall be of an appropriate size and strength to transfer the load to the fixing. When used with braces, they shall also be of sufficient size to retain the attached fixing in the brace shoe.

C2.4.1 *Reinforcing bars and prestressing strands, bent to receive a hook or shackle and cast in to the panel, are not suitable as lifting inserts.*

Designers should specify the required capacity of inserts. Contractors should not substitute ferrules from one manufacturer for those of another without checking that the capacity is at least equal to the original ferrule. Note that the ferrule capacity of a given insert will be dependent on the embedded length and ferrules will need to be installed in accordance with the manufacturer's requirements.

The slots in brace shoes are typically 22 mm to 24 mm wide and a heavy washer will be required to transfer the brace load to the insert.

2.4.2 Lifting inserts

The WLL for lifting inserts shall be determined in accordance with Clause 2.2, where the value of $k_s(LSF)/\phi$ is taken as not less than 2.5.

Lifting inserts shall comply with the following:

(a) They shall be manufactured from materials that meet a minimum of 27 J impact energy at −15°C with test pieces prepared and tested in the standard V-notch Charpy test in accordance with AS 1544.2.

(b) The failure surface shall demonstrate a 100% fibrous structure consistent with a ductile material and there shall be evidence of plastic deformation (necking) of the material in the region of the failure prior to the failure load being achieved. The method of establishing the fibrosity of the failure surface shall be in accordance with AS 1544.5.

C2.4.2 *Edge-lift inserts normally rely on component reinforcement, 'shear bars' and 'tail bars' to achieve their working load capacities.*

2.4.3 Bracing inserts

The WLL for cast-in bracing inserts shall be determined in accordance with Clause 2.2, where the value of $k_s(LSF)/\phi$ is taken as not less than 2.5.

Cast-in bracing bolts and inserts shall comply with the following requirements:

(a) Where standard ISO metric threaded bracing inserts and bolts are used, they shall comply with AS 1110.

(b) Where other types of fixings are used, e.g., cast-in helical wire coil inserts, then the bracing bolts specified for use with those inserts by the manufacturer shall be used.

(c) The engagement length of the bolt in the insert shall be as specified by the supplier of the system.

Where cast-in type inserts are not used for the brace footings, or where approval for alternative inserts has been given in accordance with Clause 2.4.1, the following requirements shall be satisfied:

(i) *Mechanical fixings* Mechanical fixings such as undercut anchors and drilled-through fixings shall be used in accordance with the manufacturer's requirements.

(ii) *Chemical anchors* Chemical anchors relying solely on chemical adhesion shall not be used for brace fixings unless each fixing is individually proof tested to the WLL.

(iii) *Expansion anchors* Expansion anchors for brace fixing inserts shall be of the load-controlled type. Where these anchors are used, the WLL shall be limited to 0.65 of the 'first slip load', established in accordance with Appendix A.

Deformation-controlled anchors, including self-drilling anchors and drop-in (setting) impact anchors, shall not be used.

C2.4.3 Bracing inserts

Deformation-controlled anchors are not used because—

(a) they have no additional expansion (and hence additional load capacity) after the initial setting process;

(b) they fail without warning; and

(c) are highly sensitive to installation procedures.

Load-controlled anchors may be used because after their installation the application of load causes these anchors to behave elastically until a load is reached at which they first begin to slip. After first slip the anchor exhibits 'ductile' load behaviour.

Cyclic load conditions, e.g., wind loads, can result in failure of an expansion anchor that has been loaded in excess of its first slip load, even if subsequent load cycles do not exceed the first slip load.

Expansion anchors should be installed in accordance with the manufacturer's recommendations and special attention should be paid to the correct drilling of holes and tightening to the correct installation torque. Expansion anchors should also be load-controlled, and of a type recommended by the manufacturer for repetitive loads of combined tension and shear.

The following discussion sets out the concepts and a basic methodology for assessing the capacity of drilled-in expansion anchors used for fixing temporary braces to footings or floor slabs.

A method for the limit states design of inserts can be found in ACI 318-02.

Method of assessing anchor capacity

Brace actions are always at an angle to the vertical axis of the drilled-in anchor. To assess the capacity of the anchor, the vertical (tensile) and horizontal (shear) capacities of the anchor need to be calculated and combined and compared with the applied actions from the brace.

The critical tensile capacity is the lesser of—

(a) the pullout load, usually concrete cone failure; or

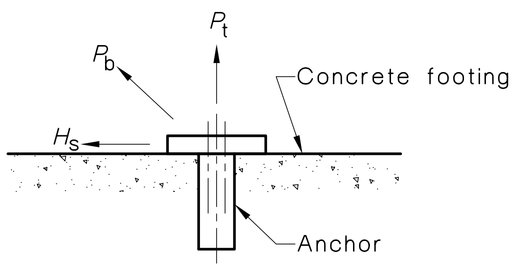
(b) the 'first slip load' due to cyclic loads.

The critical shear capacity is the lesser of—

(i) the failure load of the steel bolt (or bolt and sleeve where applicable); or

(ii) the failure load due to edge breakout of the concrete where the anchor is close to an edge.

Design model schematic



P_b = *design action in the brace (can be positive or negative)*

P_t = *vertical component of* P_b

H_s = *horizontal component of* P_b

Tensile capacity

(A) Concrete failure

Based on uncracked concrete and an edge distance greater than 1.5 anchor depth. If edge distance is less than 1.5 anchor depth a reduction factor is applied to account for the reduced cone failure surface.

$$P_{ut} \propto k_1 D_b H^{\alpha} f_{cm}{}^{\beta}$$

where

P_{ut} = *characteristic tensile capacity of the anchor*

k_1 = *factor related to anchor type*

D_b = *factor related to bolt diameter*

H = *factor related to anchor depth*

f_{cm} = *the mean value of the compressive strength of the concrete at the time being considered*

α *and* β *are constants related to the anchor*

These factors are provided by each anchor manufacturer and vary for each type of anchor.

(B) Slip failure

$$P_{st} \propto K_1 K_2 K_3 P_r$$

P_{st} = *allowable slip load (WLL)*

K_1 = *factor depending on the type of anchor (≤0.65)*

K_2 = *factor to allow for relaxation of initial preload with time. Can vary from 0.70 to 0.40 depending on the type of anchor*

K_3 = *capacity reduction factor applied to anchor proof load*

P_r = *bolt or anchor proof load*

Factors K_1, K_2 *and* K_3 *vary for different types of anchors and are provided by each manufacturer.*

The allowable tensile capacity of the anchor P_{at} *(WLL) is the lesser of* $P_{ut}/3.0$ *or* P_{st}

Shear capacity

(A) Steel failure

$$H_{us} \propto k_2 A_s f_u$$

H_{us} = *ultimate shear capacity of anchor (steel)*

k_2 = *reduction factor provided by manufacturer*

A_s = *cross-sectional area of bolt*

f_u = *ultimate strength of bolt steel*

For some types of anchors the sleeve can also contribute to the shear capacity.

(B) Concrete edge shear

$$H_{uc} \propto k_3 Hef_{cm}$$

H_{uc} = *ultimate shear capacity of anchor (concrete)*

k_3 = *factor related to direction of load*

H = *factor related to anchor depth*

e = *factor related to edge distance*

These factors are provided by each anchor manufacturer and vary for each type of anchor.

The allowable shear capacity of the anchor (WLL) H_{ah} *is the lesser of* $H_{us}/2.5$ *or* $H_{uc}/3.0$

For combined loading:

$$\frac{P_t}{P_{at}} + \frac{H_s}{H_{ah}} < 1.2$$

There are various different methods of combining shear and tensile loads. This simplified method is considered appropriate for temporary brace anchors.

2.4.4 Fixing inserts

Fixing bolts and inserts shall comply with the following requirements:

(a) Where standard ISO metric threaded fixing inserts and bolts are used, they shall comply with AS 1110.

(b) Where other types of fixings inserts are used, such as cast-in helical wire coil inserts, then the fixing bolts used shall be compatible with the fixing inserts.

(c) The engagement length of the bolt in the insert shall be as specified by the supplier of the system.

Fixing inserts for the panel connection to roof framing and other structural members shall be designed to resist the forces imposed on the connections, as determined by the appropriate Australian Standard and BCA Section C.

> ***C2.4.4*** *Before bolts of a make or model different from that specified by the supplier of the fixing insert are used, it is recommended that a written verification of the bolt's compatibility with the inserts be obtained.*

2.5 RE-USABLE LIFTING EQUIPMENT

2.5.1 General

Re-useable lifting equipment shall be designed and manufactured to have a limit state factor of 5.0, with the WLL determined in accordance with Clause 2.2.

2.5.2 Lifting clutches

Lifting clutches shall be proof tested, certified and individually identified prior to being placed into service. The proof test shall subject the device to a load of 2.0 times its WLL.

Inspections of the lifting clutches, prior to each use, shall be conducted to check for wear and deformation. A proof test using a load equal to 1.2 times the WLL shall be conducted and recorded at least at twelve-monthly intervals.

> ***C2.5.2*** *Suitable identification of lifting clutches may be by permanent marking on the clutch itself or attachment of a durable tag.*
>
> *Following visual inspection of the lifting clutch, if there are any safety concerns, a proof test should be conducted.*

2.6 BRACES

2.6.1 General

The WLL for braces shall be determined in accordance with Clause 2.2 where the value of $k_s(LSF)/\phi$ is taken as not less than 2.0.

Brace adjustment mechanisms shall have stops on the threads to prevent over-extension, and on retaining devices to prevent unintentional dislodgment of the shear pins, including the telescopic adjustment pin. Shear pins shall be constructed so they cannot be undone without the use of a tool.

Braces shall be maintained and inspected between each use to ensure that all components are correct and in good working order.

The bracing foot or shoe shall be designed so as to prevent lateral displacement of the shoe from the fixing insert after installation.

The following information, for all braces, shall be readily available at the erection site:

(a) WLL in kilonewtons for a fixed length brace and at minimum, maximum and intermediate extensions for telescopic braces.

(b) WLL in kilonewtons, when used with specified configurations of secondary bracing. This includes knee bracing and stability bracing.

The required fixing, length and capacity of braces shall be nominated on the panel brace layout plan and/or panel detail drawings.

C2.6.1 The stability of a panel in the temporary braced condition can be jeopardized if shear pins on the braces are removed either accidentally or as acts of vandalism. To minimize the risk of this occurring, site security should be appropriate to reduce the risk of vandalism. Erection procedures should be such as to ensure that a brace is not removed until the panel is secured to the structure. Shear pins on braces should be purpose-made, simple to install and unable to be removed without appropriate equipment or deliberate force.

2.6.2 Marking of braces

Braces shall have the following information displayed on a permanently fixed identification plate:

(a) The supplier or manufacturer.

(b) The model type or designation.

In addition, the load capacity of the braces shall be marked as follows:

(i) For fixed length braces, the WLL, in kilonewtons, on the permanent identification plate.

(ii) For adjustable length braces, the WLL, in kilonewtons, at maximum and minimum extension on the permanent identification plate.

(iii) For composite braces, the WLL, in kilonewtons, at maximum and minimum extension, suitably and clearly marked on the brace.

2.7 LEVELLING PADS AND SHIMS

2.7.1 General

Levelling pads and shims for the temporary support of elements shall be qualified for use by determining their compressive strength and creep characteristics. They shall be manufactured from a material that will not—

(a) fracture under full load;

(b) continue to creep after 15 min under full load;

(c) corrode, stain or be adversely affected by cold weather, alkali, ground chemicals; or

(d) rot or oxidize when exposed to moisture.

Where levelling pads are intended to provide permanent support, they shall be capable of safely carrying the design loads from the structure.

2.7.2 Physical requirements of shims

The WLL of the shims shall be specified to have a limit state factor of 2.0 against the compressive strength of the shim material. The compressive strength of the shim material shall be determined in accordance with Appendix A.

Unless otherwise designed and specified, the total height of the shim, or combination of shims, shall not exceed 40 mm and the minimum width shall be 100 mm or, where the thickness of the element is less than 100 mm, the thickness of the panel.

2.8 CRANE AND RIGGING EQUIPMENT

The capacity of the crane shall be adequate to lift the total load and place the tilt-up panels at the required radii. The total load shall include the tilt-up panel, rigging and, where appropriate, strongbacks and other attachments. All cranes used for the lifting and erection of tilt-up panels shall be fitted with load indicators. Cranes shall be selected and operated in accordance with the appropriate parts of AS 2550.

All rigging equipment shall—

(a) comply with the relevant Australian Standards;

(b) have a WLL that is adequate for its intended application; and

(c) be in a serviceable condition.

The selection of particular forms and types of rigging gear to be used in the lifting and erection of tilt-up panels shall ensure that, when used in accordance with the intended erection procedure, the rigging will not be subject to forces for which it has not been designed and intended.

C2.8 Snatch-blocks and other sheave blocks with standard plain bearings are not intended to be rotated under load. Where the nature of the lift means that rotation of sheave block swivels under load is unavoidable, ensure that only blocks with thrust races or separate swivel bearings are used.

