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AS 3610.1:2018

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Formwork for concrete

Part 1: Specifications



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 - Australian Industry Group
 - Australian Steel Institute
 - Concrete Institute of Australia
 - Concrete Masonry Association of Australia
 - Consult Australia
 - Engineered Wood Products Association of Australasia
 - Engineers Australia
 - Forest and Wood Products Australia
 - Master Builders Australia
 - National Precast Concrete Association Australia
 - SafeWork NSW
 - University of Sydney
-

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Australian Standard®

Formwork for concrete

Part 1: Specifications

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PREFACE

This Standard was prepared by the Standards Australia Committee BD-043, Formwork, to supersede, in part, AS 3610.1—2010, *Formwork for concrete, Part 1: Documentation and surface finish*.

The objective of this Standard is to set out requirements for the specification and documentation of architectural, structural and construction information necessary for formwork design and construction. This Standard also sets out requirements for documentation of formwork designs and information on proprietary formwork. It also sets out the requirements for the assessment and evaluation of completed surface quality and repairs.

The full review of AS 3610 series is in progress and therefore it was considered appropriate to issue the Standard in two Parts:

- (a) AS 3610.1, *Formwork for concrete, Part 1: Formwork specification* (this Standard), focuses on surface finish and covers various types of documentation applicable to formwork. This Part was revised and published in 2010. This latest revision includes relevant commentary clauses from AS 3610 Supplement 2—1996 *Formwork for concrete—Commentary*
- (b) AS 3610.2, will cover aspects of formwork and falsework design, construction and testing, including Section 4 of AS 3610.1—2010.

NOTE: At the time of publication, this Standard is still under review.

AS 3610.2, AS 3610—1995 and AS 3610.1 will coexist. Sections 2, 3 and 5 in this Standard (AS 3610.1) supersede Sections 2 and 3, as well as Clauses 4.7 and 5.6 of AS 3610—1995.

Statements expressed in mandatory terms in notes to tables are deemed to be requirements of this Standard.

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.

This Standard incorporates commentary on some of the Clauses. 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 only and does not form part of this Standard.

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STANDARDS AUSTRALIA**Australian Standard
Formwork for concrete****Part 1: Specifications****SECTION 1 GENERAL****1.1 SCOPE**

This Standard sets out—

- (a) the requirements for the documentation of architectural, structural and construction information necessary for formwork design and construction;
- (b) architectural requirements and procedures covering the specification of the quality, tolerance, colour, and evaluation of off-form or as-repaired in situ or precast concrete surfaces; and
- (c) structural requirements that—
 - (i) are critical to the stability, strength and serviceability of the permanent structure during construction and once completed; and
 - (ii) affect the formwork design and construction.

This Standard does not apply to unformed surfaces. The requirements in this Standard apply to plain concrete surfaces left off-form or prior to application of surface treatment or coating. This Standard does not cover the specification of textured finishes, surface treatment, coatings or paint.

1.2 APPLICATION

Project, construction, formwork and proprietary documentation shall conform with Section 2.

The physical quality, colour control, evaluation and repairs of the concrete surface, as well as test panels, shall conform with Section 3.

Structural requirements for limitations on construction loads, multistorey shoring, minimum stripping times and procedures, construction sequence and other specific information are set out in Section 4.

Appendix A provides formwork importance levels in different situations.

Appendix B provides blowhole photographs which are intended for use in the evaluation of completed work.

Appendix C provides guidance on the documentation of formwork stripping times.

Appendix D provides general commentary on Section 3.

Appendix E provides an informative glossary of terms.

1.3 NORMATIVE REFERENCES

The following are normative documents referenced in this Standard.

AS

3600 Concrete structures

3610 Formwork for concrete

1.4 ALTERNATIVE CONCEPTS AND MATERIALS

Alternative concepts, materials, designs, methods of assembly and procedures, which are not mentioned in this Standard, may be used provided it can be demonstrated that the resulting formwork conforms to the requirements specified in this Standard.

1.5 DEFINITIONS

For the purpose of this Standard, the definitions below apply.

NOTE: For guidance and informative purposes, a glossary of terms is listed in Appendix E.

1.5.1 Administrative definitions

1.5.1.1 *Acceptable*

Conforms with the criteria set out in this Standard.

1.5.1.2 *Back form*

A form for a concrete surface that is totally concealed in the finished structure.

1.5.1.3 *Bearer*

Part of soffit form framing. A primary member supported on formwork supports or hangers and carrying joists.

1.5.1.4 *Cantilever forms*

Forms that are solely supported by anchors embedded in the exposed face of previously placed concrete.

1.5.1.5 *Competent person*

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

1.5.1.6 *Construction documentation*

Documents that set out information on the planned construction method for the permanent structure, which are required for the formwork design and construction.

1.5.1.7 *May*

Indicates the existence of an option.

1.5.1.8 *Project documentation*

Drawings, specifications and associated documents that set out the information required for the construction of the permanent structure.

1.5.1.9 *Proprietary documentation*

Brochures, catalogues, drawings, specifications and associated documents that detail proprietary formwork.

1.5.1.10 *Shall*

Indicates that a statement is mandatory.

1.5.1.11 *Should*

Indicates a recommendation.

1.5.1.12 *Soldier*

Part of a side form. A vertical primary member supported by form ties or form bracing.

1.5.1.13 *Waler*

Part of a side form, either—

- (a) a horizontal primary member supported by form ties or form bracing; or
- (b) a horizontal secondary member.

1.5.2 **Technical definitions****1.5.2.1** *Action*

Set of concentrated or distributed forces acting on a structure (direct action), or deformation imposed on a structure or constrained within it (indirect action).

NOTE: The term 'load' is also often used to describe direct actions.

1.5.2.2 *Backpropping*

A process by which adjustable supports are placed to give support to the cast in situ concrete during the removal of the soffit formwork, which may also remain in position to act as multistorey shoring (see Figure 1.5.2.2).

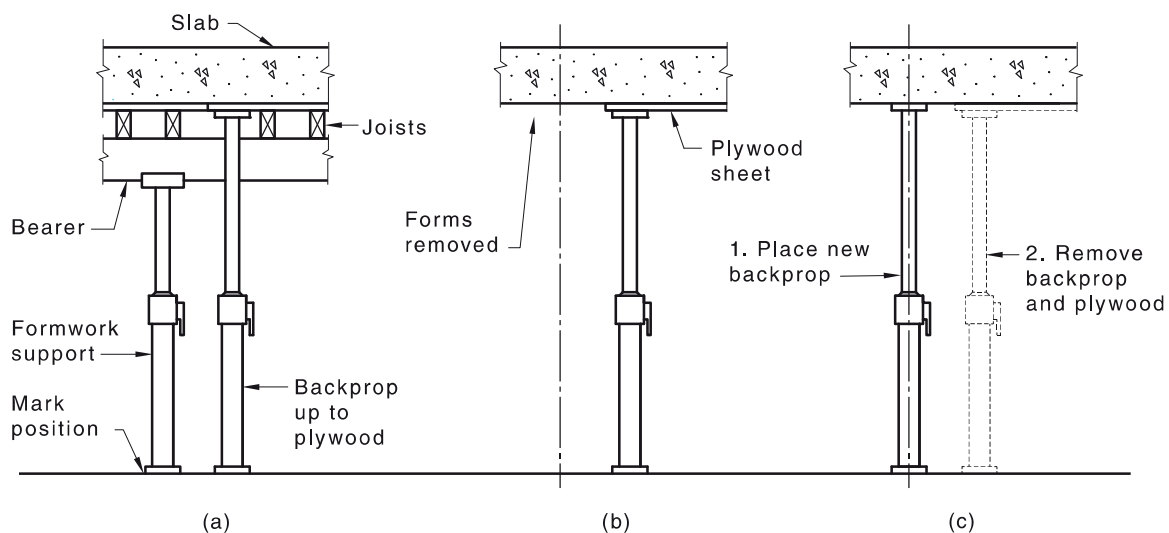


FIGURE 1.5.2.2 EXAMPLE OF BACKPROPPING

1.5.2.3 *Blowhole*

Shallow pocket or void in the formed surface of the concrete caused by a bubble of fluid or air trapped against the form face.

1.5.2.4 *Bracing*

Members that normally do not support gravity loads but are required to provide lateral stability or restraint to other members or to transfer horizontal actions to anchorage or reaction points.

1.5.2.5 *Camber*

The intentional curvature of formwork prior to concrete placement to compensate for the deflection of the formwork or element under load.

1.5.2.6 *Cast in situ concrete*

Concrete that is placed, as plastic concrete, in its final location.

1.5.2.7 *Class of surface finish*

Standard of the untreated concrete surface of the formed concrete.

NOTE: Also known as 'class'.

1.5.2.8 *Colour control*

The limitation of tonal range of cast in situ concrete and precast concrete.

1.5.2.9 *Component*

A structural member.

1.5.2.10 *Construction joint*

A joint, including a joint between precast segments, that is located for the convenience of construction.

1.5.2.11 *Deflection*

Flexural movement of a structural member or assembly in response to the forces acting on it.

1.5.2.12 *Design service load*

The permanent and imposed loads for which the design of the permanent structure is based.

1.5.2.13 *Deviation*

The divergence from the specified position.

1.5.2.14 *Element*

That concrete portion of the permanent structure defined by the formed concrete faces, mandatory joints, construction joints and the completed concrete surfaces, which is cast in one continuous operation.

1.5.2.15 *Falsework*

A part of the formwork that supports the form and transfers all the loads to a stable surface(s) prior to, during and following concrete placement.

1.5.2.16 *Flatness*

The variations in the formed surface resulting from movement of the formwork.

1.5.2.17 *Footing*

A part of the falsework in direct contact with, and transmitting load to, the supporting foundation.

NOTE: A footing may be purpose built, such as a simple sole plate, concrete footing or pile. Alternatively, an element may be used as a footing.

1.5.2.18 *Form*

A part of the formwork that contains and moulds the cast in situ concrete to the required dimensions.

NOTE: This includes the form face and framing.

1.5.2.19 *Form face*

That part of the form which comes in direct contact with the plastic concrete.

1.5.2.20 *Form face deflection*

The undulation of the concrete surface resulting from the deflection of the form face between members of the framing.

1.5.2.21 *Form liner*

Non-structural material placed on, or part of, the form face to achieve a desired surface finish.

NOTE: Also known as 'form lining'.

1.5.2.22 *Form tie*

A device that penetrates the formwork, extends through the void for the cast in situ concrete and restrains the formwork movement due to concrete pressure.

NOTE: Also known as 'wall tie' or 'tie rod'.

1.5.2.23 *Formwork*

Temporary works erected to mould and support cast in situ concrete.

NOTE: This consists of a form and, where appropriate, falsework, form bracing and form ties.

1.5.2.24 *Foundation*

Soil, subsoil or rock, whether built up or natural, upon which the permanent structure or the formwork is supported.

1.5.2.25 *Frame*

A falsework component assembled from three or more pieces into a planar unit.

1.5.2.26 *Framing*

Part of the form consisting of primary members and secondary members that support the form face.

1.5.2.27 *Grout loss*

The loss of fine material, cement and fine aggregate, from plastic concrete due to openings in the form face.

NOTE: Also known as 'mortar loss'.

1.5.2.28 *Honeycombing*

Voids in concrete caused by the mortar not filling the spaces between the coarse aggregate particles.

1.5.2.29 *In situ concrete*

Concrete which is placed in its final location in the permanent structure.

1.5.2.30 *Limit state*

A state beyond which the structure no longer satisfies the design performance requirements.

NOTE: Limit state separate desired state (no failure) from undesired state (failure).

1.5.2.31 *Mandatory joint*

A joint specified in the project documentation.

1.5.2.32 *Permanent form*

A form that it is not stripped.

NOTE: Examples of permanent forms include horizontal precast concrete elements and profiled steel sheeting.

1.5.2.33 *Permanent structure*

The subject of the project documentation.

1.5.2.34 *Plastic concrete*

Concrete that has not yet achieved an initial set.

1.5.2.35 *Precast concrete*

A concrete element produced in a location other than its final location in the permanent structure.

NOTE: Also known as a 'prefabricated concrete element'.

1.5.2.36 *Primary members*

Framing members that directly support the secondary members, e.g. soldiers, bearers, beams.

1.5.2.37 *Prop*

A structural member designed to be loaded in compression.

1.5.2.38 *Proprietary formwork*

Multiple-use or mass-produced formwork systems and/or components.

1.5.2.39 *Release agent*

A substance applied to the form face or form liner surface to prevent bonding of the fresh concrete to the form face or form liner and minimize blowholes.

1.5.2.40 *Reshoring*

The complete stripping and removal, or relaxation, of the soffit forms and formwork supports so that the concrete structure supports itself followed by the immediate installation or resetting of adjustable supports (reshores), which may also remain in position to act as multistorey shoring.

NOTE: See Figure 1.5.2.40.