2.9 PROPRIETARY DOCUMENTATION

Proprietary documentation shall set out the information required for the correct use of the component or system. It shall include the following information, where applicable:

(a) Drawing or pictorial representation that clearly identifies the component or system to which it refers.

(b) Adequate information to fully describe its intended use.

(c) Instructions for use, storage and maintenance, including all precautions to be observed in its use.

(d) Criteria for rejection and reworking of the component or system.

(e) Detailed information including, where appropriate, the following:

  (i) Part number.

  (ii) Dimensions.

  (iii) Section properties.

  (iv) Self-weight.

  (v) Details of any special attachments, e.g., coupling sleeves.

  (vi) Locations for attachment points and bracing points.

(f) The strength and serviceability limit state capacities.

(g) The WLL as calculated in accordance with Clause 2.2.

(h) A statement that the component or system depicted in the documentation complies with this Standard.

C2.9 Proprietary documentation has been separated from the other documentation requirements in Clause 3.10, as the documentation is not unique to the panels or project.

Proprietary documentation should be readily available on site, if required. It is not intended that full documentation need be held on each site but that such documentation can be obtained within a reasonably short period, if required. For example, the crane company may hold at its head office proprietary documentation for the equipment they are using on the project.

SECTION 3 DESIGN AND DOCUMENTATION

3.1 GENERAL

This Section specifies particular requirements for the design and documentation of structures incorporating tilt-up panels and the design of the tilt-up panels.

Designers should refer to BCA Section C, Design for fire, for fire design requirements.

> ***C3.1*** *The design of tilt-up buildings for fire is a complex matter and designers need to consider the behaviour of the building under fire conditions. Reference should be made to the BCA and its commentary, with particular attention to the structural adequacy provisions in the event of fire.*

3.2 PREPLANNING

The design shall take into account the interrelation of the various stages of manufacture, construction, transport and erection.

> ***C3.2*** *It is not possible to obtain the full benefit and economies, inherent in tilt-up methods of construction, without preplanning and coordination between the relevant parties. Close collaboration between the designer, contractor, panel manufacturer and the erector is necessary to ensure safety in construction.*
>
> *Prior to manufacturing the concrete elements, the builder, in association with the panel manufacturer and the erector, should have planned the complete construction and erection sequences.*
>
> *Consideration should be given to details such as the following:*
>
> *(a) Site limitations.*
>
> *(b) Local street access.*
>
> *(c) Element sizes, shapes and masses.*
>
> *(d) Crane size, mobility and access.*
>
> *(e) Casting sequence.*
>
> *(f) Overhead obstructions, especially overhead power lines.*

3.3 DESIGN STAGES

Two separate design stages shall be considered:

(a) *Handling and erection* The panel shall be designed to resist all handling forces including impact, arising out of stripping, storage, tilting, transport, lifting and temporary bracing. While in the braced condition the panel may be regarded as a temporary structure.

(b) *In-service* The in-service design provides for the performance of the panel as part of the complete structure.

> ***C3.3*** *Wind forces on panels intended to be temporarily braced should be determined using an annual probability of exceedance as given in AS/NZS 1170.0, except where the panel could fall into a public space. If the panel could fall into a public space, a lower probability of exceedance should be used.*

3.4 BUILDING STABILITY

The stability of the whole building shall be checked for each stage during erection and under in-service load conditions. Special care shall be taken in design and construction to guard against progressive collapse both during construction and in the completed structure.

> ***C3.4*** *Tilt-up concrete structures are susceptible to progressive collapse type failures. For example, the failure of a single roof-bracing member should not be allowed to lead to the complete collapse of the structure. Consideration needs to be given to the situation during construction when the dislodgment of a single panel could lead to a progressive (domino-type) collapse.*
>
> *Progressive collapse can be prevented by—*
>
> *(a) adequate structural strength and continuity of the structure and its parts; or*
>
> *(b) alternative load paths, whereby applied forces can be transmitted safely through the structure.*
>
> *Structural continuity may rely upon, among other things, moment, shear, or tensile connections, depending on the kind of structural system employed.*

3.5 DESIGN OF PANEL

3.5.1 General

The structural design of tilt-up panels shall be carried out in accordance with AS 3600 and Clauses 3.5.2 to 3.5.9.

3.5.2 Panel loading

When determining the worst load or load combination for design, consideration shall be given to construction sequences and construction procedures.

In the design for handling, transport and erection, the weight of the panel shall be considered as a dead load for the purpose of determining load factors in accordance with AS/NZS 1170.0.

The weight of the panel shall be multiplied by—

(a) not less than 1.5 when calculating insert loads and panel bending moments at the point of panel lift-off from a concrete casting bed;

(b) not less than 1.2 when calculating insert loads and panel bending moments at the point of panel lift-off from a steel casting bed;

(c) as appropriate for other casting surfaces;

(d) not less than 1.2 for the remainder of the lifting process; and

(e) not less than 1.4 when calculating stresses during transportation.

> ***C3.5.2*** *As well as the in-service design, tilt-up elements should be designed for the loads and conditions to be experienced during the manufacturing, lifting, transportation and erection phases.*
>
> *Special consideration should be given to the following:*
>
> *(a) Construction loads.*
>
> *(b) Handling and transport loads.*
>
> *(c) Erection loads.*
>
> *(d) Wind load on the braced elements.*

Erection-load design should consider variations to the load distribution during lifting, rotation, and impact during placement.

The effect of suction and adhesion at separation from the form or casting bed (lift-off) and dynamic and impact loading during transportation, erection and bracing should be considered.

The multiplying factors stated in the Clause assume the use of effective bond-breakers and release agents. Suction loads may vary according to the finish and the type of form or casting bed. Where the casting bed has a profiled or textured surface the suction load may exceed 100% of the dead load. Consideration should be given to the casting bed profile to ensure that adequate draw (slope) is provided to the fixed edges of the forms not struck prior to lifting. A minimum draw of 1:12 is recommended.

Impact loads generated during handling and transport can be significant and should be considered in the design of the lifting inserts and rigging system. These increases may range from 20% during handling by crane up to 100% during transportation. Impact loading should only be considered after release (lift-off) of the element from the casting bed. The increase in design load due to suction and impact are not cumulative.

3.5.3 Specification of concrete

The specification of concrete shall nominate the following criteria:

(a) The flexural strength required at lifting.

(b) The strength required to develop insert strength at the time of lifting.

(c) The requirements for in-service loading, durability and any construction requirements such as workability.

3.5.4 Design of panels for manufacture and erection

Panels may be designed—

(a) to be uncracked; or

(b) assuming they are cracked, in accordance with reinforced concrete design methods.

When designing a panel to be uncracked and using working stress approaches, the flexural tensile stress shall be taken as not greater than $0.413\sqrt{f_{cm}}$ under the loads specified in Clause 3.5.2.

When designing a panel on the basis of cracked sections, that is, using the assumptions of reinforced concrete design, sufficient reinforcement shall be used to provide the necessary design capacity. The designer shall ensure that the assumptions for effective depth are consistent with the reinforcement detailing.

When fixed length, multi-leg slings are to be used for lifting, the panel shall be designed to not fail if supported by only two of the lifting inserts.

C3.5.4 *Generally, panels will be designed for erection assuming they are uncracked and for the appropriate loads in the completed structure on the basis of reinforced concrete design. Cracks in panels, which occur during lifting, are difficult to repair and/or camouflage and therefore tilt-up panels are usually designed to remain uncracked during the erection process.*

In panels with large openings, designers need to make a judgement as to the position of reinforcement in the panel adjacent to the opening.

3.5.5 Lifting inserts

The number and position of lifting inserts shall be sufficient to ensure—

(a) the load capacity of the lifting inserts and available crane rigging, including any additional equipment such as strongbacks, is not exceeded; and

(b) the strength of the panel is not exceeded in the lifting process.

In determining the location of lifting inserts, the effect of additional equipment, such as strongbacks, on the centre-of-gravity shall be considered.

When fixed length, multi-leg slings are to be used for lifting, any two of the lifting inserts shall be capable of supporting the total load of the panel.

C3.5.5 *The use of lifting systems comprising of 3, 6, 9 or 12 lifting points should be avoided wherever possible due to the complex rigging required.*

All lifting inserts require adequate embedment or anchorage to function effectively. Anchorage is affected by—

(a) proximity to edges;

(b) proximity to holes, recesses or edge rebates;

(c) proximity to other loaded lifting devices;

(d) concrete thickness;

(e) concrete strength at lifting;

(f) embedment depth;

(g) the presence of cracks; and

(h) the proximity of reinforcement or prestressing tendons.

Note that horizontal bars placed around the foot of the lifting insert may provide little additional lifting capacity to the insert.

The CCD method of Elligehausen and Fuchs is accepted in Europe and America as a reliable model for predicting the pull-out strength of an insert. The concrete capacity is a function of $\sqrt{f_{cm}}$. *They have determined multipliers of* $\sqrt{f_{cm}}$ *to predict the usual edge, depth and group configurations of inserts encountered. The CCD method is also suitable for calibration by testing.*

3.5.6 Panel thickness

The thickness of the panel shall be adequate to—

(a) carry the design loadings;

(b) limit the lateral deflection of the panel to 1/250 of the panel span under serviceability loadings; and

(c) meet the minimum thickness required by AS 3600 for the specified FRL (fire-resistance level) where the panel is required to have a fire-resistance.

3.5.7 Slenderness ratio

Panels may exceed the height-to-thickness ratios specified in AS 3600, provided a detailed analysis is carried out, taking into account the following factors:

(a) Loads, as specified in Clause 3.5.2.

(b) Moments due to the eccentricity of vertical loads.

(c) Moments due to deflection of the panel and its supports (i.e P-Δ effects).

(d) Long-term effects, where applicable.

The panel shall otherwise satisfy the requirements of AS 3600.

3.5.8 Panel supports

When initially erected, tilt-up panels shall be designed to sit on only two localized shimming points. The panel and the footings shall be designed to carry the forces from the localized supports, taking into account normal construction tolerances.

> ***C3.5.8*** *By specifying the locations of only two shimming positions beneath a panel, the designer can control where the weight of the panel is supported. Construction tolerances are usually such that multiple shimming will not distribute the panel weight to its support in a predictable manner, since any two of the shims are likely to support most of the load. After erecting the panel, the addition of further shimming points, or grouting beneath the panel, may serve to redistribute load following settlement beneath the original shimming points or additional loading of the panel. These points are particularly relevant to the design of strip footings, or thickened slab-on-ground edges, to support panels.*
>
> *Construction tolerances of discrete panel supports must be considered. For example, it is unlikely that adjacent ends of two panels can be supported on a single pier of less than 750 mm diameter. For piers on boundaries, the implications of the combined effect of tolerances and eccentric loads have to be considered and usually result in the need for pier/pile caps or rectifying beams.*
>
> *Where two panels land on a discrete support, the load eccentricities that occur during construction, because one panel has to be erected before the other, can sometimes be a critical load case in design.*

3.5.9 Fixing inserts

The design of fixing inserts for connecting the roof framing, and other structural members, to the panels shall comply with Clause 2.4.4, and shall provide for the following:

(a) The number, location and placement of fixing inserts, adequate to resist the forces (static and cyclic) imposed on the connections.

(b) The reduction of insert capacity when placed near an edge or an opening.

(c) Any requirement for additional component reinforcement.

(d) Adequate cover to all inserts.

(e) Ductile behaviour of the steel insert.

The type and characteristics of fixing inserts shall be as specified on the design drawings and shall not be changed without prior approval from the designer.

> ***C3.5.9*** *Where load-controlled anchors are subject to cyclical loading, the WLL should not exceed 0.65 of the 'first slip' load.*
>
> *Deformation-controlled expansion anchors, drop-in anchors, spring-set bolts and self-drilling anchors have been found to be unreliable and should not be used in structural connections (see Clause 2.4.3 for restrictions on their use as bracing inserts).*
>
> *In general, chemical anchors exhibit poor performance at elevated temperatures.*
>
> *Fixing capacities are reduced when fixings are placed in near proximity to each other or near edges and openings. Due consideration should, therefore, be given to the effects of interference with other fixtures, fittings and proximity of openings and edges. In these cases, consideration should be given to providing additional reinforcement or other means to prevent failure.*

Care should be taken to ensure that secondary effects, for example, eccentricity of the steelwork framing cleat and semi-rigid rafter connections, are determined and considered in the selection of fixing inserts.

For information on design of inserts, see ACI 318-02.

3.6 JOINT WIDTHS

Joint widths shall be specified in the drawings. The width of joints or gaps between adjacent panels and panels and the main structure shall be sufficient to maintain the designed position and alignment of panels during erection and accommodate tolerances and the expected movements during in-service life.

When determining the joint width and selecting the joint filling materials, consideration shall be given to the combined effect of—

(a) thermal and shrinkage movement of panels;

(b) fire resistance level required (if any);

(c) acoustic level required (if any);

(d) weather resistance;

(e) structural movements;

(f) dimensional tolerance of panels; and

(g) panel location tolerance.

Unless otherwise specified, joint widths between adjacent elements shall not be less than the following:

(i) Joints with flexible sealant ....15 mm.

(ii) Mortar or grouted joints ....20 mm.