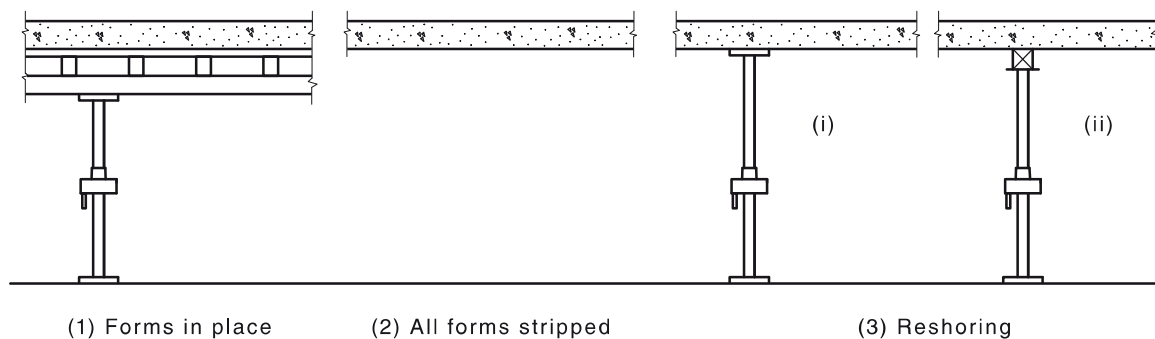


FIGURE 1.5.2.40 EXAMPLE OF RESHORING

1.5.2.41 *Secondary members*

Framing members that directly support the form face, e.g. joists and walers.

1.5.2.42 *Serviceability limit state*

A limit state of acceptable in-service condition.

1.5.2.43 *Single-use formwork*

Formwork components or systems that are used one.

1.5.2.44 *Soffit formwork*

Formwork for the undersides of slabs, beams, and other similar structural members.

1.5.2.45 *Stacked materials*

Construction materials, such as formwork, bricks and reinforcement, that temporarily load either the formwork or the previously placed concrete.

1.5.2.46 *Strain movement*

Any forced change in the position or dimension of the permanent structure.

1.5.2.47 *Strength limit state*

A limit state of collapse or loss of structural integrity.

1.5.2.48 *Stripping*

The removal of formwork from the surface of the hardened concrete.

NOTE: Also known as 'striking'.

1.5.2.49 *Structural reinforcement*

Reinforcement, including reinforcing steel and prestressed tendons, provided for crack control or to resist forces caused by design service loads and thermal and shrinkage movements.

1.5.2.50 *Supports*

The falsework members that transmit all or part of the loads to a lower level.

NOTE: This term includes multistorey supports for undisturbed shoring reshoring.

1.5.2.51 *Surface finish*

The texture and smoothness of a surface of hardened concrete where the plastic concrete has been shaped by a form face.

1.5.2.52 *Surface treatment*

The removal of a specified depth of the concrete of the permanent surface by a nominated chemical or mechanical means such as acid etching, sand blasting or jack picking.

NOTE: This does not include applied finishes such as coatings or paint.

1.5.2.53 *Surface undulation*

The undulation of the concrete surface resulting from the aggregation of form face deflection, framing deflection and the aggregation of errors in setting, movement of support points and material dimensional tolerances.

1.5.2.54 *Test panel*

A concrete element constructed, prior to the commencement of construction of the permanent structure, as an example of materials and quality of work.

1.5.2.55 *Tolerance*

Permitted variation in dimension.

1.5.2.56 *Tonal range*

The graded set of grey tones provided in this Standard, or specified in the project documentation when special-class concrete is used, for evaluation of the colour of the concrete surface.

1.5.2.57 *Undisturbed shoring*

Undisturbed supports or backpropping that remain in position and prevent the concrete structure from supporting itself.

1.5.2.58 *Undisturbed support*

A support that, as part of a soffit formwork, remains undisturbed until that part of in situ concrete structure is strong enough to support itself even though the soffit form may have been removed earlier.

NOTES:

- 1 See Figure 1.5.2.58.
- 2 The support may also remain in position to act as multistorey shoring.

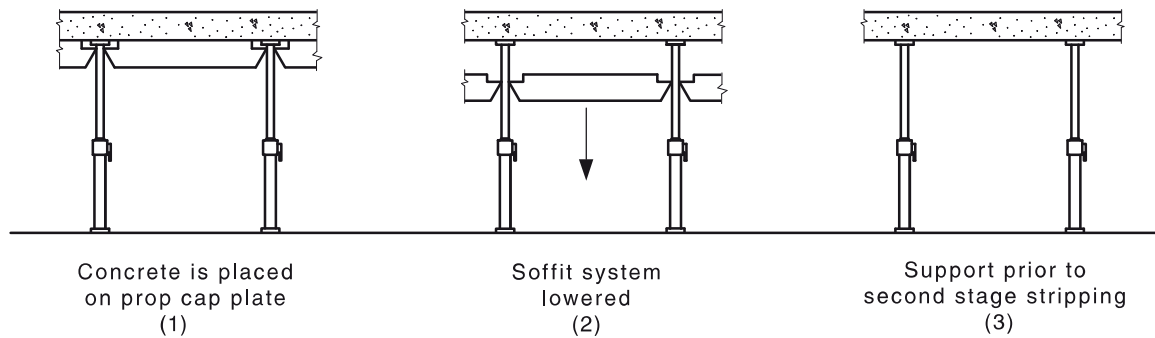


FIGURE 1.5.2.58 EXAMPLE OF UNDISTURBED SUPPORT

1.5.2.59 *Working load limit (WLL)*

The maximum unfactored load that may be applied to an item, component or system calculated in accordance with AS 3610.

NOTE: This is an unfactored load or capacity and not a strength limit states load or capacity.

1.5.2.60 *Working platform*

A platform used to provide a working area to support persons and their materials and equipment.

1.5.2.61 *Wrecking strip*

A small strip of formwork that is destroyed to facilitate stripping.

SECTION 2 DOCUMENTATION

2.1 SCOPE OF SECTION

The project and construction documentation includes all the information about the permanent structure and its construction necessary to design, construct and strip the formwork, as well as information necessary to evaluate and repair the finished concrete surface.

The formwork and proprietary documentation includes additional information necessary to design, construct and/or strip the formwork.

The information to be specified in the—

- (a) project documentation is given in Clause 2.2;
- (b) construction documentation is set out in Clause 2.3;
- (c) formwork documentation is set out in Clause 2.4; and
- (d) proprietary documentation is set out in Clause 2.5.

C2.1 In general, documentation could comprise drawings, written specifications, photographs, brochures, technical data and calculations, as well as written or even verbal instructions. Documentation may be the compilation of information from different sources.

2.2 PROJECT DOCUMENTATION

2.2.1 General

The project documentation shall meet the requirements of Sections 3 and 4, as well as include specific requirements for the project that are achievable including—

- (a) details of the concrete elements and any conditions relating to production;
- (b) architectural requirements for the concrete surface quality, dimensional tolerance, colour control and test panels; and
- (c) structural requirements matters that—
 - (i) are critical to the stability, strength and serviceability of the permanent structure during construction and once completed; and
 - (ii) affect the formwork design and construction.

NOTES:

- 1 For particular projects, the requirements of Clause 2.2 may be insufficient and many other aspects may require attention.
- 2 Preparing the project documentation often requires co-operative effort involving all participants, e.g. achieving a high quality of surface finish or specifying multistorey shoring.

The activities of the formwork construction can have a far-reaching effect on the safety and serviceability of the permanent structures, therefore, attention is drawn to the need to review the formwork documentation to ensure it meets the requirements of the project documentation.

C2.2.1 The purpose of the project documentation is to ensure that all necessary requirements are fully and accurately communicated to those concerned with the design, construction and stripping of the formwork.

2.2.2 General information

The project documentation shall include the following information:

- (a) Plans, elevations and sections showing details and dimensions of the elements to be formed.
- (b) Details of any inserts, waterstops, special purpose form ties, specially formed shapes, or penetrations to be constructed, that are critical to the serviceability of the permanent structure.
- (c) Information on specified concrete ingredients or admixtures that may affect the concrete finish by, but not limited to—
 - (i) retarding or accelerating the setting time of the concrete including artificial heating or cooling;
 - (ii) causing excessive blow holes on the surface of the concrete; and
 - (iii) increasing colour or tonal variability.
- (d) Structural details consistent with the architectural requirements.

2.2.3 Architectural information

The project documentation shall include the following information, where applicable:

- (a) Identification of class of surface finish:
 - (i) The class of surface finish and if colour control is applicable for the formed face of each element in the notation format as required under Clause 3.2.2 and as applicable under Clause 3.2.3.
 - (ii) The details set out in Table 2.2.3 relating to surface finish, colour control, critical elements, tolerances and repairs, where relevant, for all surfaces of the permanent structure.
 - (iii) Where an 'X' suffix is used as permitted in Clause 3.2, all relevant information relating to—
 - (A) any additional feature not covered by this Standard; or
 - (B) the relaxation of the requirements of this Standard (see Table 3.3.3.1 Row 3, Table 3.3.5.1, Clause 3.3.3.2(b) and Clause 3.5.2).
- (b) Physical quality:
 - (i) Critical face of elements (see Clause 3.3.2).
 - (ii) Concrete surfaces where light shines across the surface at a flat angle, particularly in the case of smooth glossy finishes (see Clause 3.3.4.1).
 - (iii) If the requirements for Class 2 are relaxed to permit the use of modular panel frames that leave imprints in the concrete surface (see Table 3.3.3.1 Row 3).
 - (iv) Where tolerances in AS 3600 govern because they are more stringent than those specified in this Standard (see Clause 3.3.5).
 - (v) Any special measuring points and small areas where more stringent tolerance values than those given in Table 3.3.5.1 apply (see Clause 3.3.5.1).
 - (vi) Permitted tolerances and methods of evaluation for the surface finish of curved. Irregular or unusual surfaces or shaped elements equivalent to the requirements specified in Clause 3.3 for straight surfaces and regular shaped elements.
 - (vii) Precast concrete panel twist tolerance reference line or surface, if applicable [see Clause 3.3.6.2(c)(iv)].

- (viii) Architectural details to be cast into the concrete (see Table 2.2.3).
- (c) Colour control:
 - (i) Concrete colour.
 - (ii) Details of special-class concrete required under Clause 3.4.2.
 - (iii) If the specified concrete colour is unsuited to the tonal range shown in Figure 3.4.4, a suitable means of representing an equivalent tonal range and gradation shall be specified (see Clauses 3.4.3 and 3.4.4).
 - (iv) Details consistent with the achievement of the specified colour and acceptable tonal range, including stripping time.
 - (v) The concrete age for checking colour control (see Clause 3.4.6).
- (d) Repairs:
 - (i) Any restriction on repairs to Class 1 concrete surfaces (see Clause 3.6.1).
 - (ii) Limitations on the extent of repairs permitted (see Clause 3.6.1).
 - (iii) Acceptable method of repair for unacceptable blow holes, honeycombing and grout loss (see Table 3.3.3.1 and Clause 3.6.2).
 - (iv) Whether or not form ties holes are to be repaired and acceptable method of repair (see Table 3.3.3.1 Item 2 and Clause 3.6.2).
- (e) Test panels:
 - (i) The details set out in Table 2.2.3 relating to test panels.
 - (ii) Construction details of test panels that contain accurate representations of the completed work (see Clause 3.7.3).
 - (iii) Procedures for evaluating the completed work using test panels, where permitted (see Clause 3.7.2).

TABLE 2.2.3
PROJECT DOCUMENTATION REQUIREMENTS
FOR CLASS OF SURFACE FINISH

Details to be provided for	Class 1	Class 2	Class 3	Class 4	Class 5	Reference
1 Test panels, for—						Clause 3.7
(a) untreated surfaces	TBS	TBS	OPT	N/A	N/A	Clause 3.3.8
(b) colour controlled surfaces	TBS	TBS	TBS	N/A	N/A	Clause 3.4.7
(c) repaired surfaces	SIA	TBS	OPT	N/A	N/A	Clause 3.6.4
2 Form face sheet, form face fixing and form tie patterns as well as details	SIA	SIA	OPT	N/A	N/A	N/A
3 Chamfers, drip-grooves and other inlays	SIA	SIA	SIA	SIA	N/A	N/A
4 Form liner details, pattern and accuracy	N/A	SIA	SIA	N/A	N/A	N/A
5 Surface pattern details and accuracy	SIA	SIA	SIA	N/A	N/A	N/A
6 Surface treatment pattern of part of surface	SIA	SIA	SIA	N/A	N/A	Clause 3.5
7 Surface treatment of whole of surface	N/A	SIA	SIA	N/A	N/A	Clause 3.5
8 Form face span and direction of span	OPT	OPT	N/A	N/A	N/A	Table 3.3.3.1
9 Critical faces of elements	SIA	SIA	SIA	SIA	N/A	Clause 3.3.2
10 Face steps	OPT	OPT	OPT	N/A	N/A	Table 3.3.5.1
11 Plumb of elements height >8 m	SIA	SIA	SIA	SIA	SIA	N/A
12 Repairs (see Note)	OPT	ACC	ACC	ACC	ACC	Clause 3.6
13 Colour control	SIA	SIA	SIA	NA	NA	Clause 3.4

LEGEND:

TBS To be specified—these are mandatory project documentation requirements for all work where the particular class of surface finish has been specified

N/A Not applicable—these are matters that are not applicable to the particular class of surface finish

OPT Optional—these are matters that may be included in the project documentation

SIA Specify if applicable—these are mandatory where the particular feature is included in the project documentation

ACC Acceptable—repairs to the particular class of surface finish is acceptable

NOTE: Repairs to a class of surface finish marked ACC shall not be excluded in the project documentation.

C2.2.3 *Class 1 is extremely difficult, time consuming and costly to achieve. Class 1 should not be specified for any situations other than very special features of buildings of a monumental nature. For all other situations requiring the highest quality architectural off-form concrete surface finish, Class 2 should be specified. Where the concrete surface finish is not subject to close scrutiny and viewed as a whole, Class 3 should be specified. See Clause 3.2.3 for further guidance.*

2.2.4 Structural information

The project documentation shall include the following information, where applicable:

- (a) Construction loads (see Clause 4.2):
 - (i) The design service loads for the structure, including any reduction factors incorporated.
 - (ii) Permission to use part of the permanent structure or existing structures to support the formwork as a point of resistance or restraint for the formwork and any limitations that may apply to the magnitude and locations of vertical or horizontal construction loads permitted to be applied in relation to the minimum concrete strength and stiffness to be achieved prior to the application of the loads.
 - (iii) The maximum permitted construction loads that can be applied directly to the structure and any limitations on the location of these loads, e.g. stacked materials.
 - (iv) Information on the magnitude, location and any redistribution of, or change to, the construction loads the formwork shall support; any movements that may occur; and any special formwork provisions necessary as a result of the effects of post-tensioning or prestressing procedures.
- (b) Multistorey shoring (see Clause 4.3).

The method and details of multistorey shoring, the anticipated load distribution between the floors and the assumptions upon which the multistorey shoring design is based.
- (c) Minimum stripping times and procedures (see Clause 4.4).
- (d) Construction sequence (see Clause 4.5):
 - (i) Sequence of construction of concrete elements, if this is critical.
 - (ii) Location and details of any mandatory joints or delayed pour strips.
 - (iii) Details and any special procedures for locating construction joints.
- (e) Specific information (see Clause 4.6):
 - (i) Requirements for any composite construction (see Clause 4.6.2).
 - (ii) Information about any permanent form systems (see Clause 4.6.3).
 - (iii) Information necessary to take account of the effects of concrete shrinkage, creep and axial shortening (see Clause 4.6.4).
 - (iv) Any information about the foundation that is relevant to the support of the formwork or design of the footings for the falsework (see Clause 4.6.5).
 - (v) Guidelines and limitations on the locations of inserts and penetrations that otherwise may impair the safety and serviceability of the permanent structure.
 - (vi) Details of areas where congestion of reinforcement or cast-in items will require modifications to the formwork to ensure correct concrete placement and vibration, e.g. openings for immersion vibrators, provision for external vibration or use of self-consolidating concrete.

2.3 CONSTRUCTION DOCUMENTATION

2.3.1 General

The construction documentation shall conform with the project documentation and set out specific requirements of the planned construction that affect the formwork.

NOTES:

- 1 The purpose of the construction documentation is to ensure that all necessary requirements are fully and accurately communicated to those concerned with the design, construction and stripping of the formwork.
- 2 Attention is drawn to the need to review the formwork documentation to ensure it meets the requirements of the construction documentation.

2.3.2 Documentation

The construction documentation shall include the following, where applicable:

- (a) Details of any anticipated changes to the project documentation.
- (b) Construction method, sequence and schedule.
- (c) Details coordinating building services, assembly of reinforcement and cast-in items.
- (d) Location of construction joints required in addition to those specified in the project documentation.
- (e) Where colour control has been specified:
 - (i) Details and methods to ensure the consistency of raw materials, concrete placement, curing and avoiding visible layers of concrete.
 - (ii) Details of the quality management and supervision procedures for assembly and erection of the formwork, application of release agent, placement of reinforcement, quality of concrete, casting and compacting concrete, stripping formwork, curing and protection of the concrete surface.
- (f) Relevant details of the plant and equipment to be used in the construction.
- (g) Details of the interface between the formwork and other construction equipment and activities.
- (h) The location and weight of all materials to be stored on or supported directly or indirectly by the formwork; including formwork and other construction materials and equipment, as well as building materials, plant and equipment.
- (i) Information on construction activities and constraints that affect the formwork.
- (j) Information on construction loads the formwork supports and any redistribution of loads.
- (k) Details of access, egress and edge protection that affect the formwork.
- (l) Documentation for equipment, material or components to be incorporated in the formwork.
- (m) Plans for transporting, handling, moving and re-use of the formwork.
- (n) Method and rate of concrete delivery, placement sequence, discharge heights and rate of rise.
- (o) Concrete temperature at time of placement, if greater than 30°C or less than 5°C.

2.4 FORMWORK DOCUMENTATION**2.4.1 General**

The formwork documentation shall set out the requirements of the formwork design. The formwork documentation shall contain a statement that the formwork design and documentation conforms with AS 3610.

To permit the formwork to be verified, constructed and inspected prior to use, providing formwork documentation is mandatory for formwork in Importance level II or Importance level III (see Appendix A).

2.4.2 Documentation

The formwork documentation shall include the following, where applicable:

- (a) Plans, elevations and sections sufficient to depict the general arrangement of the formwork and multistorey shoring, and to identify and locate all members, including bracing.
- (b) Details sufficient to fully describe important or unusual features of the design, including all items specified in the project documentation as required in Table 2.2.3.
- (c) Method statements covering the erection and stripping of formwork and multistorey shoring.
- (d) Where colour control is specified, procedures and details necessary to satisfy the requirements of project documentation, including: form face materials, sealing of form face sheet and all joints.
- (e) Reference to proprietary documentation (see Clause 2.5).
- (f) Where non-destructive test methods are to be used to evaluate the structural capacity of formwork, the appropriate test load and details of the test procedure.
- (g) Acceptance criteria for single-use formwork.
- (h) The weight of stacked materials taken into account in the formwork design and details of the areas of the formwork designed to carry stacked materials and any limitations thereto.
- (i) Requirements of the project and construction documentation that relate to formwork, as specified in Clauses 2.2 and 2.3.
- (j) Method of field adjustment of the formwork.
- (k) Where required, location of inserts, weepholes, vibrator holes, clean-out holes, and inspection openings.
- (l) Sequence and method of concrete placement and the minimum elapsed time between adjacent placements.
- (m) Location and details of construction joints.
- (n) Stripping procedures, including details and placement of wrecking strips and other details relating to stripping.
- (o) Details of deviation indicators, if required.
- (p) The design assumptions in accordance with AS 3610, as follows:
 - (i) Permanent actions.
 - (ii) Imposed actions.
 - (iii) Accidental actions.
 - (iv) Concrete pressure and the parameters used to determine its magnitude including—
 - (A) wet density of concrete;
 - (B) rate at which concrete rises vertically up the formwork;
 - (C) type of cement;
 - (D) percent content of fly ash and slag;
 - (E) concrete temperature at placement;
 - (F) form height;

- (G) concrete discharge height; and
- (H) vertical pour height.
- (v) Whether the design allows for any admixture that has a retarding effect to be used in the concrete.
- (vi) Environmental actions and site conditions.
- (vii) Other actions.
- (viii) Permitted imperfections.
- (q) The footing design assumptions, such as foundation material description, minimum bearing value, limitations on settlement during Stages 1, 2 and 3. Reference to information sources such as geotechnical reports shall also be included.
- (r) Preparation of the foundation, such as filling, compaction, drainage and precautions against flooding.
- (s) The footing details such as type, size and relevant levels.
- (t) Details of materials and components, including the type, quality, grade and, where applicable, the relevant Australian Standard.
- (u) Application and type of release agent.
- (v) Details of any specialist surface finish requirements such as board, rope finish, etc.

C2.4.2 *Until its removal, the formwork carries the construction load and also provides safe working areas and access ways for construction personnel. It is therefore of significant importance that the engineering design be communicated by adequate documentation.*

The extent of the documentation will largely depend on the complexity of the structure, and on the design and details of the formwork. In preparing the formwork documentation, it is expected that the supervision, fabrication, erection, use and removal of the formwork will be carried out by competent persons (see Clause 1.5.1.2).

Regardless of whether the formwork design is carried out by one or more persons, it is essential that the formwork documentation adequately covers the design. Where separate documentation is provided (e.g. documentation for single-use items, proprietary items, footings) it should be brought together to make up the formwork documentation in a contiguous and coordinated manner.

2.5 PROPRIETARY DOCUMENTATION

2.5.1 General

The proprietary documentation shall set out the information required for the correct use of proprietary formwork.

2.5.2 Documentation

Proprietary documentation shall include the following information:

- (a) Drawing or pictorial representation that clearly identifies the formwork to which it refers.
- (b) Adequate information to fully describe its intended use and any limitations thereto.
- (c) Instructions for use and, where applicable, maintenance of the formwork.
- (d) The strength and serviceability limit state capacities in accordance with AS 3610 and relevant materials Standards.

- (e) The working load limit as calculated in accordance with AS 3610.
- (f) A statement that the formwork depicted and the proprietary documentation is in accordance with AS 3610.
- (g) Detailed information including, where appropriate—
 - (i) part number;
 - (ii) dimensions;
 - (iii) structural properties, including: section and material properties, weight, axial elastic stiffness and moment-rotation characteristics;
 - (iv) geometric imperfections which affect its use or structural capacity and behaviour, including: eccentricities, out-of-straightness and any permanent camber built into the item;
 - (v) details of any special attachments (e.g. access brackets, hand rail posts, plumbing feet); and
 - (vi) locations for tie bolts or support points.

NOTE: Proprietary documentation should include adequate information to permit structural analysis of formwork assemblies to determine or verify their structural capacity and behaviour.

C2.5 *Clause 2.5 lists the minimum information to be given on an information brochure so that it can be a valid and acceptable part of the formwork documentation.*

SECTION 3 ARCHITECTURAL REQUIREMENTS

3.1 SCOPE OF SECTION

3.1.1 General

This Section specifies the requirements for—

- (a) identifying and selecting the appropriate class of surface finish (see Clause 3.2);
- (b) the acceptable physical quality of cast in situ and precast concrete (see Clause 3.3);
- (c) colour control of untreated surfaces (see Clause 3.4);
- (d) matters related to surfaces prior to treatment (see Clause 3.5);
- (e) repairs (see Clause 3.6); and
- (f) test panels (see Clause 3.7).

3.1.2 Application

The following requirements apply:

- (a) Plain concrete surfaces left off-form or prior to application of surface treatment or coating.
- (b) Both formed precast and cast in situ concrete surfaces.

This Section does not apply to—

- (i) unformed concrete surfaces, textured or treated surfaces (for example, where the surface is treated with a secondary finishing operation using chemical or mechanical means); and
- (ii) the surface of permanent forms made from materials other than concrete, e.g. sheet metal permanent forms.

The quality of the surface finish and colour control of precast concrete permanent forms shall be evaluated after pre-casting.

C3.1.2 The intention of Clause 3.1.2 is to specifically exclude the application of Section 3 to permanent form surfaces of materials other than concrete, e.g. metal, GRC, etc. In addition, the Clause clarifies that Section 3 applies to the physical quality and colour of the concrete surface of precast concrete permanent forms after they have been cast (i.e. as result of the precast element formwork) and not after installation on site.

3.2 CLASSES OF SURFACE FINISH AND COLOUR CONTROL

3.2.1 General

The class of surface finish and where colour control is incorporated shall be—

- (a) identified in accordance with Clause 3.2.2; and
- (b) selected in accordance with Clause 3.2.3.

3.2.2 Notation

There are five classes of surface finish, each class being identified by the appropriate numeral from 1 to 5.

Where colour control is incorporated this shall be denoted by the suffix ‘C’ following the surface finish class numeral (see Notes 1 and 2).

The suffix 'X' shall be added to identify where the project documentation [see Clause 2.2.3(a)(iii)], specifies:

- (a) Any additional feature (an extra feature not covered in this Standard, see Note 3).
- (b) Less stringent requirements than specified in this Standard (see Note 3).
- (c) Concrete faces with small areas where more stringent tolerance values than those given in Table 3.3.5.1 apply (see Note 4).

NOTES:

- 1 The requirements set out in Clause 3.4 do not apply without the suffix 'C' (see Notes 2 and 3).
- 2 Attention is drawn to Clause 3.4.1, which prohibits colour control for Classes 4 and 5.
- 3 For example, 2C denotes Class 2 with colour control and 2X and 2CX are valid descriptors of surface specifications that are either not covered in this Standard or less stringent than specified in this Standard (see Clause 3.2.1).
- 4 Attention is drawn to Clause 3.3.5.1, which limits the extent to which values that are more stringent than those assigned to the selected class can be specified in the project documentation as required by Clause 2.2.3(b)(v).

C3.2.2 *In recognition of the fact that no Standard can ever cover all the possibilities that are available in concrete finishes, and that many project designers may want to vary some of the provisions of the Clauses, a means of indicating an extra feature not covered by this Standard or a less stringent requirement is given by using the 'X' suffix to the surface designation, e.g. 1X, 2X, 3X. Additionally, using the 'C' prefix indicates that colour control is required in addition to the specified finish, e.g. 1CX, 2CX, 3CX. The use of this notation indicates to the formwork designer and the site staff the need to examine the project documents for information on extras and exceptions.*

This Standard does not place any limitations on the extras that the project designer may specify, but does place restrictions on the use of the 'X' notation for exceptions (variations) to this Standard. The 'X' suffix is applicable only to colour control and the mandatory requirements of the surface specification.