(iii) In-situ concrete infill....................150 mm.

3.7 FOOTINGS

3.7.1 Panel footings

The design of footings for tilt-up panels shall take account of the following:

(a) When panels are initially erected, their self-weight will bear on two localized shimming points.

> ***C3.7.1(a)*** *This is particularly relevant where panels are erected onto strip footings, raft thickened edges, and beams. Only after the insertion of further shims, grouting the underside of the panel, or some settlement will the panel weight redistribute from the initial shim supports.*

(b) Provide sufficient footing dimensions to accept the load and location of shims and accommodate the required reinforcement, considering the allowable construction tolerances.

(c) The overall area of the shim shall be selected so that the bearing strength of the footing surface with which it is in contact is not exceeded.

(d) The erection sequence of panels that could produce a more adverse loading condition in a supporting member than the final in-service loads.

> ***C3.7.1(d)*** *An example of how the erection sequence of panels may produce adverse loading conditions in a supporting member is the connection between a single pile and its pile cap, positioned symmetrically beneath the joint of two adjacent panels. The pile cap may be subjected to a greater moment (resulting from load eccentricity) after the erection of the first panel, than after erection of both members.*

(e) Settlement of supports.

> ***C3.7.1(e)*** *This may be particularly critical for tall, narrow panels where a small vertical settlement at the base could result in a significant horizontal deflection at the top of the panel.*

3.7.2 Brace footings

Brace footings shall be designed or selected to ensure sufficient capacity to resist the forces from the bracing, especially for uplift.

The specification of concrete for brace footings shall nominate the following criteria:

(a) The strength required to develop insert strength at the time of bracing.

(b) The requirements for in-service loading, if any, durability and any construction requirements such as workability.

Brace footing inserts shall comply with Clause 2.4.3.

> ***C3.7.2*** *The requirement for the development of concrete strength at the time of bracing will commonly require the specification of early-age strength concrete.*

3.8 CONNECTIONS

3.8.1 General

Connections shall allow for independent shrinkage and thermal movements between panels, and allow for the construction tolerances in locating fixing ferrules and other cast-in components.

3.8.2 Horizontal restraint of panels

A fixing system shall be used to resist the horizontal load transmitted from the panel into the footings or floor slabs in the in-service condition. Friction forces shall not be used to resist any part of this load.

The fixings shall be capable of resisting the greater of—

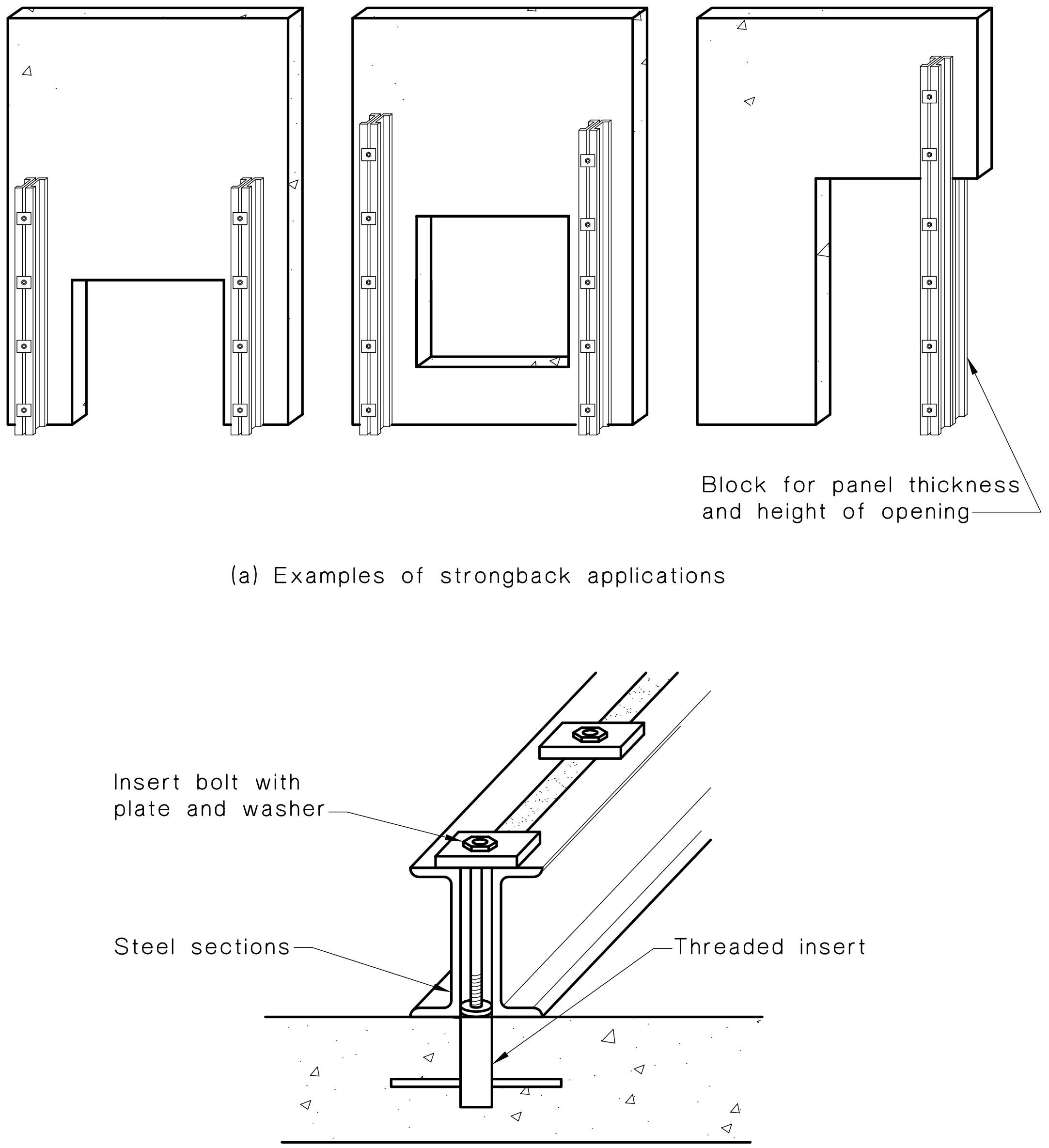
(a) forces resulting from the design loadings; or

(b) an unfactored live load of 3 kN/m applied over the full panel width, perpendicular to the plane of the panel, at the level of the connections.

3.9 STRONGBACKS

When strongbacks are required, they shall be designed and located to ensure that the strongback is sufficiently stiff to prevent cracking of the panel due to differential deflection. See Figure 3.9 for examples of strongbacks and their application.

Pre-attached braces and strongbacks, if used, shall be located to allow the rigging to operate, without interference, at all angles of panel rotation.



(a) Examples of strongback applications

(b) Heavy-duty strongback—Steel

FIGURE 3.9 STRONGBACKS

3.10 DOCUMENTATION

3.10.1 General

Drawings shall comply with AS 1100.501. The shop drawings of the panel shall also include both the design details for the in-service condition and for its erection and temporary bracing phases (see Figure 3.10). A symbol legend shall be shown on the drawings.

3.10.2 Information required on structural drawings

In order to facilitate the preparation of suitable shop drawings, the structural drawings shall include the following:

(a) Date and issue number of the drawing.

(b) Plans and elevations clearly indicating the structural framing and panel layout.

(c) Structurally critical dimensions.

(d) Panel reinforcement required for in-service loadings and conditions.

(e) Framing connection locations and required type (e.g., cast-in) and the capacity of fixing inserts.

(f) Levelling pad details.

(g) Structural design criteria affecting construction.

(h) The concrete specification, including all special requirements to meet in-service loadings and conditions, and that the concrete shall also meet the strength requirements at the time of lifting nominated on the panel shop drawings.

(i) Base connection details, for example, grouting sequence of dowel connections.

(j) The maximum value of the initial lift load, including an allowance for suction when lifting off the casting bed.

3.10.3 Information required on shop drawings

Shop drawings shall include the following:

(a) Date and issue number of the drawing.

(b) Project location.

(c) Panel number for each element.

(d) The mass of each element.

(e) Location of each element on a layout (marking) plan.

(f) Element dimensions and centre of gravity.

(g) Structural reinforcement.

(h) The location, orientation and depth of all inserts and the configuration and cover of any component reinforcement that is required.

(i) Where applicable, the type, make, capacity and technical specifications of—

  (i) temporary braces;

  (ii) lifting inserts;

  (iii) bracing inserts;

  (iv) fixing inserts; and

  (v) if required, strongbacks, strongback fixing inserts and locations.

(j) The size, configuration and cover of any additional reinforcement required for the transport and lifting of the element.

(k) The requirements for brace footings, if required.

(l) Levelling pad details.

(m) The concrete specification including—

  (i) all special requirements to meet in-service loadings and conditions;

  (ii) concrete strength of the panels required at the time of lifting; and

  (iii) concrete strength of the footings and bracing support elements required at the time of erection.

(n) Surface finish of each element.

(o) Where appropriate, the tolerance limits on the element.

(p) The orientation of the elements.

(q) Configuration of secondary braces, including knee braces and lateral restraints including required capacities.

(r) Rigging details.

C3.10 *The concrete strength grade on the shop drawings may be higher than that specified on the structural drawings to achieve the concrete strength required at the time of lifting.*

When the structural drawings and shop detail drawings are being produced as one entity by one organization it may be sufficient if the information specified in Clause 3.10.1 is included in the complete set of drawings.

In addition, it is recommended that the shop drawings include a layout drawing (marking plan) showing the following:

(a) Location of each element.

(b) Where applicable, rigging diagrams detailing the required configurations with sling lengths, spreader/lifting beam requirements and arrangement of sheaves.

(c) Requirements for erection brace footings, brace fixings and concrete strength of footing at the time of erection.

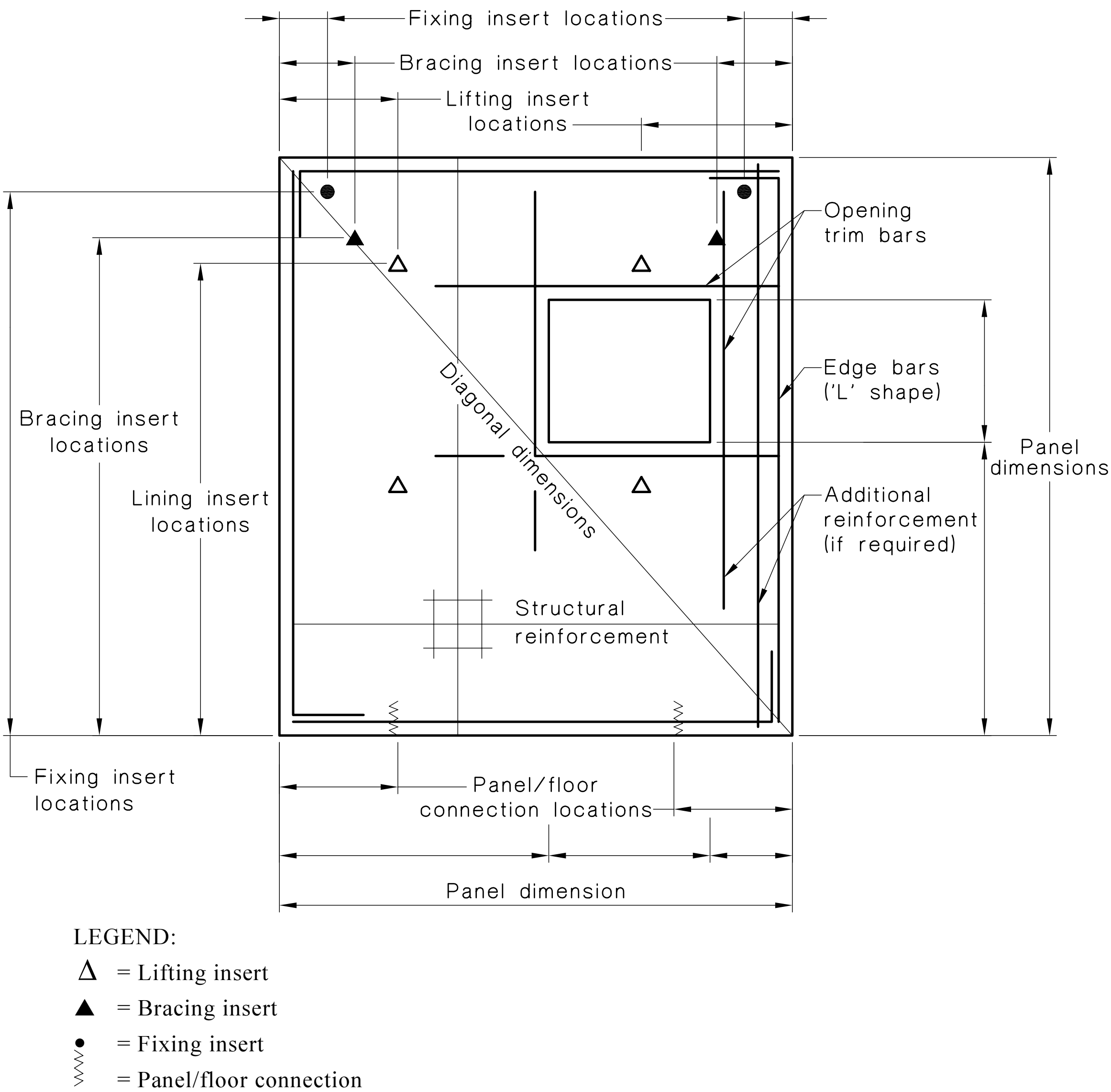


FIGURE 3.10 TYPICAL PANEL SHOP DRAWING

3.11 TOLERANCES

Recommended tolerance for as-cast panels, casting bed, and insert locations are as follows:

(a) *As cast panels* The recommended tolerances for as-cast panels are as set out in Table 3.11(A).