The 'X' suffix cannot be used to include any matters listed as 'Excluded' in Table 2.2.3. Neither can it be used to make the requirements of any class or its associated colour control more stringent. It is only used to denote changes to the requirements which are less stringent than those given in this Standard. For example, if the project designer requires a surface which is generally satisfied by Class 3 but wants some parts of this class made more stringent, then the project designer is required to specify this as 2X, with the specification giving details of those requirements of Class 2 that are reduced by the 'X' notation. The effect of this is to prevent the project designer from specifying anything which is more stringent than Class 1 or Class 1C. To specify this would be to ask for an impossibly high standard of workmanship.

The 'X' suffix can be useful in reducing the stringency of requirements for surfaces that are only viewed at a distance.

3.2.3 Applicability

The physical quality of the concrete surface shall be specified in the project documentation under a class numeral in accordance with Table 3.2.3.

If the class is not specified in the project documentation, the quality of the off-form surface is not required to be superior to Class 3, and selection of the appropriate class shall be by the visual characteristics and suitable uses set out in Table 3.2.3.

TABLE 3.2.3
APPLICABILITY OF SURFACE CLASSES

	Class 1 (see Note 2)	Class 2	Class 3	Class 4	Class 5
	Visual quality important			Visual quality not significant	
Visual characteristics	Highest quality attainable Subject to close scrutiny Best possible uniformity of appearance Excellent quality of edge and joint details	Uniform quality and appearance over large areas Built to close tolerances Consistently good quality to edge and joint details	Good visual quality when viewed as a whole	Appearance not important Good general alignment	Alignment and appearance not important
Suitable uses	Selected small elements contained in a single pour Areas of special importance in limited quantities	General external and internal facades intended to be viewed in detail and as a whole	General external and internal facades intended to be viewed as a whole	Surfaces concealed from general view Surfaces to have thick applied finishes after preparation	Totally concealed areas
Situations where not to be specified	For whole elevations or extended surface areas, trafficable slopes, soffits, formed tops of slopes except where means to dissipate entrapped air are employed, form liners. Not applicable where treatment is to 100% of surface	Formed tops of slopes except where means to dissipate entrapped air are employed	No restriction		
Colour control	May be specified. See Clause 3.4.4 for the tonal range that can be specified. Not appropriate for surfaces with applied finishes such as coatings or paint.			Excluded	
Surface treatment	Not applicable	May be specified (see Clause 3.5)			Not suitable

NOTES:

- 1 Achieving a high quality surface finish requires a timely co-operative effort involving all participants.
- 2 Class 1 is the highest standard with the most rigorous specification and is only recommended for use in very special features of structures of a monumental nature.
- 3 Different methods of forming elements and repair may affect the appearance of the surface finish. It is essential that test panels take this into account.
- 4 In regard to Class 2, the term 'viewed in detail' is applied at the viewing distances specified in Clause 3.3.3.2.
- 5 Facades equal to vertical faces only.
- 6 For tolerances see Table 3.3.5.1.

C3.2.3 *In keeping with the theme of this Standard, Table 3.2.3 is expressed in performance terms. Particular examples of the use of the several classes are as follows:*

Class 1 shall not be specified for concrete surfaces (as is common practice) other than prominent elements of monumental structures. This class represents the highest standard of workmanship. It is very expensive and extremely difficult to achieve. It should only be specified for surfaces that will be subject to close scrutiny. It should not be regarded as representing perfection as it, like the other classes, has permissible deviations for both colour and dimensions. The high standard of work required for its achievement precludes its use in all but elements contained in a single pour.

Ideally, the concrete should come from a single concrete delivery because of the near impossibility of repetitively meeting the stringent requirements of this class.

Foot or other traffic on the formwork usually leaves marks that are reflected in the poured face. For this reason Class 1 cannot be used on trafficable formed areas. Formed tops of elements usually have a problem of excessive blowholes and they are also excluded from Class 1.

Class 2 This class is also expensive. It would normally be used for general architectural work, e.g. the complete facades of buildings, public access areas, visible areas of bridge work and areas subject to close scrutiny. Its parameters are such that with stringent supervision and consistency of material supply, formwork, concrete placing, curing and protection, it can be repetitively achieved over large areas. This is the highest class for trafficable soffit work and is the highest class necessary for surfaces that are to be totally treated.

Class 3 Class 3 is for buildings and structures that are to be viewed as a whole, and where minor blemishes and defects do not tend to detract from the overall appearance. Carparks, basement walls, industrial constructions, and portions of bridgework not readily visible, are suitable cases for its use. It is the lowest class for visible surfaces that do not have an applied finish or are untreated. It is also the lowest class for which colour control may be specified.

Class 4 This is for surfaces that are concealed from view, e.g. backs of retaining walls and insides of tanks and ducts, or that have an applied surface, e.g. render or tiling. The project designer should note the details of this class as its adoption may require some surface preparation before the application of the finish, e.g. the smoothing of face steps and filling of blowholes before the application of tanking membranes to retaining walls.

Class 5 This class is for totally concealed areas where the only requirements are structural adequacy, durability and serviceability, e.g. footings, foundation beams.

3.3 PHYSICAL QUALITY

3.3.1 General

Criteria for the acceptable physical quality and method of evaluation of each class of concrete surface finish and obligation for test panels is specified in this Section.

The tolerances given in this Section shall be read in accordance with those given in AS 3600. Tolerances in AS 3600 take precedence where more stringent than those specified in this Section. The concrete surfaces affected shall be identified in the project documentation [see Clause 2.2.3(b)(iv)].

For curved, irregular or unusual surfaces or shaped elements the requirements of Clause 3.3 may not be appropriate [see Clause 2.2.3(b)(iv)].

NOTE: Formwork tolerances for position and deviation from specified dimensions are not specified in this Standard. Taking account of the tolerances permitted in Tables 3.3.3.1, 3.3.4.1 and 3.3.5.1 may require adopting more stringent formwork tolerances for position and deviation from specified dimensions than specified in AS 3600 for as-cast concrete. Tolerances for position and deviation from specified dimensions that are not achievable (e.g. zero tolerance) should not be specified.

C3.3.1 *This Standard considers the dimensional aspects of concrete elements at two levels. The first are those required for structural acceptability in accordance with AS 3600. The second relates to the particular surface class and its project documentation.*

It is not the intention of this Standard to recommend that all concrete work should be automatically evaluated. It is expected that these procedures will only be used when there is some doubt about the acceptability of the complete element.

As a performance standard, the emphasis is on the construction process. Accordingly the tolerances are measured on the concrete surface for this is the final product and represents the formwork in its service state, i.e. deflected and distorted under the forces of fluid concrete placement and other construction activity.

The one exception to this is the case where some strain movement of the permanent structure is expected, e.g. slab deflection. In such cases the relevant element needs to be checked while it is still being supported by the formwork.

This Standard covers the methods to be used in the evaluation of the completed concrete elements for acceptance or rejection. It applies to work that has been repaired as well as to the elements that may not require any rectification. This Standard does not limit the number of times that evaluation may be carried out after repair.

For work which is to have the surface treated in some way, e.g. tooled or gritblasted, evaluation will take place when the concrete element has been poured and stripped prior to surface treatment.

The intention of the requirements is to lay down fair procedures for the evaluation of the completed work, and to minimize the number of situations where subjective judgement is required.

Experience has shown that situations where judgement is based on personal opinion, rather than quantitative measurement, are those that lead to disputes and accusations of unfair treatment. However, no set of requirements can possibly cover every circumstance. It is recommended that the project documentation provide guidance on all the critical aspects of each project. It may be necessary to specify extra procedures for particular circumstances. In these cases, it is recommended to avoid, wherever possible, specifications which call for the exercise of discretionary judgement.

3.3.2 Critical face

Where a concrete element has several faces each with an equal class of surface finish, the project documentation shall specify which faces take precedence in the checking of deviations. Where the opposite faces are of different classes then the face with the higher quality shall take precedence in the checking [see Clause 2.2.3(b)(i)].

3.3.3 Surface finish

3.3.3.1 Acceptable criteria

Table 3.3.3.1 specifies the acceptable criteria for surface finish.

C3.3.3.1 *The quality of workmanship and the various other factors needed to produce the specified physical quality of the different surface classes are—*

- (a) quality and consistency of concrete materials;*
- (b) a very low and uniform level of moisture absorption of the form surface for colour control (this is aided by the correct selection and use of a release agent);*
- (c) a rigid and mortar tight formwork structure (it is desirable to form and use compressive joint types or suitable compressible sealant grooves at construction joints to aid the achievement of mortar-tightness;*
- (d) good and consistent concrete compaction;*
- (e) careful and consistently timed formwork stripping and surface curing;*
- (f) appropriate surface curing; and*
- (g) protection of the completed element.*

**TABLE 3.3.3.1
ACCEPTABLE CRITERIA FOR SURFACE FINISH**

Imperfection	Class 1	Class 2	Class 3	Class 4	Class 5
1 Blowholes	Acceptable if size and distribution is no greater than given in:			Acceptable if not detrimental to concrete strength or durability	
	Figures B1 (a) and (b)	Figures B2 (a) and (b)	Figures B3 (a) and (b)		
	Method of repair shall be specified in project documentation [see Clause 2.2.3(d)]				
2 Form tie holes	Acceptable				
	Any requirement to plug form tie holes and the acceptable method of plugging shall be specified in project documentation [see Clause 2.2.3(d)]				
3 Imprints of modular panel frames	Acceptable if face step in accordance with Table 3.3.5.1 or unless specified 'unacceptable' in the project documentation	Unacceptable, unless permitted in the project documentation (see Clauses 2.2.3(a)(iii)(B) and 2.2.3(b)(iii) and see Table 3.3.5.1)	Acceptable		
4 Grout loss (a) No colour control (b) Colour control specified	Unacceptable	Minor grout loss is acceptable, if repairable (see Note 3)	Acceptable		
		Unacceptable, if colour control specified (see Note 2)			
5 Honeycombing	Unacceptable				
	Method of repair shall be specified in project documentation [see Clause 2.2.3(d)]				
6 Vibrator burns in form face	Acceptable if not disfiguring and the resulting imperfection does not detract from the overall visual characteristics specified in Table 3.2.3 (see Note 4)		Acceptable if colour control is not specified; otherwise unacceptable (see Note 2)	Acceptable	
7 Scratches in formed face					
8 Cement residue on formed face					
9 Holes in formed face with a diameter less than 5 mm					
10 Imperfection: Grain imprinting	Unacceptable	Permitted provided not disfiguring	Acceptable	Acceptable	
11 Holes in formed face with a 5 mm or greater diameter	Acceptable if not disfiguring and the resulting imperfection does not detract from the overall visual characteristics specified in Table 3.2.3 (see Note 4)	Acceptable up to a diameter of 10 mm provided the imperfection does not detract from the overall visual characteristics specified in Table 3.2.3 (see Note 4)	Acceptable provided the imperfection does not detract from the overall visual characteristics specified in Table 3.2.3 (see Note 4)		
12 Imprints of nail and screws	Acceptable if not disfiguring and the resulting imperfection does not detract from the overall visual characteristics specified in Table 3.2.3 (see Note 4)		Acceptable	Acceptable	

(continued)

TABLE 3.3.3.1 (continued)

Imperfection	Class 1	Class 2	Class 3	Class 4	Class 5
13 Formed face repairs	Acceptable if not disfiguring and the resulting imperfection does not detract from the overall visual characteristics specified in Table 3.2.3 (see Note 4) unless prohibited in the project documentation (see Note 4)		Acceptable		
14 Protruding bar chairs	Unacceptable	Protruding bar chairs shall be ground flat and the resulting imperfection acceptable provided it does not detract from the overall visual characteristics specified in Table 3.2.3 (see Note 4)	Acceptable		

NOTES:

- 1 Figures B1, B2 and B3 (see Appendix B) shall be used only for the purpose of evaluating blowhole size and distribution.
- 2 Damaged form surfaces and loss of moisture through leaking joints will initiate hydration staining.
- 3 If colour control is not specified, minor grout loss is acceptable providing it is repaired and the physical quality of the concrete surface is not impaired.
- 4 If colour control is specified, variations in form face permeability caused by holes, nail or screw holes, scratches and form face repairs may result in unacceptable tonal variations (see Clause 3.6).
- 5 The images in Appendix B are for walls only.

3.3.3.2 Evaluation of surface finish

Evaluation of surface finish shall be viewed from a distance that is not less than the greater of 2 m or the closest distance from which the subject area will normally be observed when the project is completed and include the assessment of the following:

- (a) *Blowholes* Blowholes shall be evaluated by comparison of the completed work with the relevant photograph from Figures B1 to B3 of Appendix B for the specified class, as shown in Figure 3.3.3.2. The 1:1 scale photograph shall be held against the surface.
- (b) *Other imperfections* Other surface imperfections shall conform with the requirements specified in Table 3.3.3.1, unless less stringent requirements are specified in the project documentation.

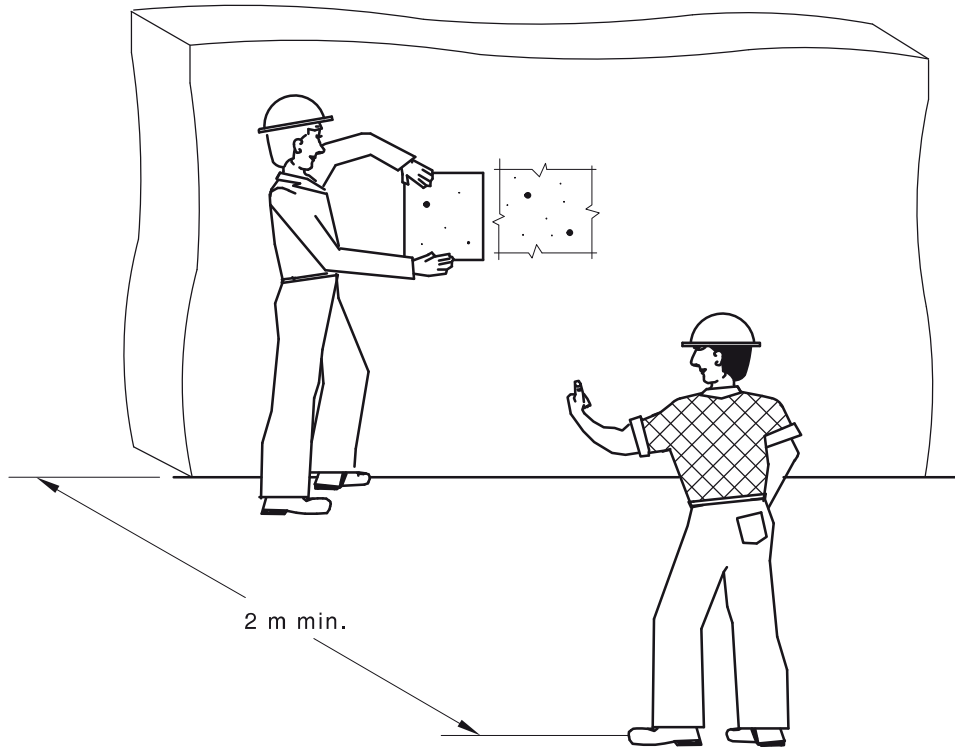


FIGURE 3.3.3.2 COMPARISON OF BLOWHOLE PHOTOGRAPHS WITH FINISHED WORK

C3.3.3.2 *The viewing distance at which this comparison is made is very important. Defects which would be considered most unsightly on surfaces that can be examined at close quarters will become insignificant if the closest view distance is a lot greater, e.g. the upper level walls of multistorey buildings that can only be examined from similar buildings on the opposite side of the street. In this case, the defects can become invisible to the naked eye.*

3.3.4 Form face deflections

3.3.4.1 Acceptable limit of form face deflections

The acceptable limit of form face deflections for concrete surfaces specified in Table 3.3.4.1 shall apply, except for Classes 1 and 2 concrete surfaces that have been identified in the project documentation in accordance with Clause 2.2.3(b)(ii) for which the acceptable limit of form face deflections of span/500 shall apply.

TABLE 3.3.4.1

ACCEPTABLE LIMIT OF FORM FACE DEFLECTIONS

Quality of surface finish	Class 1	Class 2	Class 3	Class 4	Class 5
Formed face deflections (not greater than)	Lesser of 2 mm or span/360	Lesser of 3 mm or span/270	Span/270	Span/270	N/A

NOTE: Table 3.3.4.1 does not provide acceptable limits for formwork primary and secondary member deflections (see Appendix B).

3.3.4.2 Evaluation of formed face deflections

The form face span shall be checked by inspection of the formwork prior to placing the concrete.

At least 10 readings shall be taken at regular intervals but not closer than 300 mm. These shall be measured by placing a straightedge against the concrete surface, in line with the direction of the span of the formed face, and measuring the gap between the concrete face and the straightedge as shown in Figure 3.3.4.2.

The length of the straightedge shall be equal to or longer than the formed face span.

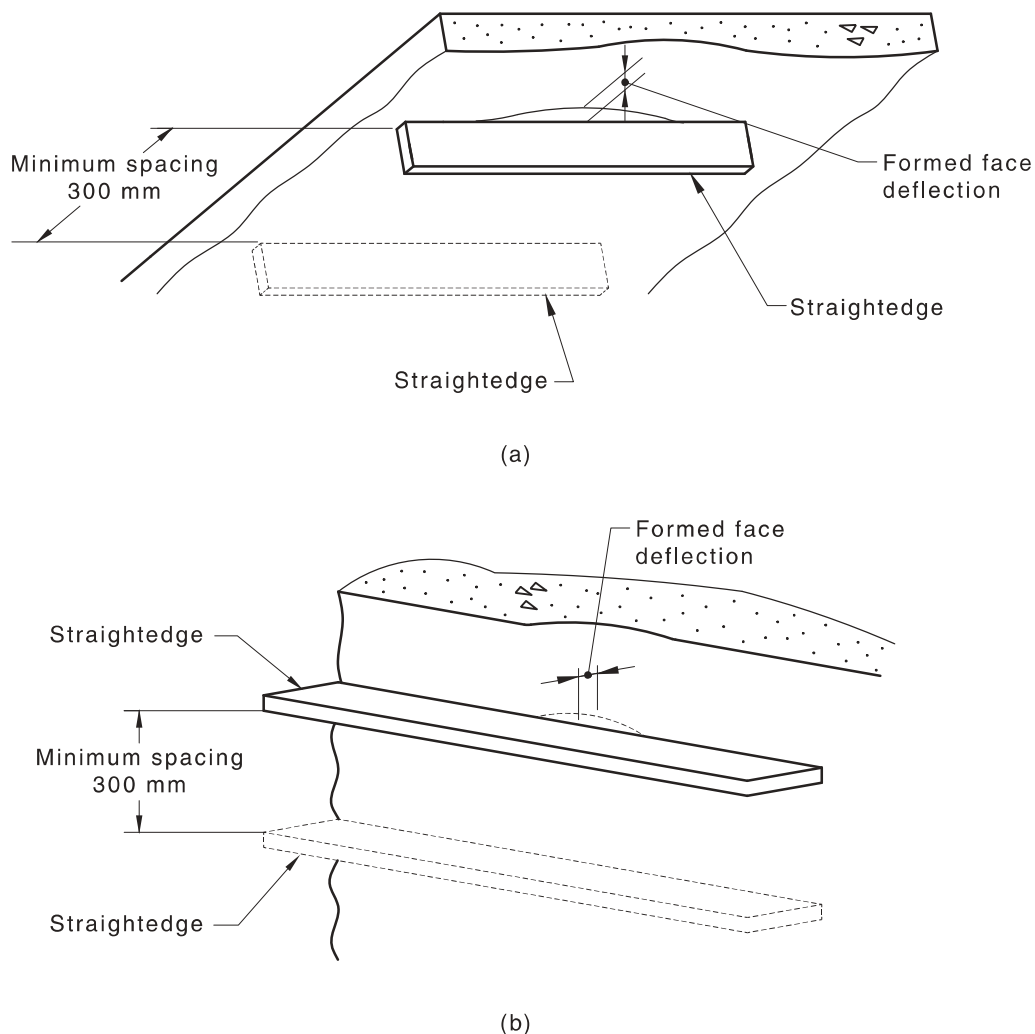


FIGURE 3.3.4.2 MEASUREMENT OF FORMED FACE DEFLECTION

3.3.5 Tolerances for concrete surface undulations, steps, flatness and out-of-plumb

3.3.5.1 Maximum tolerances

Table 3.3.5.1 gives tolerances for the concrete face steps, surface undulations, flatness and out-of-plumb which represent the acceptable quality appropriate to each class. The tolerances given in Table 3.3.5.1 shall apply to the formed concrete surface. More stringent tolerance values than those given in Table 3.3.5.1 may be specified for small areas, but not for the whole area of the element [see Clause 2.2.3(b)(v)].

NOTES:

- 1 More stringent tolerance values should be considered when designing junctions with other forms of construction such as window framing, brickwork, etc.
- 2 Table 3.3.5.1 does not provide acceptable limits for formwork primary and secondary member deflections (see Appendix C).
- 3 For elements where light shown across a surface at a flat angle, particularly in the case of smooth glossy finishes, the surface tolerances specified in the Table 3.3.5.1 may not be appropriate and alternative finishes should be considered.

C3.3.5.1A *Notwithstanding the general rule, that a change to the given tolerance values should always be a relaxation with the adoption of larger tolerances (dimensions or colour), there is one case where small areas may be more stringent. A typical example is the junction between the concrete surface and the work of other trades, e.g. door frames, modular ceilings, shop fronts, skirtings, patterned floor finishes, tiling (see Figure C3.3.5.1A). The greater accuracy is needed only at the junction or interface. Beyond that, the tolerances of this Standard, with 'X' suffix if applicable, apply. These small areas of smaller tolerances should be listed in the specification, or shown by way of suitable details in the project documentation.*

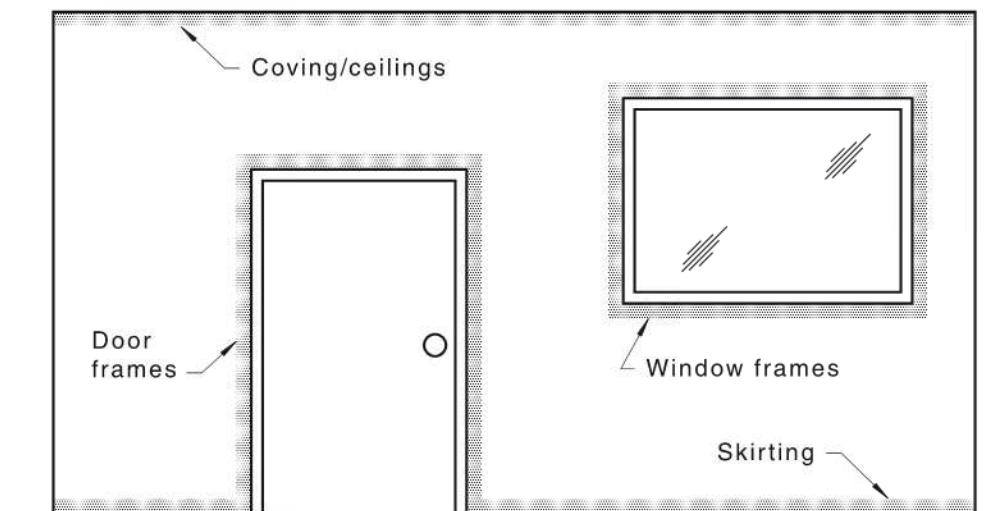


FIGURE C3.3.5.1A JUNCTION WITH OTHER TRADES

TABLE 3.3.5.1
MAXIMUM TOLERANCES FOR STRAIGHT ELEMENTS

Quality of surface finish	Class 1		Class 2		Class 3		Class 4		Class 5		Ref. Clause
	95	100	90	100	80	100	70	100	70	100	
1 Face step, in mm:											3.3.5.2(b)
(a) Within the element	1	2	2	3	3	5	5	8	*	*	
(b) At in situ construction joint	2	3	2	3	3	5	5	8	*	*	
2 Surface undulations, in mm:											3.3.5.2(a)
(a) $l = 300$											
(a - b) \leq	1	2	2	4	3	4	5	7	*	*	
(b) $l = 1500$											
(a - b) \leq	2	4	3	6	5	7	8	10	*	*	
3 Flatness, in mm:											3.3.5.2(c)
(a) 1.25 m grid	4	5	6	7	7	10	*	*	*	*	
(b) at 5 m over 10 m (not applicable to precast concrete)	5	7	7	10	10	15	*	*	*	*	
4 Out-of-plumb, in mm:											3.3.5.2(d)
(a) height <3 m	3	5	4	6	5	7	*	*	*	*	
(b) $3 \leq$ height <8 m (not applicable to precast concrete)	6	8	8	10	10	12	*	*	*	*	

NOTES:

- The values given in the Table for the acceptable minimum quality for a particular class of surface finish may be relaxed. This relaxation shall be signified by the use of 'X' suffix to the notation.
- The Table provides tolerances for surface finish which may vary from those given in AS 3600. The project documentation may also need to provide more stringent tolerances relating to deviations from specified positions and deviations in specified dimensions.
- Tolerances in AS 3600 govern where more stringent than those specified in this Section (in particular when the acceptable minimum quality may be relaxed as signified by the use of 'X' suffix to the notation). Full details of such matters shall be given in the project documentation.
- Where tolerances are marked with an asterisk (*) this indicates that AS 3600 tolerances can generally be adopted; however, larger dimensions may require a maximum to be specified.
- Where surface treatment is specified, recognition should be made of the facility for the surface treatment to remove irregularities. Less stringent tolerances may then be appropriate.
- The percentage of readings means that of all the readings taken, the nominated percentage shall not exceed the specified tolerance. For example, for Class 1 Face Step (a), 95% of the readings shall have a face step not exceeding 1 mm and 100% readings shall have a face step not exceeding 2 mm.
- For elements where light shown across a surface at a flat angle, particularly in the case of smooth glossy finishes, the surface tolerances specified in the Table 3.3.5.1 Item 2 may not be appropriate and alternative finishes should be considered.
- For curved, unusual or irregular surfaces or shaped elements see Clause 2.2.3(b)(iv).