(b) *Casting bed* The recommended tolerance on deviation from planeness of the casting bed, measured in any direction using a 3 m straightedge as set out in AS 3610 is .... ±3 mm.

(c) *Inserts* The recommended tolerances on the location of inserts are as set out in Table 3.11(B).

(d) *Panel location* The recommended tolerance on the deviation of the panel from the specified final position in the structure is........................ 5 mm but should not reduce the specified joint width by more than 33%.

Where more stringent tolerances are required, they shall be specified in the appropriate design documentation and shop drawings.

The effects of cumulative tolerances shall be considered. The total accumulation of tolerance shall not be greater than 20 mm when related to setout grids and datums.

C3.11 The tolerances in Table 3.11(A) have been derived from the pre-publication draft of AS 3610.

It is recommended for stack casting that the top surface of the first panel be carefully levelled, using a dumpy level for example, to ensure successive panels do not inherit profile deviations from the base panel.

TABLE 3.11(A)
RECOMMENDED TOLERANCES ON AS-CAST PANELS

Panel height (m)	Tolerance (mm)						
	Linear			Angular	Profile		
	Width	Height	Thickness	Squareness (Note 1)	Twist (Note 2)	Warp (Note 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 precast unit deviates from a straight line perpendicular to the longer side and passing through the corner of the unit.

2 Per metre width in 3 m length.

3 Per metre width.

TABLE 3.11(B)
INSERT LOCATION TOLERANCES

Type of insert	Tolerance mm
Face lifting	±20
Bracing	±50
Strongback	±5
Edge-lifting	
longitudinal	±20
thickness	±5
Fixing	±5

SECTION 4 CASTING

4.1 GENERAL

Tilt-up panels shall be manufactured in accordance with the current version of the shop drawings.

4.2 LAYOUT

Prior to the casting bed being set out, consideration shall be given to the following:

(a) The orientation of the panels on the casting bed.

(b) Vehicular access to and around the site.

(c) Location of power lines, utility trenches and other services.

(d) Panel storage positions, where required.

(e) Crane type, size and lifting position.

(f) Erection sequence and bracing layout.

4.3 CASTING BED

Casting beds shall be capable of supporting formwork, panels and other loads, particularly where the casting bed is to be used as an erection platform.

The release agent to be used with the panels (see Clause 2.3.2) shall be compatible with any curing compound used on the casting bed.

The surface of the casting bed shall be appropriate for the surface finish specified for the tilt-up panel.

> ***C4.3*** *Any cracks and casting defects in the casting bed may reflect in the cast panels. Where there is insufficient room to cast all panels on the casting bed, panels may be cast one on top of another, in reverse order of erection. Care is needed with this casting method to limit the tolerances of a panel, especially flatness, as the deviation may be cumulative as successive panels are cast one on top of another.*

4.4 FORMWORK

Formwork shall be in accordance with AS 3610 except that the tolerances shall be as specified in Clause 3.11.

4.5 COMPACTION OF CONCRETE

Concrete shall be adequately compacted, especially around cast-in inserts and formed corners and edges.

4.6 CURING AND RELEASE AGENTS

In addition to the requirements of Clause 2.3.2, the curing compound and release agent shall be applied in accordance with the respective manufacturer's recommendations.

4.7 LIFTING, BRACING AND FIXING INSERTS

All inserts shall be positioned and fixed as specified in the shop drawings and to the tolerances set out in Table 3.11(B).

All cast-in inserts and any component reinforcement shall be located and fixed against dislodgment during concreting, prior to casting.

C4.7 Proprietary inserts should always be fixed in accordance with the insert manufacturer's requirements, unless otherwise specified in the shop drawings. Where the structural drawings specify specific inserts with the statement 'or approved equivalent', authorization for substitution of a different insert has to be given by the designer and the variation noted in the design documentation, commonly in the shop drawings.

Due to the close tolerances on the location of fixing inserts, the inserts should be supported from the mould sides or the casting bed, if practical.

See C3.5.5 for factors that affect the performance of inserts.

4.8 WELDING

Site welding of reinforcement to lifting, bracing or fixing inserts (other than weld plates) shall not be carried out, unless prior approval has been given by the designer of the relevant inserts.

The welding of reinforcement shall comply with AS 1554.3. Tack welding not complying with AS 1554.3 shall not be used.

4.9 TILT-UP PANEL IDENTIFICATION AND ORIENTATION

Tilt-up panel identification (panel number) and orientation (e.g., top and bottom edges of the panel) shall be maintained throughout the casting process until that information is transferred to the panel.

All tilt-up panels shall be permanently marked during or immediately after manufacture with a unique identification designation, commonly the panel number, and date of casting.

4.10 INSPECTION

Prior to casting, the form set-up shall be checked for compliance with the shop drawings, in particular the following:

(a) Formwork dimensions.

(b) Formwork stability.

(c) Panel edge details and penetrations.

(d) Connection details.

(e) Insert locations, types and fixing.

(f) Reinforcement sizes, location and fixing.

(g) Bond-breaker effectiveness.

C4.10 The inspection of the form set-up should be carried out by a competent person not involved in the original form set-up. For stack casting of panels, an inspection should be done prior to the casting of each panel.

Bond breaker effectiveness generally can be checked by sprinkling water over the casting bed, where the water should form into beads.

SECTION 5 TRANSPORT, CRANAGE AND ERECTION

5.1 TRANSPORT

5.1.1 Planning

The following points shall be taken into account when tilt-up panels are to be transported to and around the site:

(a) The shape, size and mass of the panels.

(b) Specific design requirements, including the concrete strength required for transportation and the stability of long or unusually shaped panels during transportation.

(c) Local traffic regulations governing maximum weight, length, width and height of the laden vehicle.

(d) Providing all-weather access for the delivery vehicle to and around the site.

(e) Capacity of permanent structures to carry transport loads where required.

(f) Temporary storage, where required.

C5.1.1 *Designers should give due consideration to transport requirements, difficulties and limitations during the design of panels. Consultation, if available, with the transport contractor is recommended during the design phase, to avoid potential changes due to transport limitations.*

Reference may be made to VicRoads (1999) 'A Guide to Restraining Concrete Panels'.

Although special vehicles may be available, it is generally advisable to proportion panels so that they may be transported on standard vehicles during normal working hours.

Access for the transport vehicle and load on site should be via all weather roads onto and across the site.

Dunnage, cushioning and packing are required for the support of panels on the delivery vehicle, to prevent local damage.

5.1.2 Loading

The panels shall be securely tied or attached to the delivery vehicle by restraints that will not damage the panel.

Panels shall be loaded so that identification marks are visible during unloading.

The order of stacking and the support details on the delivery vehicle and the design of transport frames shall permit the panels to be safely unloaded to temporary storage or be safely erected into the structure in the required sequence.

C5.1.2 *Particular attention should be given to the following:*

(a) Specific requirements for the unloading of panels, such as sequence or orientation on the building.

(b) Checking the lifting points on the panels to ensure they are in the correct location and compatible with the lifting system to be used. Lifting inserts should be clearly identified to assist in the loading and unloading stages.

(c) Checking the lifting system to ensure that it is in the correct location.

(d) *When loading, separating, supporting and protecting the panels so as to prevent damage and to permit safe unloading, in accordance with any special requirements that may be provided.*

(e) *Checking the anticipated behaviour of the panel on the delivery vehicle and designing and manufacturing of appropriate supporting frames, bracing and support points.*

(f) *Stability of drop trailers left at the site and securing the load.*

Slender panels may require temporary stiffening against lateral buckling. Differential road cambers could induce torsional loads in long panels and, thus, may need to be taken into account.

Low friction material should not be used as packing to support a panel.

5.1.3 Unloading

Particular requirements for the unloading of panels, such as sequence or orientation on the building, shall be specified.

During unloading, the delivery vehicle shall be on firm ground and, if necessary, blocked to prevent tipping when partially unloaded. Where the unloading sequence may lead to instability of load, panels shall be individually restrained and the loading configuration shall be checked to ensure that removing individual panels does not result in instability of the load and/or the vehicle. Restraints shall not be removed until the crane takes the initial weight.

Panels shall be inspected before lifting for damage, particularly around cast-in lifting inserts. Any such damage shall be referred to the designer for action and, where appropriate, approval of repairs.

C5.1.3 *The preferred method of erection is to lift directly from the delivery vehicle into the final position. If unloading delays are anticipated, 'drop' trailers should be used.*

All suspended slabs and temporary support systems intended for access should be confirmed as being adequate to withstand the anticipated loading.

Where the site is not level, unloading should be commenced from the low side, once again taking care to prevent tipping when partially unloaded.

Information on load movement and cranage can be found in 'A guide to rigging', a joint WorkCover Authority of New South Wales and Victorian WorkCover Authority document (Second edition June 1997).

5.2 STORAGE AND MULTIPLE HANDLING

Panels shall be stored in a designated area and in such a manner as to minimize multiple handling.

Panels shall be supported to ensure that the panel is stable, as specified by the designer.

C5.2 *After initial handling, panels should only be stored as specified by the designer.*

Where site storage is envisaged, consideration should be given to the following:

(a) *A well-drained and consolidated area, located where there is little chance of damage, to be provided to support the weight of the stored panels and any necessary stacking frames. The storage area should be checked for the possibility of differential settlement.*

(b) *Panels to be adequately supported at the specified points.*

(c) *Identification marks on stacked or stored panels to be visible.*

(d) *Panels to be stored in the specified order in such a manner as to provide safe access and removal.*

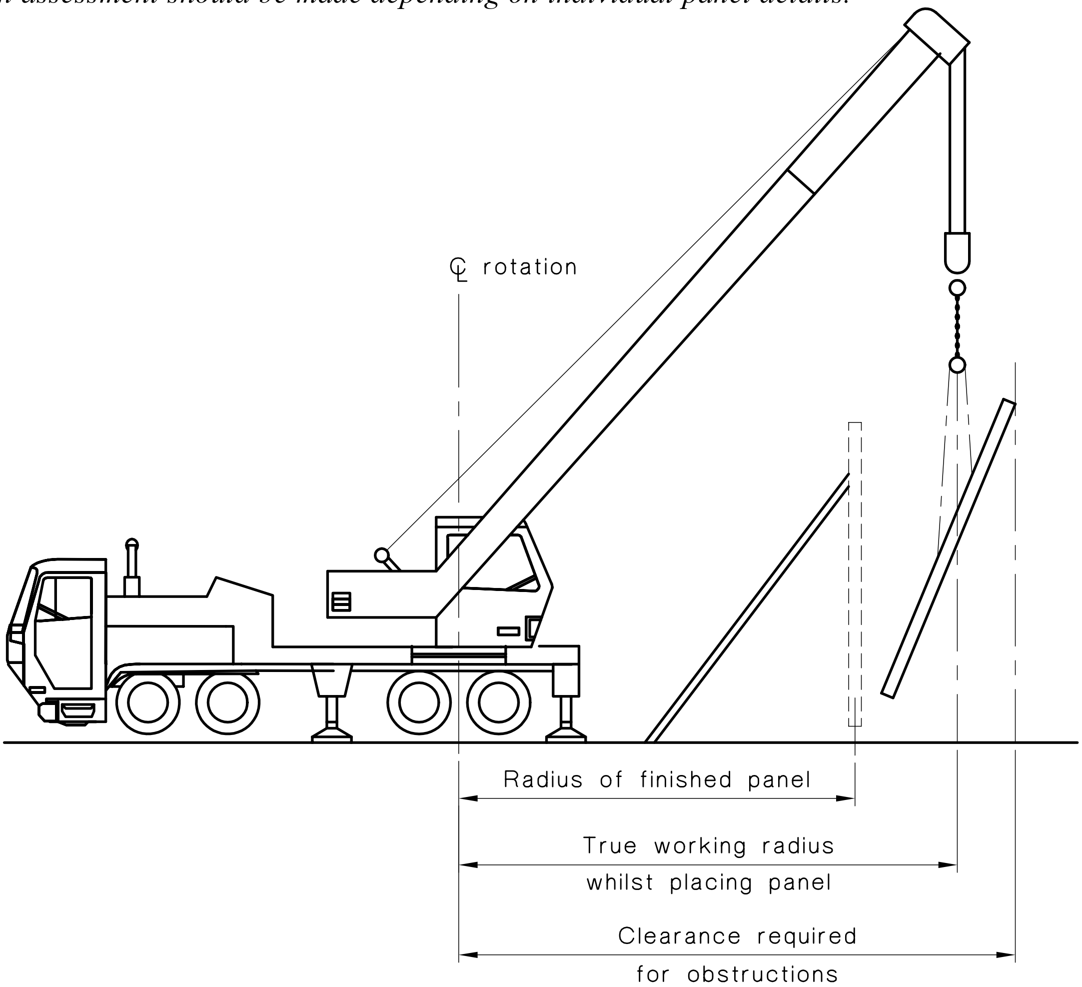
Panels should preferably be stored in the vertical position. Where edge-lifted panels are stored horizontally, they should be placed as originally cast to ensure that component reinforcement around edge-lifting inserts is correctly orientated for re-lifting.