C3.3.5.1B Note 2 to Table 3.3.5.1 first refers to the tolerances being more stringent than those given for surface alignment in AS 3600. The second sentence of the Note acknowledges that the tolerances of this Standard and those of AS 3600 serve quite different purposes. The tolerances of this Standard apply only within the element and control its appearance but not its location. This is controlled by AS 3600. The tolerances in AS 3600 will, however, often be found to be insufficiently stringent, when in situ concrete interfaces with other trades, e.g. precast concrete, curtain walls. As noted in AS 3600, more stringent tolerances on dimensions and position should then be specified. Unlike this Standard, AS 3600 has no restrictions on this.

Note 3 indicates that tolerances marked with an asterisk (*) are limited by AS 3600. These would be the tolerances on reinforcement cover and element depth or thickness. AS 3600 does not restrict these tolerances being made more stringent and this could be justified for large elements.

3.3.5.2 Evaluation

Concrete surface undulations, steps, flatness and out-of-plumb shall be measured as follows:

- (a) *Surface undulations* Surface undulations shall be ascertained by using two straightedges, a short one of 300 mm and a long one of 1500 mm. The straightedge shall be used systematically over the whole face of the element to ensure even coverage, but shall not be used across construction joints. Two offsets, namely 'a' and 'b', are taken as shown in Figure 3.3.5.2(A) and the reading for evaluation is $(a - b)$.

NOTE: It is recommended that for elements greater than 2 m in any direction, at least 30 readings be taken.

- (b) *Face steps* Readings shall be at 200 mm intervals for the full length of the visible step. Prior to measurement, cement slurry resulting from outflow at face steps shall be removed. The face step spacing shall be measured from visible step to step on the concrete surface. Face steps shall be measured within an element by placing a straightedge against the concrete surface at right angles to the line of the step and measuring the gap between the concrete face and the edge of the straightedge, as shown in Figure 3.3.5.2(B).
- (c) *Flatness* Flatness shall be measured on the critical face of the element. The readings shall be used for evaluating any relative variations in the surface flatness or line of the element. They shall not be used as an evaluation of the absolute position of the element (refer to AS 3600).

The readings shall be taken using a suitable instrument, a stringline in still air conditions or other equivalent method. For elements or series of elements of the permanent work that are intended to be straight, with any overall dimension not less than 15 m, the check may be made along any straight line measuring more than 15 m. The readings shall be measured in 10 m sections, with each overlapping by 5 m, and with the variations from the straight determined by measurements at the ends and middle of each 10 m section, as shown in Figure 3.3.5.2(C).

Within these 10 m sections, and for elements less than 15 m, the flatness shall be checked by taking measurements on a 1.25 m × 1.25 m grid from a parallel plane with no measurements taken within 300 mm of any edge of the element, as shown in Figure 3.3.5.2(D).

The deviation at any point shall be taken as the difference between the offset reading at that point and the mean of all the offset readings taken for this area.

- (d) *Out-of-plumb* Readings shall be taken along the length of walls, on the critical face only, at not more than 5 m centres. Not less than two readings shall be taken.

Unless specified otherwise, the plumb of columns shall be checked as follows:

- (i) *Rectangular columns* On adjacent faces, at two positions on each face.
- (ii) *Circular columns* At two positions at right angles.
- (iii) *Irregular shapes* At positions specified in the project documentation.

Plumb shall be measured from a point 300 mm from the top of the vertical surface and to a point 300 mm from the bottom, as shown in Figure 3.3.5.2(E).

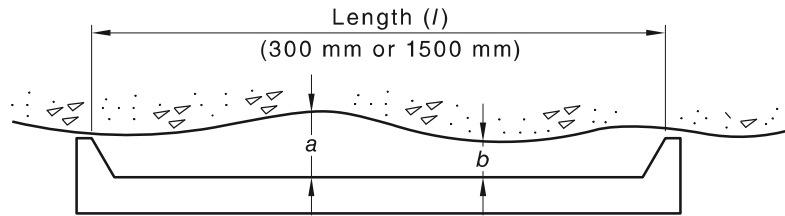


FIGURE 3.3.5.2(A) MEASUREMENT OF SURFACE UNDULATIONS

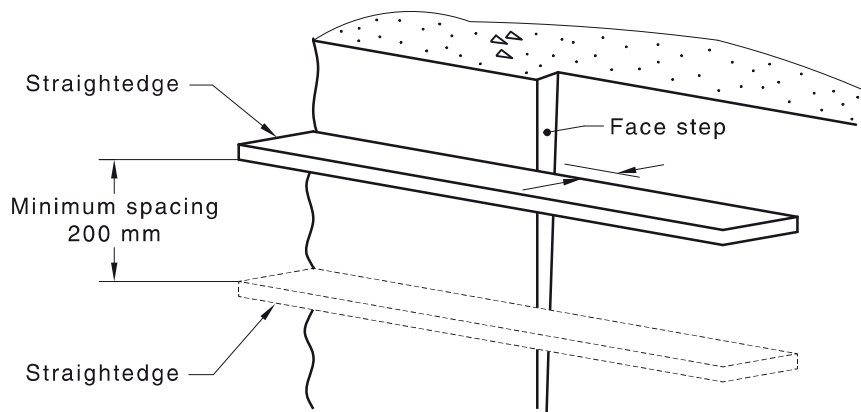
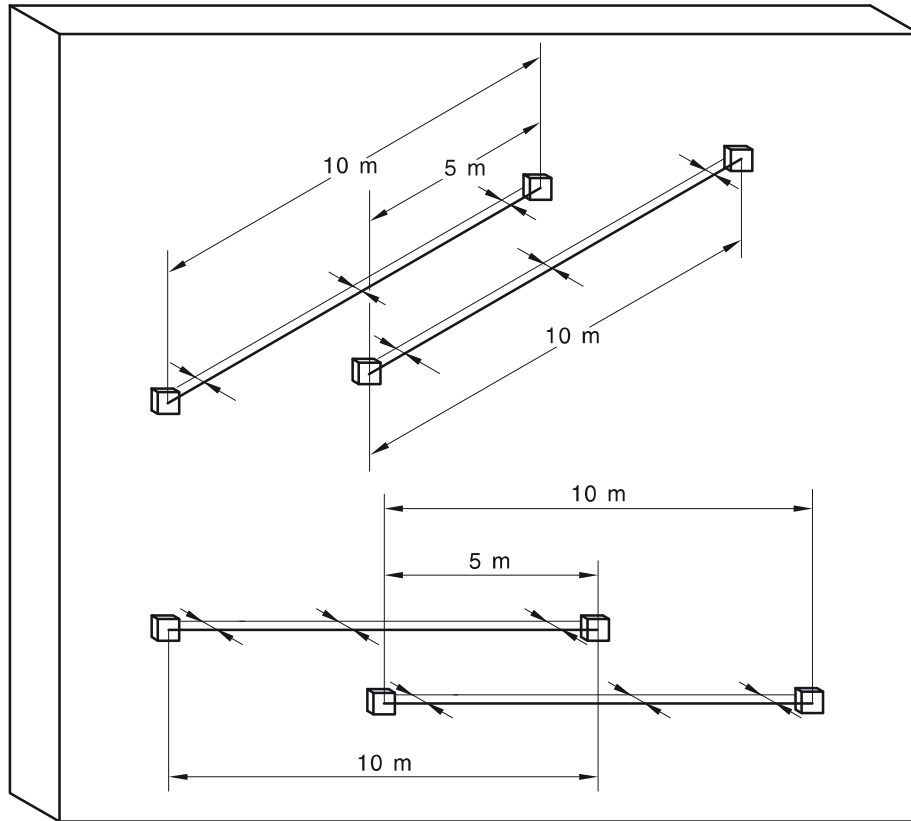
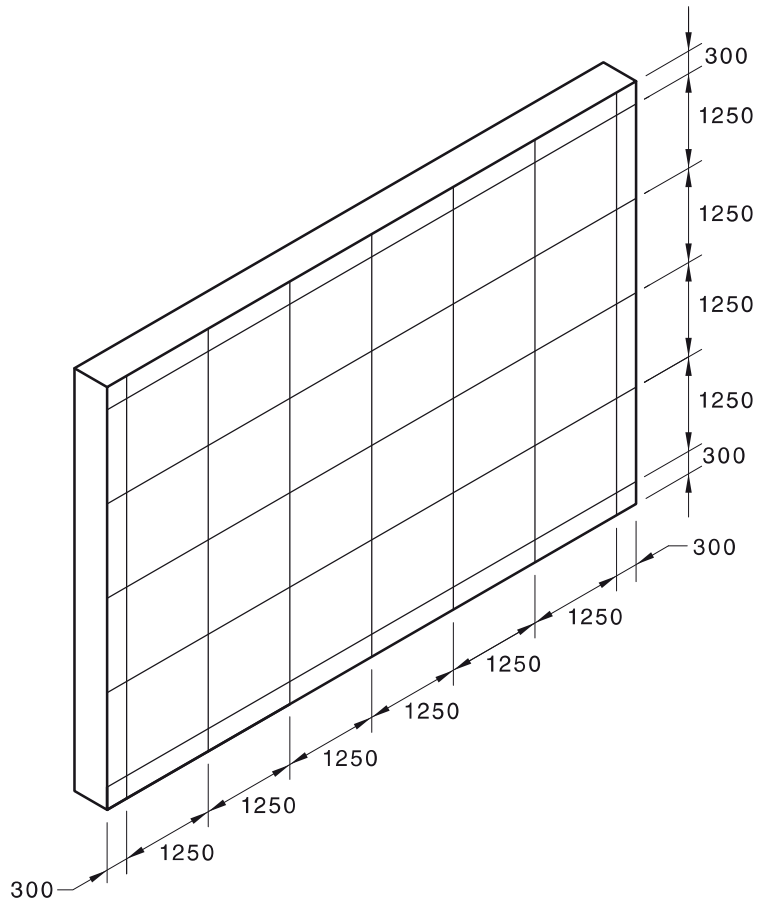


FIGURE 3.3.5.2(B) MEASUREMENT OF FACE STEPS



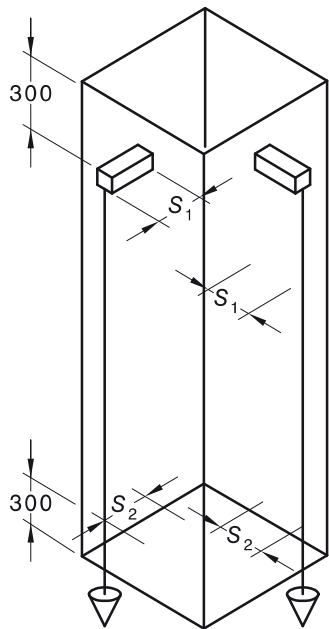
NOTE: Figure 3.3.5.2(C) shows stringlines offset from the concrete face by equal thickness blocks.

FIGURE 3.3.5.2(C) FLATNESS MEASUREMENTS FOR ELEMENTS OVER 10 m LONG



DIMENSIONS IN MILLIMETRES

FIGURE 3.3.5.2(D) PATTERN OF FLATNESS MEASUREMENTS FOR ELEMENTS UP TO 10 m LONG



DIMENSIONS IN MILLIMETRES

FIGURE 3.3.5.2(E) MEASUREMENT OF OUT-OF-PLUMB

C3.3.5.2 *Surface undulations are gradual, not abrupt, surface deviations. The deviations may be over a short distance, or may be more gradual and only discernible over 1.5 m. Accordingly two checks are called for, one with a 300 mm straightedge the other with a 1500 mm straightedge. In all cases random readings are taken with an offset straightedge and the difference between the maximum and minimum reading at each location is the reading. For acceptance, all the readings need to be equal to or less than the higher value shown in Table 3.3.5.1 and the stated percentage need to conform to the lower figure.*

Face steps in the completed concrete surface generally arise from either: misalignment at the junction of two concrete elements; or within the area of a form, from misalignment of the form face materials. Even in Class 1, a 1 mm face step is permitted in the case of Item (a). This is due to the manufacturing tolerances of plywood being $\pm 3\%$ of the thickness (i.e. 1 mm for a 17 mm sheet). The permitted values are given in Table 3.3.5.1.

In addition to the above checks, there are two test for the overall flatness of an element, as follows:

- (a) *The first test is for long elements or a sequence of in situ elements that are intended to be straight. The deviation within 10 m length is checked by offset readings at the ends and the middle, and the net deviation taken as the difference between the mean of the readings at the ends of the 10 m length and that at the middle. To keep control of any general deviations, the 10 m lengths need to overlap by 5 m.*
- (b) *With these 10 m length the second check for flatness applies. This is carried on a 1.25 m \times 1.25 m grid with the outer rows not closer to the edges than 300 mm. As before, the offset readings are related to those at the corners of the 5 m grid to obtain the true deviation.*

The check on flatness gives the deviation of a continuous grid of surface locations. Within these grid lines the other checks for deviation apply, i.e. form face deflection, face steps and surface undulations.

The important aspect of out-of-plumb is the determination of the critical face (see Clause 3.3.2). For walls, the critical face should be one face as nominated in the project documentation. For columns, the critical faces should be two selected adjacent faces. In this way the out-of-plumb check also monitors the possibility of a spiral twist but does not conflict with the AS 3600 tolerances on thickness of elements.

3.3.6 Precast concrete elements

3.3.6.1 General

Clauses 3.3.3, 3.3.4 and 3.3.5 shall apply to precast concrete.

In addition, precast concrete shall be manufactured within the acceptable deviations given in Table 3.3.6.2 for each tolerance classification specified in Clause 3.3.6.2.