5.3 CRANES AND RIGGING

5.3.1 Cranes

The requirements for cranes shall be in accordance with Clause 2.8.

C5.3.1 *When placing face-lifted panels, the true working radius of the crane should include an allowance over the radius to the finished panel position to take account of the hang of the panel from the lifting inserts and any lifting beams etc. (see Figure C5.3.1). An assessment should be made depending on individual panel details.*



The increase in radius may be 1.5 m or greater.

FIGURE C5.3.1 CRANE WORKING RADIUS

5.3.2 Rigging

The rigging system shall be specified in the shop drawings. Any alterations to the specified rigging shall be approved by the panel designer before being implemented.

C5.3.2 *The rigging system should distribute equal loads to all lifting points, unless otherwise specified and should include the use of slings running through sheaves on spreader or lifting beams (see Figure C5.3.2(A)). Sling lengths are important and the rigging system should be designed to suit the spacing and layout of the lifting inserts. Spreader or lifting beams should be of adequate length to suit the specified rigging system. Common configurations are shown in Figure C5.3.2(B). The use of lifting systems comprising of 3, 6, 9 or 12 lifting points should be avoided wherever possible due to the complex rigging required. When using multi-leg, fixed length slings, the full load is required to be taken on any 2 legs of the system.*

Lifts should be planned so that rotation of snatch-block swivels under load is not required. Where the snatch block is required to rotate, it should have thrust races or separate swivel bearings.

An inspection and check of rigging should be performed prior to lifting, usually by the rigger in-charge, especially where steel wire rope is being used in the rigging system. A visual check should be carried out before each use to ensure that the collar pin is intact and that the collar has not become loose.

Where blocks with lockable clamp bolts are not available, care must be taken to ensure that the cheek plate clamp bolt is fully tightened and that rubbing and abrasion under load does not occur (see Figure C5.3.2(C)).

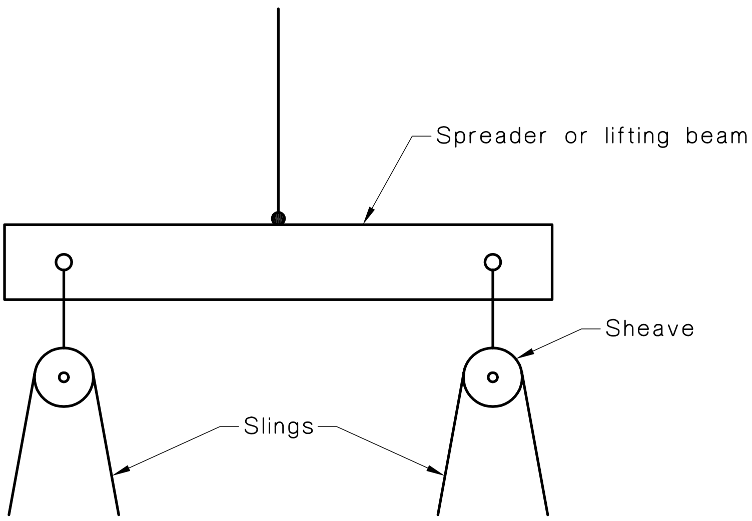
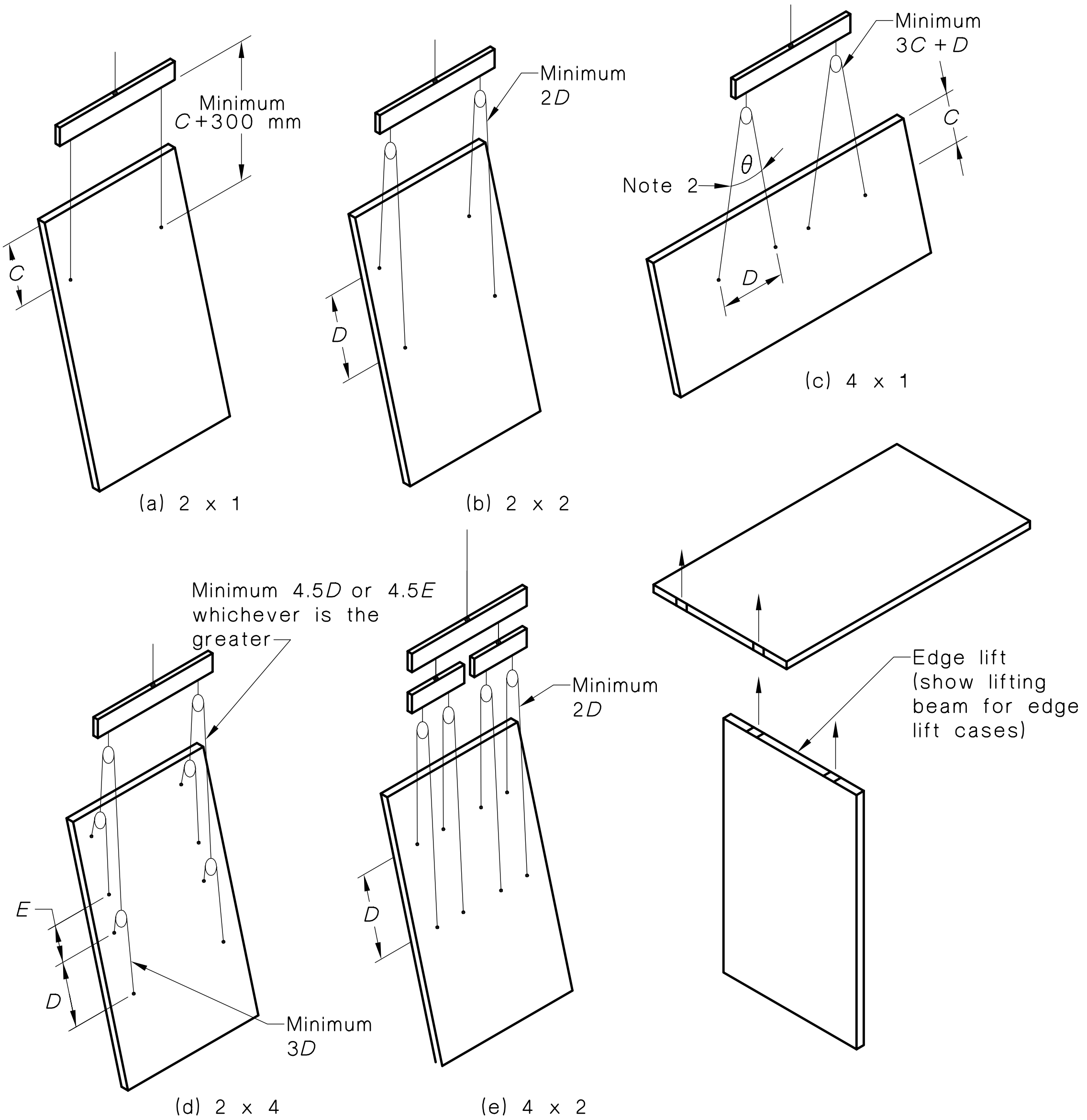


FIGURE C5.3.2(A) RIGGING SYSTEM COMPONENTS



Although the loads in the slings attached to each insert are equal, the components of the sling load in the plane and perpendicular to the panel may not be equal for each lifting insert because of the differing inclination of the slings to the panel. The sling loads, and their in-plane and perpendicular components, will also vary during rotation of the panel.

FIGURE C5.3.2(B) COMMON RIGGING CONFIGURATIONS

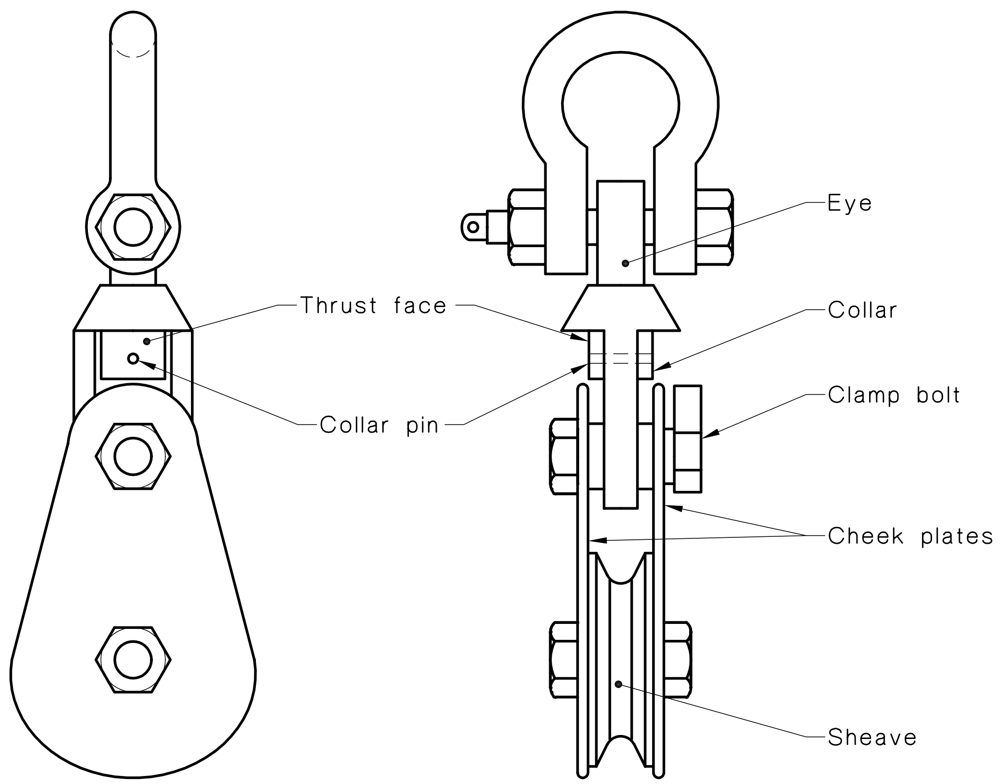


FIGURE C5.3.2(C) SNATCH-BLOCK

5.4 ERECTION

5.4.1 Planning

Planning and use of cranes shall be in accordance with the appropriate parts of AS 2550, and the following shall be taken into account:

(a) Access and egress routes to, from, in and around the site.

(b) Crane siting, to ensure clearance around structures and temporary braces, including the braces of the panels to be erected before the crane is relocated.

(c) Maintenance of public safety.

(d) Proximity to power lines.

(e) Ground support conditions, including suspended slabs.

(f) Proximity to excavations and underground services.

(g) Selection of lifting gear.

C5.4.1 *Planning for erection should include the following considerations:*

(a) Written procedures covering setting up and dismantling of the crane and lifting method as well as a risk assessment of these procedures.

(b) Make-up of the crane crew, dependent on the crane and its usage, which could include erection crew, crane operator, dogger, spotter, riggers and additional skilled labour as required.

(c) Communication system.

(d) Personal safety equipment.

(e) Emergency procedures.

(f) Panel lifting sequence and crane positions.

(g) Clearance between panels, braces, or other structures, including those to be erected and the crane's counterweight slewing path.

A number of accidents have occurred where a slewing crane's superstructure has struck a brace to a panel that had been installed subsequent to the crane's setting up, resulting in the panel collapsing on the crane.

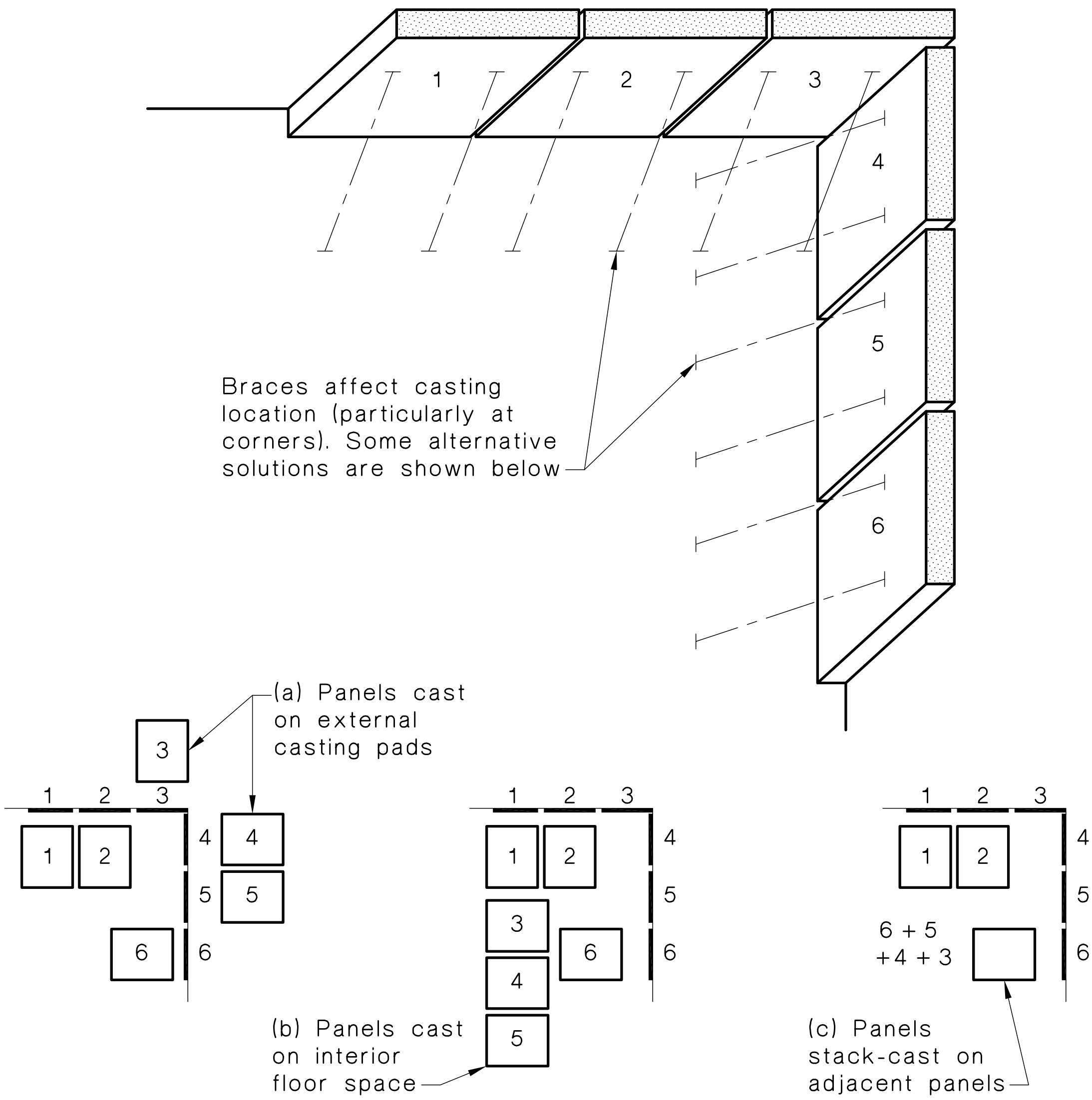


FIGURE 5.4.1 BRACING INFLUENCE ON CASTING LAYOUT

(Extracted from: Cement and Concrete Association of Australia, (1990) *Tilt-up Manual*, T27)

5.4.2 Erection preparation

Prior to commencing erection, the following points shall be taken into account:

(a) Verifying that the erection platform can carry the erection loads.

(b) Verifying that there is sufficient clearance around the site for crane access and mobility, including sufficient room for crane outriggers and panel bracing as well as ensuring sufficient clearance from overhead powerlines.

(c) Confirming that the concrete in the panel has attained the specified strength for lifting.

(d) Confirming that the concrete in bracing support elements has attained the specified strength.

(e) Confirming the type, orientation, location and condition of lifting and bracing inserts.

(f) Ensuring lifting, bracing and fixing insert recesses have been cleaned out.

(g) Reporting any incorrectly located lifting or fixing inserts to the designer for resolution.

(h) Checking to ensure that the lifting clutches and lifting inserts to be used in the erection process are compatible.

(i) Ensuring the appropriate rigging equipment is available and is serviceable.

C5.4.2 *When preparing for erection, the following should be checked:*

(a) The levelling pads and/or shims, to ensure they have been set to the correct height and location.

(b) All other inserts, to ensure they are in their correct locations.

Where possible, the bracing should be fixed to the panel and the brace insert bolts torqued before lifting.

Eye protection should be worn when using compressed air for the cleaning of insert recesses.

Where possible, trenches for services should not be excavated until erection has been completed due to the higher than normal axle loads on mobile cranes. The location of back-filled trenches should be clearly marked so that outriggers are not placed on uncompacted soil.

5.4.3 Erection platform

The erection platform shall be selected and shall be capable of withstanding the loads imposed by the crane and the panels.

The design of all suspended slabs and temporary support systems intended for use as erection platforms shall be checked by a suitably qualified person and confirmed in writing as being adequate to withstand the design loading.

C5.4.3 *Where the erection platform is a suspended slab, strengthening may be achieved by the use of temporary supports.*

The area of the erection platform should be checked for any backfill areas. Assessing the erection platform is a requirement in AS 2550 and should be carried out in accordance with that Standard.

5.4.4 Structural capacity of panel

Where any of the following defects are noted they shall be referred to the panel designer:

(a) Misalignment of lifting inserts.

(b) Loss or incorrect orientation of lifting inserts.

(c) Poor compaction of concrete around inserts.

(d) Inadequate concrete strength.

(e) Cracks in the panel passing through or close to lifting inserts.

Authority to proceed shall be obtained from the panel designer and recorded.

Where chemical or load-controlled expansion anchors are used to replace lifting inserts, they shall be individually proof tested prior to lifting.

> ***C5.4.4*** *Solutions for incorrectly located, faulty or missing lifting inserts may include:*
>
> *(a) Fixing a plate with undercut anchors.*
>
> *(b) Fixing a plate with chemical or load-controlled expansion anchors.*
>
> *(c) Drilling through the panel and attaching lifting plates by bolting through.*

5.4.5 Panel release (lift-off)

During the lifting process of tilt-up panels, the adhesion of the panel to the casting bed has to be broken. If the panel does not come free when the crane load indicator registers the maximum value of the lift load specified on the drawings, the load on the crane shall not be increased.

> ***C5.4.5*** *Where the panel does not come free, advice should be sought from the panel designer or panel manufacturer about the appropriate procedures to be used. Procedures such as wedging or jacking should be undertaken by or under the direction of a competent person, such as a qualified rigger. After the panel is free, the panel should be checked for damage. If the panel is damaged, it should be inspected by the panel designer.*
>
> *Where used, long tapered wedges should be located between the panel and the casting slab so as to follow the line of lifting inserts. Such lines are drawn from the lifting inserts to the top and edges of the panel (see Figure C5.4.5).*
>
> *The first wedges should be driven at the top of the panel in line with the lifting inserts. If the panel does not readily come free, pairs of wedges should be driven opposite successive rows of lift points down the edges of the panels.*
>
> *Where used, wedges should be aligned with the lifting inserts unless written instructions state otherwise.*

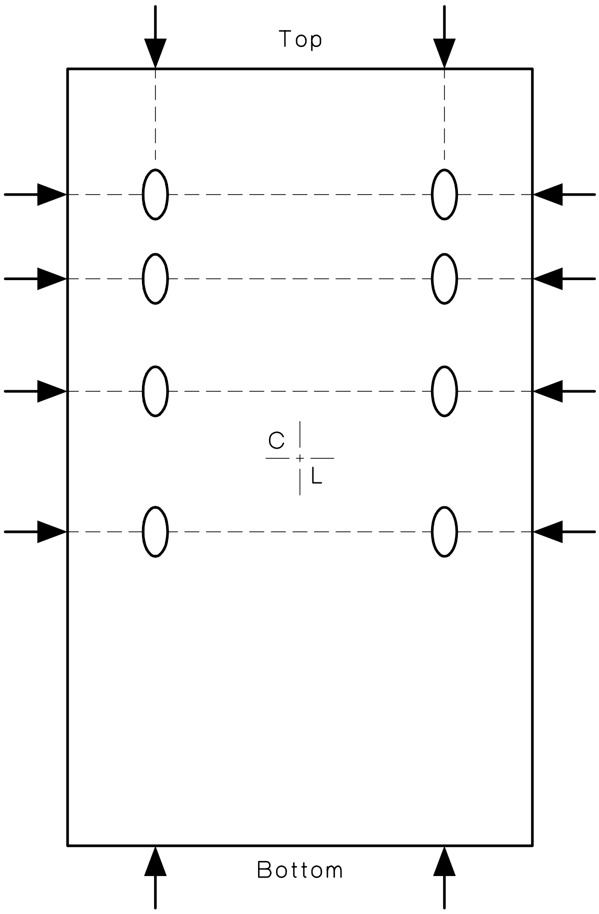


FIGURE C5.4.5 WEDGING OF STUCK TILT-UP PANELS

5.4.6 Lifting and placing

Lifting shall not be undertaken until the concrete in the panel and bracing footings have attained their specified strength.

During lifting and placing—

(a) all personnel shall be outside the drop zone when lifting, tilting or rotating the panel from horizontal to vertical;

(b) when taglines (tail ropes) are used to control the swing of the panel, personnel shall work clear of the panel edges as the panel may slew sideways;

(c) the lifting and placing method shall be such that sudden failure of the panel or rigging will not endanger the crane or crane operator;

(d) panels shall not be lifted in winds that prevent control of the panel in all stages of erection;

(e) when it is necessary to attach the braces to the panel after the panel has been positioned, the panels shall be held firmly and safely by the crane while the braces are attached;

(f) at no time shall any panel lean on any braced panel or other part of the structure without prior approval from the designer; and

(g) clutch release ropes shall not be used as taglines (tail ropes).

C5.4.6 *Whenever possible, panels should be lifted with the rigging equipment in view of the crane operator.*

All lifting equipment (i.e., shackles, slings, sheave blocks and clutches) should be checked prior to use and at regular intervals during erection.

Persons should not be placed between a panel being lifted and another panel, trench wall or other object where the movement of the panel could cause crushing. This applies until the release of the crane from the panel.

The situation where the braces are to be attached after a wall panel has been positioned should be avoided. If this situation is unavoidable, the panel should be tilted, just past vertical, until the braces are installed. In the case where the bracing inserts are located on the opposite side of the panel to the lifting inserts, an industry practice has been to tilt the panel back onto the rigging and attach the braces.

Care should be taken with release ropes to ensure that they are kept free from catching on any obstruction.

5.4.7 Release of rigging

The load supported by the rigging shall not be released until the panel is either adequately braced or incorporated into the supporting structure.

5.5 DAMAGE AND REPAIR

Any damage to panels and any proposed remedial measures shall be referred to the panel designer for approval before repair is commenced and the panels used.

SECTION 6 TEMPORARY BRACED CONDITION

6.1 DESIGN OF TEMPORARY BRACING FOR PANELS

The following requirements apply to the design of temporary bracing for tilt-up panels:

(a) The temporary bracing shall be designed to resist the appropriate loads. Regional wind speeds shall be based on a probability of exceedance as given in AS/NZS 1170.0 except where the panel could fall into a public space then a lower probability of exceedance should be considered. Wind forces in temporary braces, calculated on the basis of AS/NZS 1170.2, shall be divided by 1.5 in order to compare them with the working load limit of the brace. See Figure 6.1 for an example of typical bracing.

(b) The overall stability and the sequence of panel erection shall be checked to ensure that, at any stage, the risk of a mechanism leading to progressive collapse of the panels is minimized.

(c) Except as provide for in Item (d), each panel shall be supported by a minimum of two braces of adequate capacity.

(d) If specified on the shop drawings, one or more braces may be replaced by—

    (i) equivalent supports, such as corner supports, main structure and box structures; or

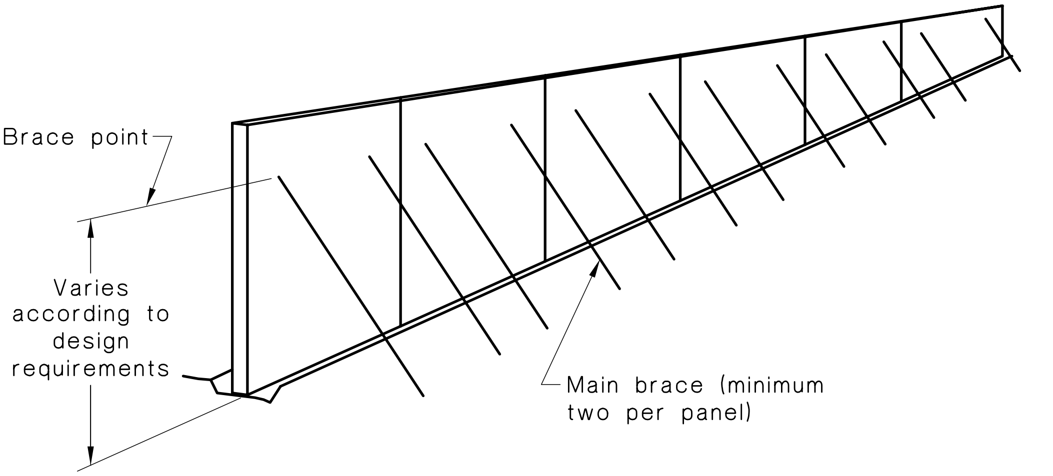
    (ii) a single fixed-length brace purposely designed for the specific application with two fixings to each end of the brace.