Where the shape of a precast unit is such that there is conflict between the acceptable tolerances specified in Table 3.3.4.1 and Table 3.3.5.1, the tolerances in Table 3.3.6.2 shall take precedence.

C3.3.6.1 *The type of surface finish required will depend on the nature of the unit, its final location, and whether or not it is to receive an applied finish. The appropriate finish, which may vary from face to face, should be carefully chosen and clearly specified. Surface finishes depend on properly fabricated forms, and the project designer should clearly understand the capabilities and limitations of form production.*

It would be optimistic to imagine that every unit cast during the course of a contract will be perfect. Minor defects and blemishes will sometimes occur, and the main operations in making good these defects are filling blowholes, removing stains and repairing mechanical damage.

3.3.6.2 Tolerance classification for precast concrete

Tolerances for precast concrete shall be classified as follows:

- (a) *Type L—Tolerances in linear dimensions* Tolerances in linear dimensions cover thickness, width, length, and cross-section [see Figure 3.3.7(A)].
- (b) *Type A—Tolerances in angular dimensions* Tolerances in angular dimensions cover squareness or trueness to any specified angle [see Figure 3.3.7(B)]. Angular tolerance for squareness shall be 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. Trueness to an angle other than 90° shall be expressed in similar terms, but setting the check line in the specified angle.
- (c) *Type P—Tolerances in profile* Tolerances in profile cover flatness, straightness, warp and twist [see Figure 3.3.7(C)] as follows:
 - (i) Flatness tolerance shall be expressed as the maximum acceptable distance by which any point on a nominally plane surface may be from a 3 m long straightedge placed anywhere on the surface and parallel to the nominally plane surface.
 - (ii) Straightness tolerance shall be expressed as the maximum distance by which any point on an edge of a unit may be from a straight line drawn through the extremities of the particular edge.
 - (iii) Warp tolerance shall be expressed as the maximum acceptable distance of any point on a surface from a plane containing any three corners of the surface or points on the perimeter of the unit. If the surface is not a rectangle these three corners shall be those points on the surface that are the corners of a rectangle covering the greatest possible surface area of the unit.
 - (iv) Twist tolerance shall be expressed as the rotation of one end relative to the other end or relative to some other line or surface specified by the project documentation.

C3.3.6.2 *In determining dimensional tolerances, the following should be taken into consideration:*

- (a) *Tolerances should be based on the specific requirements of structural sufficiency and dimensional accuracy, having regard to the size and type of unit.*
- (b) *Tolerances should be measured with the unit orientated in the same attitude and supported in the same manner as in the completed structure.*
The effects of differential temperature in the unit should be taken into account when tolerances are measured.
- (c) *Due regard should be given to the tolerances specified (or achievable) in the supporting structure. These need to be compatible with those required for the precast elements. In addition, the connections between the precast elements and the permanent structure should make adequate allowance for the limitations achievable in the permanent structure.*

TABLE 3.3.6.2
ACCEPTABLE DEVIATIONS FOR PRECAST CONCRETE UNITS

Tolerance classification	Description			Acceptable deviation mm	
				Plus	Minus
Linear dimensions	Dimensions of flat panels	Panel length or width	<3 m	3	3
			≥3 m <6 m	6	6
			≥6 m	6	6
		Panel thickness at any location		3	3
		Openings length or width		3	3
	Dimensions of units other than flat panels	Cross-section overall dimensions	<600 mm	3	3
			≥600 mm <1500 mm	6	6
			≥1500 mm	10	6
		Cross-section, dimensions of parts such as webs, ribs or flanges	≤1500 mm	6	6
			>1500 mm	10	6
		Length, critical dimensions of abutting members		0	6
		Length, non-critical	<6 m per metre length	3	3
	≥6 m per metre length		6	6	
	Features in all units	Diameter or side dimensions of core holes, ducts or similar		3	3
		Width or depth of grooves		2	2
		Location of grooves and fastenings for window frames, doorframes and similar features		3	3
		Location of grooves or strips for flashings		6	6
		Location of electrical outlets and similar features		12	12
		Other requirements		As specified*	As specified*
Irregular curved or unusual shapes		As specified*	As specified*		
Position of individual connecting bolts, bolt holes, projecting metal or other devices in any associated group (e.g. the joint of two precast units), with respect to their position in the group		3	3		
Longitudinal location of any group of bolts, bolt holes, projecting metal or other devices, with respect of its true position in the unit in which the group is cast		6	6		
Angular dimensions	Squareness of corners	Up to 2 m on shorter side	3	3	
		Over 2 m, up to 4 m	5	5	
		Over 4 m	6	6	
Profile	Straightness of edges and flatness of surfaces				
	Warp	Per metre width, in 3 m length	3	3	
	Twist	Per metre width, in 3 m length	3	3	

* As given in the project documentation.

3.3.7 Evaluation of precast tolerances

The evaluation procedures specified in Clauses 3.3.3.2, 3.3.4.2 and 3.3.5.2 shall also apply to precast concrete, as appropriate. Optical instruments, jig frames or string lines shall be used, as applicable. There shall be adequate checking to ensure that all the units are consistent with the required tolerances.

Where it is required to check the dimensional accuracy of precast concrete units for conformance with the specified values in Table 3.3.6.2, the sequence of checking shall be as follows:

- (a) Check surface finish for conformance with tolerances specified in accordance with Clauses 3.3.3.2, 3.3.4.2 and 3.3.5.2.
- (b) Check linear dimensions for conformance with tolerances specified in accordance with Clause 3.3.6.2(a).
- (c) If the linear dimensions checked under Item (b) above conform with the specified tolerances, check the angular dimensions for conformance with the tolerances specified in accordance with Clause 3.3.6.2(b).
- (d) If the angular dimensions checked under Item (c) above conform with the specified tolerances, check the profile for conformance with the tolerances specified in accordance with Clause 3.3.6.2(c).

C3.3.7 *It is important to check the dimensional accuracy of precast concrete in the order specified as each of the subsequent types of deviations can affect the resulting measurement of the preceding ones.*

The angular dimensions need only be checked if the unit is acceptable for surface finish and linear dimensions.

The profile need only be checked if the unit is acceptable for both linear and angular dimensions.

The age of the unit at which the checks are made is most important and needs to be pre-arranged. Obviously the acceptance/rejection criteria needs to be imposed at the earliest possible time after production of the unit. For surfaces to be treated, they need to be checked prior to surface treatment. However, there are many practical situations in a precast yard that need consideration, and for reasons of damage and economy it is recommended that matters such as multiple handling of panels to enable the checks to be done are avoided. Improper storage of panels and differential temperature movements during storage will have a considerable effect on profile tolerances and need to be taken into account as part of the evaluation.

Where a test panel has been used, it is recommended that the tolerances be assessed on that element and approved before site work proceeds.

It is also recommended that, whenever possible, the tolerances are checked with the unit orientated and supported in the same attitude as in the completed structure. If this cannot be done, then the method may need to be determined by consultation and agreement before the work commences.

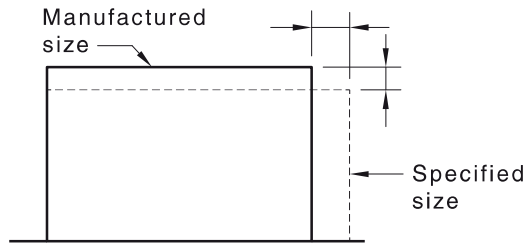
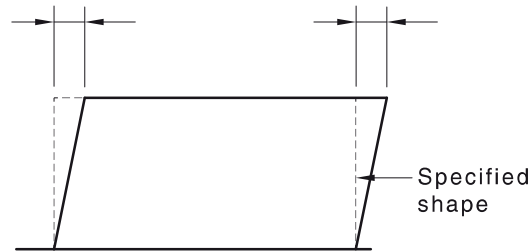


FIGURE 3.3.7(A) PRECAST CONCRETE—TOLERANCES IN LINEAR DIMENSIONS



NOTE: Out-of-squareness may affect measurement of tolerances in linear dimensions.

FIGURE 3.3.7(B) PRECAST CONCRETE—TOLERANCES IN ANGULAR DIMENSIONS

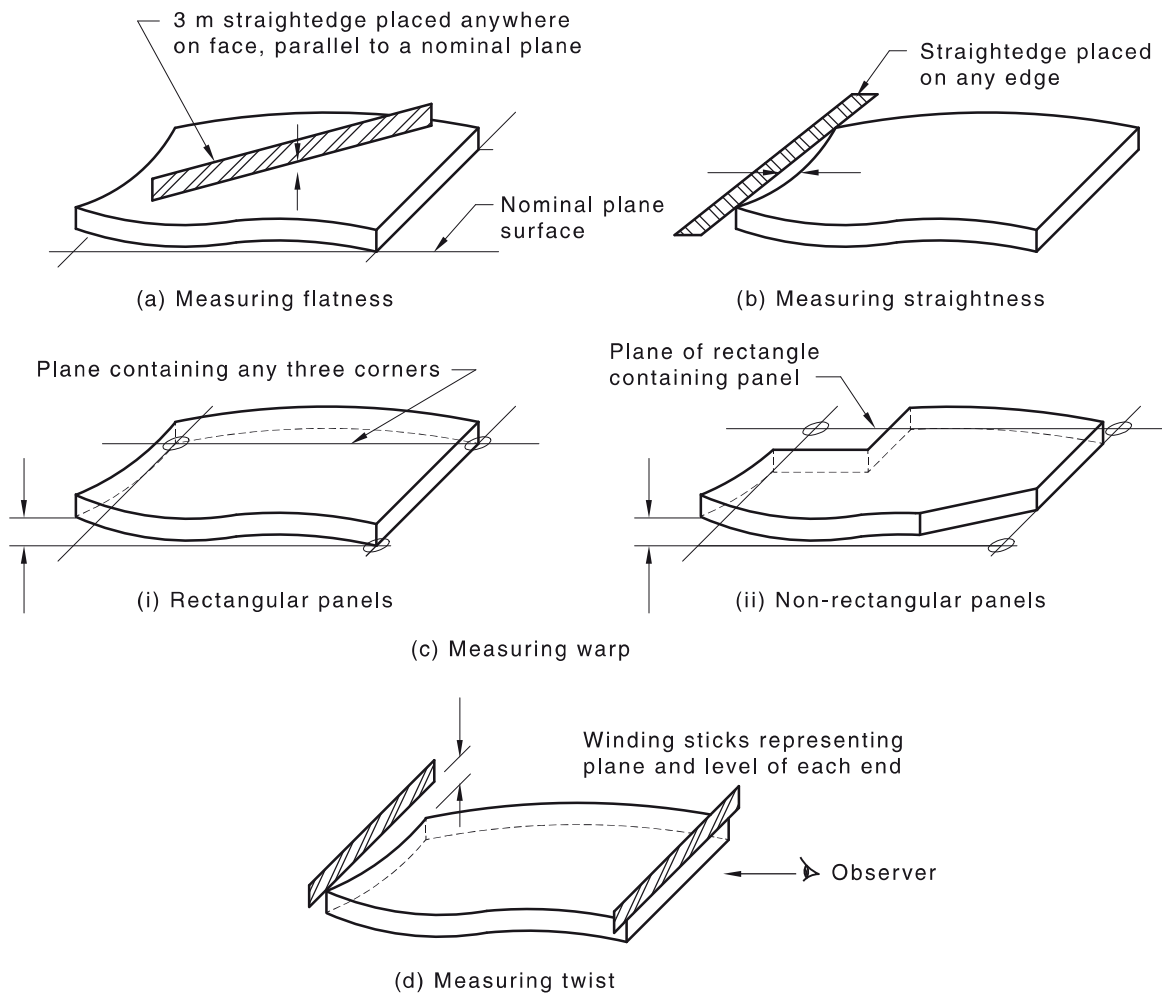


FIGURE 3.3.7(C) PRECAST CONCRETE—TOLERANCES IN PROFILE

3.3.8 Test panels for physical quality

Test panels shall be provided for Classes 1 and 2. However, test panels are optional for Class 3 and not applicable for Class 4 or Class 5 (see Clauses 2.2.3 and 3.7).

NOTE: Test panels for Classes 1 and 2 should be provided irrespective whether or not details of the test panels have been specified in the project documentation.

3.4 COLOUR CONTROL OF UNTREATED SURFACES

3.4.1 General

The control of the colour of concrete surfaces may only be imposed on surface finish Classes 1, 2 and 3.

NOTES:

- 1 In this Standard, the term 'colour' applies to equally to 'grey' concrete and is not limited to concrete containing pigments or coloured constituent materials.
- 2 Attention is drawn to the notation (adding suffix 'C') to identify surfaces where colour control is specified (see Clause 3.2.2).

C3.4.1 *This Standard permits the specification of colour control for surfaces of Class 1, Class 2 or Class 3. The stringency of the colour control is related to the surface class. The tonal scale of Figure 3.4.3 (or an equivalent one for colours other than grey) is used to limit the degree of consistency of colour that can be demanded. As given in Table 3.4.3 the permitted range is least for Class 1. This range can be widened in the specification by the adoption of the 'X' suffix to the surface class.*

Class 1 is only suitable for small and special areas. This is due to the extreme difficulty, if not impossibility, of achieving such a consistently high standard of workmanship over large areas. The same limitation is even more appropriate to colour control. Concrete is a composite material produced from an indigenous base, and as everything from which it is made varies in consistency, it is not possible to produce concrete with absolutely no variation in quality. Even if good consistency can be achieved in the mix, the formwork and its release agent, the concrete placing and finally the curing, there will still be observable colour variation due to minor differences in the ambient temperature or the humidity. The larger the surface area, the less the likelihood of achieving Class 1C, regardless of quality control.