(e) Fixings at each end of the brace shall be adequate to transmit the calculated force in the brace. The type of fixing or the required capacity of the fixing shall be nominated on the shop drawings.

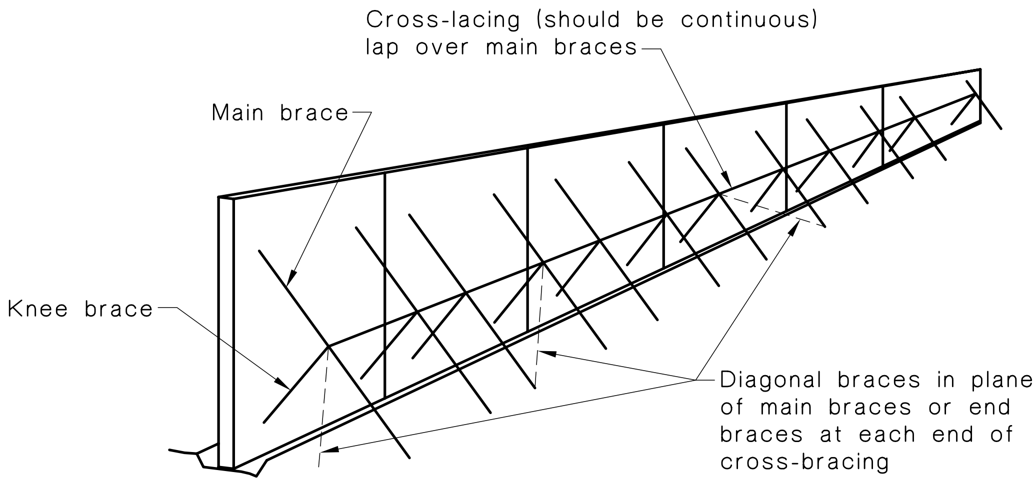
(f) The end of a brace remote from the panel shall be connected to a member or system capable of resisting the calculated force in the brace.

The bracing requirements shall be fully documented on the shop drawings.

> ***C6.1*** *For wind loading see Commentary C3.3. The choice of the return period for the wind load on braced panels should be reviewed in terms of the likelihood of high winds due to the season while the panels are temporarily braced and in terms of the length of time the panels may be in the braced position.*
>
> *The bracing of panels off other temporary braced panels should be avoided and, if used, the system is required to be appropriately designed to provide equivalent or better temporary support to the panel. Where this is necessary, this needs to be approved by the designer prior to application.*
>
> *Particular consideration needs to be given to the strength of brace support elements at the time of bracing, especially isolated footings.*
>
> *Where single braces are used, e.g., on narrow panels, care needs to be exercised in preventing out of balance loads, which may tend to rotate the panel about the brace and cause collapse.*
>
> *The design and installation of skew braces, that is, braces not perpendicular to the panel in plan, need to be carefully reviewed to consider any induced lateral and torsional forces onto the panels.*



(a) Primary bracing of panels
(where loads are less than WLL)



NOTES:

1. Knee brace should have positive connection at each end and connect at mid-span of main brace.
2. Cross-lacing should be continuous and have positive connection at each brace and at the end of each line.

(b) Secondary bracing of panels
(where additional load capacity is required)

FIGURE 6.1 PRIMARY AND SECONDARY BRACING OF PANELS

6.2 INSTALLATION AND INSPECTION OF TEMPORARY BRACING

Bracing shall be installed in accordance with the shop drawings unless prior written approval for the variation has been obtained.

A check of the torque of bolts shall be carried out 24 h after erection.

Regular visual inspection of panels in the braced condition shall be carried out, specifically to check the braces and bracing insert connections.

C6.2 Further checks of the torque of bolts are recommended at regular intervals after installation. Daily visual inspection is recommended on all braced and bracing elements.

Two temporary braces on a panel may be adjusted in alternate directions to ensure a minimal pre-load in the braces, which will reduce vibration under cyclic loading.

6.3 SUPERIMPOSED LOADS

Superimposed loads shall not be applied to panels in the temporary braced condition unless such loads have been specifically allowed for in the design. These include loads from erection of steelwork and other attachments.

C6.3 Designers should be aware that pitched rafters can exert significant outward loads onto braced panels. In some cases these forces are sufficient to cause failure of the bracing inserts/bolts.

Lateral outward forces on panels during the erection of pitched roof rafters can result in the overloading of the temporary bracing and its connections.

During release of the rafter's weight from the crane, the braces adjacent to the rafter being erected should be monitored and adjusted accordingly.

6.4 LEVELLING PADS AND SHIMS

Levelling pads and shims shall comply with the material requirements of Clause 2.7 and shall be installed in accordance with the shop drawings. See Figure 6.4 for a typical panel support detail.

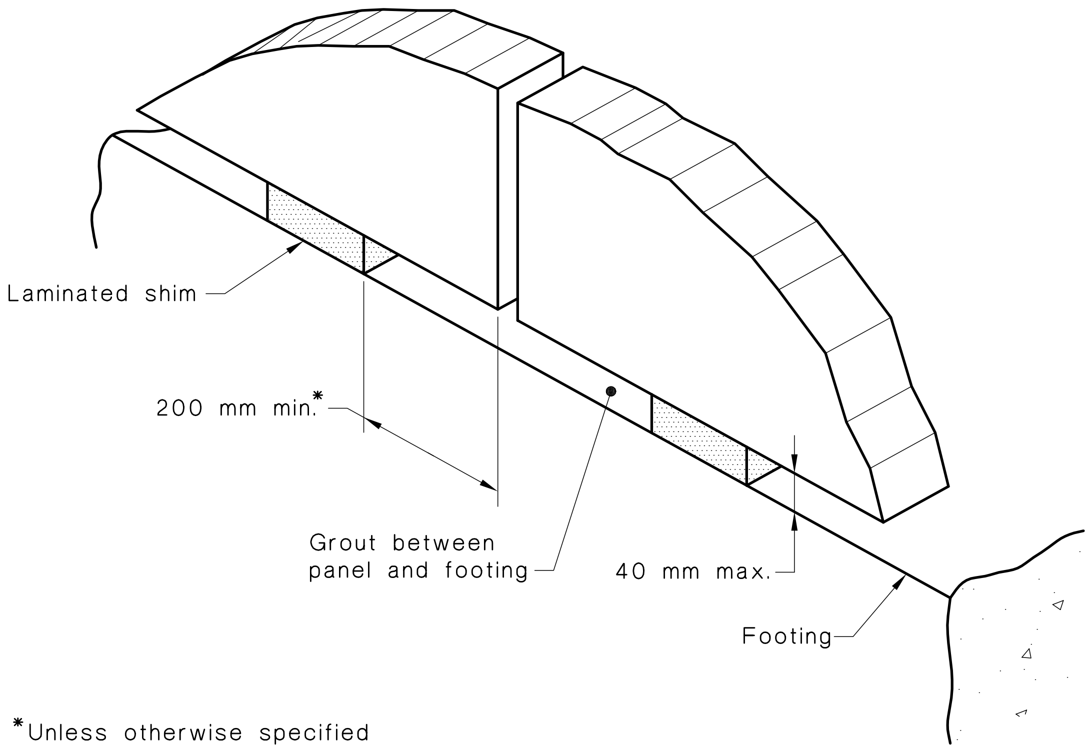


FIGURE 6.4 TYPICAL SHIMMING DETAIL

C6.4 *The panels should be designed to carry the loads from the bearing pads. This can best be done using strut-and-tie approaches (see ACI 318-02.)*

6.5 GROUTING OF THE BASE

After panels have been finally plumbed, the base of the panel and any dowel pockets shall be fully grouted unless otherwise stated on the drawings. Grouting and appropriate strength gain shall take place before any formwork is removed from beams or slabs supported by a panel.

C6.5 *The designer should be aware that the weight of the panel, and any loads applied to it before grouting, would be applied to the supporting structure at two discreet points where the levelling shims are located.*

SECTION 7 INCORPORATION INTO FINAL STRUCTURE

7.1 FIXING TO FINAL STRUCTURE

The fixing of the panels shall be in accordance with the structural drawings, shop drawing and other design documentation. Braces shall not be removed until the panel is incorporated into the structure and the structure is capable of supporting the panel for the applied loads.

C7.1 *Incorporation into the structure would include dowel pockets being grouted and cured before removal of the braces.*

7.2 INSPECTION PRIOR TO REMOVAL OF BRACES

Prior to the removal of braces, the structure shall be inspected to ensure that all structural elements affecting stability are securely fixed to the panels.

C7.2 *The inspection is usually carried out by the designer or an authorized agent and written approval to remove braces given to the builder.*

7.3 REMOVAL OF BRACES

The removal of braces from a panel shall be planned and conducted in a controlled manner to prevent risk of injury to people and damage to equipment. Braces to be removed from site shall be loaded in such a manner as to allow safe transport.

APPENDIX A

TESTING OF MATERIALS AND COMPONENTS USED WITH TILT-UP PANELS

(Normative)

A1 SCOPE

This Appendix sets out requirements for the testing of materials and components used with tilt-up panels.

General requirements for all testing, certification and test reports are given in Paragraph A3. Destructive testing is covered in Paragraph A4 and sample testing in Paragraph A5. The certification requirements and details to be reported with these tests are described.

A2 CONCRETE TESTING

Where concrete strength or other concrete properties are referred to in this Appendix, these shall be determined in accordance with the requirements of the appropriate Parts of AS 1012.

Concrete used to construct test elements shall comply with the requirements of AS 1379.

A3 TESTING OF COMPONENTS AND SYSTEMS

A3.1 General

Because of the mode in which failure can occur, it may be necessary to test complete systems and not calculate values obtained from the group of components that make up the system. The mode of failure of an individual component does not necessarily reflect the mode of failure of the system.

The arrangement for the application of the test load(s) shall be made to simulate the field use of the component or system.

A3.2 Test reports

Test reports shall be provided for all tests. The reports shall be clearly identified by title, description and report number, and provide the following information:

(a) The purpose of the test.

(b) The location of the testing facility.

(c) The date, time and environmental conditions at the time of the test.

(d) A detailed description of the component or system being tested, providing identification of the specific type of component or system and including, where appropriate, date of manufacture, batch number, etc.

(e) A detailed description of the test arrangement.

(f) A detailed description of the test procedure.

(g) Names, positions and qualifications of personnel carrying out or supervising the test.

(h) Names, positions and qualifications of witnesses, if any, to the test.

(i) The results of the test, covering the following, where relevant:

   (i) The load at failure in the case of destructive testing.

(ii) Description of the progress of the test including mode of failure and any permanent deformations.

(iii) Details of load deformation curves so proportioned that if there has been any discontinuity or considerable departure from linearity during the progress of increasing the loads then this will be clearly evident.

(iv) Strength limit state load capacity and WLL.

(v) Any other relevant information such as signs of distress prior to failure.

(j) The number of this Australian Standard, i.e., AS 3850.

A4 DESTRUCTIVE TESTING

A4.1 General

In addition to the general requirements set out in Paragraph A3, the specific requirements set out in Paragraphs A4.2, A4.3, A4.4, A4.5, A4.6 and A4.7 shall also apply.

A4.2 Principle

Destructive methods involve tests on a prototype component or on a sample of components or systems tested by the application of load(s) until the component fails. For the purpose of this test, failure of a component or system is deemed to have occurred when it is unable to carry the applied load(s) or when the test is terminated.

The strength limit state capacity shall be determined by a statistical analysis from the test results in accordance with Paragraph A4.5. The test results may be used as the basis of acceptance of all components of systems and population from which the prototype test components were taken.

A4.3 Sample size

A random sample shall be selected from the population and may be of any size. Although no limitation is placed on the sample size, attention is drawn to the sampling factor (k_s) (see Table A2) which reduces as the sample size increases.

NOTE: It is recommended that a minimum sample size of three be used.

A4.4 Test data

Comparable test data shall comprise data from current tests and any previous test reports.

A4.5 Analysis of test data

A4.5.1 *General*

After the completion of the destructive tests, the mean of the accumulated sample (x) shall be calculated. The coefficient of variation shall be determined in accordance with Paragraph A4.5.2 or A4.5.3, as appropriate.

A4.5.2 *Sample size less than 30*

For an accumulated sample size of less than 30, comprising current tests plus previous test results, the coefficient of variation (V) shall be that taken from Table A1.

TABLE A1

RECOMMENDED VALUE OF COEFFICIENT OF VARIATION (V)

Member	Value of coefficient of variation
Compression members	0.15 for steel
Tension members	0.10 for steel
Flexural members	0.10 for steel
Connectors	0.05 for steel
Inserts	0.05 for steel 0.10 for concrete

A4.5.3 *Sample size of 30 or more*

For an accumulated sample size of 30 or more, comprising current tests plus previous test results, the coefficient of variation (V) shall be calculated by the following equation:

$$V = \frac{100s}{x} \qquad \text{. . . A4.5.3}$$

where

$$s = \sqrt{\sum_{i=1}^{n} \frac{(x_i - x)^2}{n-1}}$$

and

V = coefficient of variation for the failure load of the components

x = mean value of the test results of the accumulated sample of components

s = standard deviation of a finite population of components tested to destruction

n = accumulated sample size or total number of components tested to destruction

x_i = test result of each individual component of the sample

A4.6 Calculation of strength limit state capacity (ϕR_u)

The strength limit state capacity ϕR_u shall be calculated from the following equation:

$$\phi R_u = \frac{x}{k_s} \qquad \text{. . A4.6}$$

where

ϕR_u = strength limit state capacity

x = mean value of test data (Paragraph A4.4)

k_s = sampling factor, from Table A2

In the determination of the sampling factor, a value for the coefficient of variation is required to be determined in accordance with Paragraph A4.5.2 or A4.5.3.

TABLE A2

SAMPLING FACTOR (k_s)

Sample size	Value of sampling factor (k_s) — Coefficient of variation of the strength of components					
	0.05	**0.10**	**0.15**	**0.20**	**0.30**	**0.40**
1	1.3	1.5	1.9	2.2	3.3	4.8
2	1.3	1.5	1.7	2.0	2.7	3.6
3	1.3	1.4	1.6	1.8	2.4	3.2
4	1.3	1.4	1.6	1.7	2.2	2.8
5	1.2	1.3	1.5	1.6	2.1	2.6
10	1.2	1.3	1.4	1.5	1.7	2.0
30 or more	1.1	1.1	1.2	1.2	1.2	1.3

NOTE: For intermediate coefficients of variation, use linear interpolation.

A4.7 Use of components and systems subject to destructive testing

Components and portions of systems subject to destructive testing shall not be used again.

A5 SAMPLE TESTING

A5.1 General

In addition to the general requirements set out in Paragraph A3, the specific requirements set out in Paragraphs A5.2, A5.3, A5.4 and A5.5 shall also apply. When testing is being carried out to confirm the standard of manufacture of a component or system, it shall be done in accordance with sample evaluation as set out in Paragraph A5.4.

A5.2 Principle

The sample testing involves the testing by load application of all or part of a population of components or systems. The magnitude of the testing load or loads shall be determined in accordance with Paragraph A5.4.

The acceptance criterion is that the tested component or system shall be capable of withstanding the applied test load(s) without signs of failure.

For the purpose of this test, failure of a component or system is deemed to have occurred when it is unable to carry the applied load(s), exhibits permanent deformation or when the deflection is greater than the serviceability limit.

A5.3 Sample size

Where the number of components to be tested (the sample) is equal to the total number of components under test (the population), the test procedure shall be known as proof testing. Where the sample is less than the population, the testing procedure shall be known as sample evaluation.

A5.4 Test load

The test load, or loads, as appropriate, shall be calculated from the following equation:

$$S_t = k_s S^* \qquad \text{. . . A5.4}$$

where

S_t = the test load

k_s = sampling factor, given in Table A2. The coefficient of variation may be obtained from Table A1. Alternatively, where destructive tests have been previously carried out on components or systems of the same type in numbers adequate to enable calculation of the coefficient of variation in accordance with Paragraph A4.5.3, the calculated value may be used

S^* = strength limit state load obtained from Items (i) and (ii) below, as appropriate:

(i) The loads specified in Clause 2.1

(ii) The strength limit state capacity (ϕR_u) derived from previous destructive tests (carried out in accordance with Paragraph A4.6) on production run components or systems that are similar to those that are subject to these tests

A5.5 Evaluation of test results

Where all of the components or systems tested sustain the test load(s) without signs of failure or excessive distortion, they shall be deemed to have passed this test.

In sample evaluation, if a component or system fails to sustain the test load(s) and only if it is clear that the failure of this unit was for a reason other than faulty design or construction, a further two units may be tested. The test load for those further tests shall be the same as that used for the test that failed. Only if both additional units satisfactorily sustain the test load(s) shall all remaining units be deemed to be satisfactory. If there are any further failures, that batch shall be deemed to have failed.

A6 ADDITIONAL REQUIREMENTS FOR TESTING MATERIALS OF LIFTING INSERTS

A6.1 General

In addition to the general requirements set out in Paragraph A3, lifting inserts shall also be tested as follows:

(a) Ductility testing of component material—the standard V-notch Charpy test in accordance with AS 1544.2.

(b) Ductility testing of manufactured component—to ensure the impact resistance has not been affected by the method of fabrication.

A6.2 Apparatus

The apparatus used for the testing of these components is as follows:

(a) The lifting clutch specified for use with the appropriate insert.

NOTE: An alternative lifting clutch may be used provided the section in contact with the insert has identical dimensions and shape to the device specified for use with the insert.

(b) Component testing, as follows:

(i) Apparatus for carrying out the standard V-notch Charpy test as specified in AS 1544.2.

(ii) A system capable of applying a destructive load to the insert using a minimum crosshead travel speed of 20 mm per minute.

(iii) A system capable of establishing the fibrosity of the component fracture as specified in AS 1544.5.

A6.3 Procedure

A6.3.1 *Charpy V-notch test*

The Charpy V-notch test shall be carried out in accordance with AS 1544.2.

A6.3.2 *Manufactured component*

The procedure for testing the ductility of the manufactured component is as follows:

(a) Connect the lifting clutch to the insert.

(b) Using a minimum crosshead travel speed of 20 mm per minute, apply the load to the insert until failure occurs.

(c) Examine the failure surface of the insert as set out in AS 1544.5 to establish the fibrosity of the surface.

A7 ADDITIONAL REQUIREMENTS FOR TESTING PULL-OUT CAPACITY OF LIFTING INSERTS

A7.1 General

In addition to the general requirements set out in Paragraph A3, the pull-out capacity of lifting inserts embedded in concrete shall be tested as set out in Paragraphs A7.2 and A7.3.

These requirements shall be applied only to inserts where the full shear cone can be developed.

NOTE: Test methods for edge inserts and inserts located close to edges of concrete should be agreed between the manufacturer and the testing authority.

A7.2 Specimen

The specimen for testing the insert shall be prepared as follows:

(a) The minimum distance to any edge, support, discontinuity or parts of the test apparatus bearing on the concrete surface shall be sufficient to allow the development of a full shear cone.

(b) The insert shall be embedded to the depth specified in the manufacturer's documentation (see Clause 2.9).

(c) The compressive strength of the concrete at the time of test shall be as specified for lifting and shall not be less than 10 MPa.

A7.3 Procedure

The procedure shall be as follows:

(a) Restrain the specimen outside the assumed failure shear cone.

(b) Connect the appropriate lifting device to the insert.

(c) Apply the load at a uniform rate until failure occurs.

(d) Record the load at failure.

(e) Calculate the load capacity as set out in Paragraph A4.6.

A8 ADDITIONAL REQUIREMENTS FOR BRACE INSERTS

A8.1 General

In addition to the general requirements set out in Paragraph A3, the strength capacity of the brace fixing shall be tested as set out in Paragraphs A8.2 to A8.4 as appropriate.

Tests shall be conducted using installation procedures issued by the anchor supplier. Details of the procedure, including type and grade of bolts used in inserts, shall be recorded.

A8.2 Testing parameters for expansion anchors to be used as brace inserts

A8.2.1 *General*

The WLL of panel brace fixings shall be determined by measuring the residual preload in tension 14 days after setting into 20 ±2 MPa concrete. The anchors are then loaded in tension until failure, and the characteristic ultimate tensile capacity calculated from the results.

A8.2.2 *Setting information*

The anchor supplier shall, as a minimum, state the hole size, minimum embedment depth and setting torque of the anchor.

A8.2.3 *Setting*

Hole diameter shall be the nominal drill bit diameter +0.3 mm to +0.4 mm. The anchor shall be inserted into the hole in the concrete through a fixture. The fixture shall be a 20 mm thick × 100 mm diameter steel cylinder with a hole in the centre with a diameter equal to the nominal outer diameter of the anchor +2 mm to +4 mm. The fixture shall be fitted with a 16 mm diameter × 100 mm long handle extending radially from its upper surface. A steel sheet with minimum thickness 0.5 mm, hot-dip zinc coated to AS 1397, with the same dimensions as the fixture, shall be inserted between the steel fixture and the concrete. Ensure that the fixture does not rotate while the anchor is being tightened.

The anchor shall remain undisturbed for a period not less than 14 days from the date of installation.

A8.2.4 *Sample size*

A minimum of 10 anchors shall be tested.

A8.2.5 *Test method*

Anchors shall be loaded after 14 days to remove the residual preload. Preload is equalized when the fixture plate can be rotated by application of a load of 1 kg to the end of the handle. The load required to equalize the clamping force shall be recorded as the 'residual clamping load'. The anchors shall then be tested to failure.

A8.2.6 *Expansion anchors*

Expansion anchors shall be tested to determine the first slip load. The procedure shall be as follows:

(a) Install the anchor in accordance with the manufacturer's recommendations, paying particular attention to the correct drilling of holes and the correct installation torque.

(a) Progressively apply the load until the fixing has moved 0.1 mm.

(b) Record this load as the first slip load.

A8.2.7 *Cast-in helical wire coil fixings*

The load capacity of helical wire coil fixings shall be determined with the brace-fixing bolt in the engagement position, applying the load through the bolt.

A9 ADDITIONAL REQUIREMENTS FOR TESTING BRACES

A9.1 General

In addition to the general requirements set out in Paragraph A3, the strength capacity of braces shall be tested as set out in Paragraph A9.2.

A9.2 Procedure

All tests shall be carried out in accordance with Paragraph A4 with the brace feet inclined at an angle to simulate in-service conditions. Testing shall include the following:

(a) Testing in tension and compression.

(b) The incorporation of all accessories normally used in the bracing system, particularly when the brace is intended to be used together with lateral and knee bracing.

(c) Where telescopic braces are used without further support, testing at—

  (i) maximum and minimum extensions; and

  (ii) three intermediate and equally spaced extensions.

A10 ADDITIONAL REQUIREMENTS FOR TESTING LEVELLING SHIMS

A10.1 General

In addition to the general requirements set out in Paragraph A3, the compressive strength of levelling shims shall be tested as set out in Paragraphs A10.2 to A10.5.

A10.2 Specimen

The specimen shall consist of either a prism 13 mm × 13 mm × 2 mm or a cylinder with a diameter of 13 mm and a length of 26 mm.

A10.3 Conditioning

The specimen shall be conditioned in accordance with ASTM D618, Procedure A.

A10.4 Procedure

The compression test shall be in accordance with ASTM D695.

A10.5 Expression of results

The compressive strength of the material shall be calculated as the stress in megapascals required to either rupture or deform the specimen at a given percentage of its height. The compressive strength is then expressed as the stress in megapascals either at rupture or the specified deformation.

APPENDIX B

MEANS FOR DEMONSTRATING COMPLIANCE WITH THIS STANDARD

(Informative)

B1 SCOPE

This Appendix sets out the following different means by which compliance with this Standard can be demonstrated by the manufacturer or supplier:

(a) Evaluation by means of statistical sampling.

(b) The use of a product certification scheme.

(c) Assurance using the acceptability of the supplier's quality system.

(d) Other such means proposed by the manufacturer or supplier and acceptable to the customer.

B2 STATISTICAL SAMPLING

Statistical sampling is a procedure which enables decisions to be made about the quality of batches of items after inspecting or testing only a portion of those items. This procedure will only be valid if the sampling plan has been determined on a statistical basis and the following requirements are met:

(a) The sample needs to be drawn randomly from a population of product of known history. The history needs to enable verification that the product was made from known materials at essentially the same time, by essentially the same processes and under essentially the same system of control.

(b) For each different situation, a suitable sampling plan needs to be defined. A sampling plan for one manufacturer of given capability and product throughput may not be relevant to another manufacturer producing the same items.

In order for statistical sampling to be meaningful to the customer, the manufacturer or supplier needs to demonstrate how the above conditions have been satisfied. Sampling and the establishment of a sampling plan should be carried out in accordance with AS 1199, guidance to which is given in AS 1399.

B3 PRODUCT CERTIFICATION

The purpose of product certification is to provide independent assurance of the claim by the manufacturer that products comply with the stated Standard.

The certification scheme should meet the criteria described in HB 18.28 in that, as well as full type testing from independently sampled production and subsequent verification of conformance, it requires the manufacturer to maintain effective quality planning to control production.

The certification scheme serves to indicate that the products consistently conform to the requirements of the Standard.

B4 SUPPLIER'S QUALITY MANAGEMENT SYSTEM

Where the manufacturer or supplier can demonstrate an audited and registered quality management system complying with the requirements of the appropriate or stipulated Australian or international Standard for a supplier's quality management system or systems, this may provide the necessary confidence that the specified requirements will be met. The quality assurance requirements need to be agreed between the customer and supplier and should include a quality or inspection and test plan to ensure product conformity.

Information on establishing a quality management system is set out in AS/NZS ISO 9001 and AS/NZS ISO 9004.

B5 OTHER MEANS OF ASSESSMENT

If the above methods are considered inappropriate, determination of compliance with the requirements of this Standard may be assessed from the results of testing coupled with the manufacturer’s guarantee of product conformance.

Irrespective of acceptable quality levels or test frequencies, the responsibility remains with the manufacturer or supplier to supply products that conform to the full requirements of the Standard.

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NOTES

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