Construction matters important to colour control include:

- (a) *Concrete placement* Consideration should be given to the following:
- (i) *Placing* For vertical elements, the use of chutes or baffles is recommended to ensure that the concrete is placed and falls between the reinforcement. This reduces segregation and the splashing of the mortar onto the forms.
 - (ii) *Placement rate* For vertical elements, a minimum vertical rate of placement is required to provide the pressure that assists in blowhole reduction. A minimum rate of 2 m vertically every hour is suggested.
This is relatively easy to achieve in columns and other small elements, but requires planning, and additional personnel and equipment, to achieve in large walls. The high rate in walls will also assist in the elimination of the flow lines and cold joints that occur due to the interruption of the pour.
 - (iii) *Vibration* For vertical elements vibration needs to be done more consistently and thoroughly than for normal concrete. In precast operations, good use can be made of table and form vibrators, but these are not readily suited to on-site activity. The immersion vibrator is the most suited to these situations.

Concrete should be vibrated from the bottom up to enable the air bubbles to escape. When it is placed in layers, the vibration should continue through into the lower layer to eliminate the segregation and colour trouble that normally occurs at this location.

Vibration is also related to the rate of placing. The number of vibrators should be adequate for the amount of concrete to be handled and the intended rate of placement. Spare vibrators should always be available on site as backup.

While vibration is important for all types and classes of finish, its extent and systematic use is vital for work where the evenness of aggregate exposure is demanded.

- (b) *Formwork stripping For colour control it is important to expose the finished concrete to the drying atmosphere at a common age. Concrete that is allowed to dry faster may be lighter in colour.*

It would be typical to expect the stripping of in situ concrete to occur within $\pm 1/2$ day of that specified. However, this will not suit all structures, or be possible with some construction schedules. The accepted Figure need therefore be worked out for each individual job or concrete element.

Where colour control is specified, it is important to remove the forms as quickly as possible.

At this time the concrete will have a low strength, so stripping should be done carefully to avoid damage to the concrete. Such damage is difficult to patch well enough to meet surface finish criteria.

Forms should never be eased before stripping as this will permit variable drying and consequently, colour variations.

- (c) *Curing As formwork is stripped at the earliest possible age, it is vital for strength, durability and surface hardness that curing methods be applied immediately. Precast concrete is normally given accelerated curing (e.g. low pressure steam, hot water curing), to allow the early re-use of forms. Post-stripping curing may then be used.*

The following comments on post stripping curing are applicable to both precast concrete and to in situ concrete:

- (i) *Water Water is a good curing medium and does not mar the surface, but its use is frequently impractical.*
- (ii) *Plastic Plastic can be used but it needs to be well held down to avoid wrinkles and to prevent air movement under the plastic otherwise differential drying will result and this will give colour variation.*
- (iii) *Curing compounds Curing compounds are good, but tend to change the colour of the surface and will often cause bond problems. They should be carefully investigated before use and checked out on the test panels. Where they are used it is important to use the same compound from the same source and apply it at the same age and at the same rate throughout the job if colour consistency is to be achieved.*

The quality and consistency of the concrete materials is one of the important factors that affect the final surface quality. For work having colour control, the specification should cover all the aspects of the concrete mix that can affect the consistency of the final surface colour. These include—

- (A) cement colour, source and content;*
- (B) aggregate colour, source and grading;*
- (C) water quality and content; and*
- (D) time and temperature restrictions relating to delay between mixing and placing.*

Close consultation with potential suppliers is necessary, to ensure that the specification is not unnecessarily prescriptive. Some aspects (e.g. cement content, aggregate grading, water content, mix temperature) may be determined after samples are produced.

The following provide some guidance on the topic:

- (1) Special class concrete Concrete for Classes 1, 2 and 3 will normally be special class concrete in accordance with AS 1379. Any concrete that has colour control specified should be special class concrete. This is imposed by the need to have special cements, minimum cement contents, special aggregates or aggregate gradings and other like matters.*
- (2) Materials All materials should conform to the relevant Australian Standards.*
- (3) Cement type (refer to AS 3972) Cement should always be of the same type and come from the same cement plant for the duration of the job. Cement from different plants will be produced from different raw materials and, despite meeting the code requirements, will be a different shade or colour.*

It should not be necessary to store cements for a particular job.

- (4) Cement colour Grey, white and off-white cements can all conform to the relevant Australian Standards and offer the designer great scope for finish work.*
- (5) Cement content Surface finish work normally demands a higher paste content than normal structural concrete. Minimum cement contents of around 330 kg/m³ are typical.*
- (6) Aggregate type (refer to AS 2758.1) The type and colour of both the coarse and fine aggregates is important to finish quality. The sand in particular plays a big role in the colour of off-form surfaces and the aggregate colour is obviously important where it is intended to be exposed. Special treatments such as abrasive blasting and polishing demand careful selection of aggregates.*

Aggregates should come from the one source. It may be required that they be stockpiled for large jobs as the variations may occur throughout a quarry over an extended period. This stockpiling will normally have to be done at the quarry, as there is not usually adequate space at precast facilities or ready-mixed plants.

Flaky and elongated aggregates should be kept to a minimum as they detract from the ability to achieve good finishes of all types.

- (7) Aggregate grading This is vital to the production of surfaces with good quality for off form concrete, or to the production of exposed finishes with the required aggregate density. Sand contents for many finishes are required to be higher.*

Gap-graded aggregates are often used to get the required aggregate density in exposed work.

- (8) *Aggregate cleanliness* Special care shall be taken to avoid material that is deleterious to the finished surface. Standards tend to concentrate on structural considerations, and the impurities permitted for finish work may have to be significantly reduced, or even eliminated, for special work.
- (9) *Admixtures* Calcium chloride is the only admixture with a known adverse effect on colour, but this now should not be used in any reinforced or prestressed concrete built in accordance with AS 3600.
All admixtures, and the likely combinations and changes that may occur throughout a job, should be tested in the test panels to ensure they do not contribute to colour variation.
- (10) *Strength* While this in itself has no role in colour control, it should be noted that the strength required for finish work with colour control is unlikely to be less than 32 MPa.
- (11) *Water/cement ratio* Water content or, more precisely, variation in water content in a given mix, has a marked effect on colour variation. The addition of more water will produce a concrete that is lighter in colour. The slump of the concrete is a good guide in this matter, for if that varies significantly, then it is most likely that the water content has varied and the resulting colour will be different from that already produced.
- (12) *Pozzolans* Flash and blast furnace slag have a marked effect on concrete colour when added to a mix. Where they are used they should come from the same source, be used in the same percentage and be used throughout the job.

3.4.2 Special-class concrete

Where colour control is required, the concrete for this work shall be specified as 'special-class concrete' in accordance with AS 1379.

3.4.3 Acceptable tonal range

From the tonal range and gradation exhibited in Figure 3.4.4, the acceptable tonal range for the cast in situ and precast concrete is given in Table 3.4.3.

An acceptable tonal range not less than represented by the number of contiguous tones given in Table 3.4.3, shall be selected and specified in the project documentation.

TABLE 3.4.3
ACCEPTABLE TONAL RANGE

Class	Number of contiguous tones
1C	4
2C	5
3C	6

NOTE: See Figure 3.4.4.

C3.4.3 *The tonal range and gradation illustrated in Figure 3.4.4 is not intended to represent the actual colour of the concrete but to illustrate a sufficiently wide tonal range of the colour from which the acceptable tonal range can be selected. For example, Class 1 concrete may have a colour tone towards the dark end of the range in Figure 3.4.4, which would be acceptable provided the tone falls within the selected tonal range of not more than four contiguous tones. For the specified Class, by adding the suffix 'X' the project documentation may permit selecting a wider tonal range than the number of contiguous tones given in Table 3.4.3.*

Elements shall be deemed to conform, when evaluated in accordance with Clause 3.4.6, if they exhibit a—

- (a) range of tones which are not outside the selected tonal range; and
- (b) tonal gradation no greater than shown in the tonal range in Figure 3.4.4.

3.4.4 Tonal range and gradation

Figure 3.4.4 sets out the tonal range to be used for specification and evaluation of colour control.

For concrete that is grey in colour, the tonal range and gradation specified in Figure 3.4.4 shall be used. For concrete of other colours or where the grey is not within the range of Figure 3.4.4, the project documentation shall contain a suitable means of representing an equivalent tonal range and gradation.

NOTE: It is recommended that the selected tonal range be printed by a commercial printer using the CMYK values in Figure 3.4.4 and all parties to a contract agree to abide by the tonal range as printed.

C3.4.4 *So that there will always be a fair and consistent means of comparing the newly completed work, the method contained in this Standard involves the use of a graded grey tonal scale (see Figure 3.4.4), or its equivalent.*

For concretes other than grey, or where the tonal scale of Figure 3.4.4 is not suitable, a 'suitable means' of making the comparison should be included in the project documentation, or be available for inspection. This is necessary in the interests of fair tendering and the obligation of the project designer to fully inform the contractor. Examples of 'suitable means' are a painted colour scale and colour photographs.

The tonal range is not intended to represent an actual colour of the concrete but is intended to indicate a range from light to dark.

If a coloured tonal scale is specified, the gradation in colour should be of similar to those shown for grey concrete (which in 10 tonal steps goes from near white to near black). In the case of coloured photographs, these should show the outer limits of acceptable colour tones.

The project documentation should be consistent with the achievement of the required colour. It is therefore recommended that laboratory samples be made of a range of concrete mixes, to determine which mix will give the required colour. Naturally, this is done prior to completion of the project documentation.

C	0.89
M	1.26
Y	0.00
K	11.83
C	0.00
M	0.47
Y	0.08
K	15.49
C	1.54
M	1.55
Y	0.00
K	18.88
C	1.44
M	1.42
Y	0.00
K	23.59
C	1.86
M	1.41
Y	0.00
K	29.50
C	1.64
M	0.84
Y	0.00
K	34.51
C	1.25
M	0.81
Y	0.00
K	43.96
C	0.00
M	0.14
Y	0.41
K	51.92
C	0.00
M	1.64
Y	4.26
K	66.49
C	0.00
M	2.12
Y	5.06
K	69.27

NOTES:

- 1 Monitors and printers need to be properly colour calibrated to display colour correctly or consistently.
- 2 Methods for specifying colour control include tonal range and gradation similar to that in Figure 3.4.4 (for grey concrete) or photographs of laboratory samples.

FIGURE 3.4.4 TONAL RANGE AND GRADATION

3.4.5 Other colour imperfections

Rust and dirt stains, as well as visible pouring layers are unacceptable.

3.4.6 Evaluation of colour control

Where the colour control is being checked by use of a selected tonal range from within the range given in Figure 3.4.4:

- (a) Checks shall be carried out on concrete at an age specified in the project documentation [see Clause 2.2.3(c)(v)].

- (b) The selected tonal range shall be held against the surface area being examined from a distance which is not less than the greater of 2 m or the closest distance from which the concrete element will normally be viewed when the project is completed and a comparison shall be made between the colour of the concrete surface and selected tonal range.

The concrete age and light conditions at the time of evaluation is carried out shall be consistent for all elements with similar requirements.

For other cases, the method of evaluation shall be appropriate to the means used to record the selected acceptable tonal range (see Clause 2.2.3).

Elements of the permanent structure that exhibit a range of tones which are not outside the range of tones specified in the project documentation shall be deemed to conform with Clause 3.4.

C3.4.6 *The use of a tonal range guards against the approval problem that arises when supervisors endeavour to use an approved test panel for comparison purposes over a period of time. Test panels not only gradually change colour over time, but they are also subject to pollution, staining and damage. They are not an unchanging record of the approval state.*

In contrast, the tonal scale can be just that, provided that lighting conditions do not vary during viewing. Any alternative colour scale should also exhibit that feature.

For work which is to have the surface treated in some way, e.g. tooled or sandblasted, evaluation will take place when the concrete element has been poured and stripped prior to surface treatment. Some extra latitude can be extended with regard to minor tonal variations. For example, such matters as light hydration staining or light release-agent stains can be minimized by sandblasting or the like.

The viewing distance at which this comparison is made is very important. Tonal variations which would be considered unacceptable on concrete elements that can be examined at close quarters will become insignificant if the closest view distance is a lot greater, e.g. the upper level walls of multistorey buildings that can only be examined from similar buildings on the opposite side of the street.

This Standard contains very few direct statements that give unequivocal guidance on contract decisions. This Clause is one of them. If the subject work has tonal variations that are not outside those specified in the project documentation (taking the limitations of Table 3.4.3 into account), then that aspect of the permanent structure can be deemed to have conformed with the requirements of Clause 3.4.

The Clause does not state the converse deliberately. There may be situations where the subject work will be accepted, even though elements have tonal variations outside those specified. Examples could include—

- (a) some elements slightly darker (or lighter) overall than the specified tone, but with the overall effect acceptable; and*
- (b) some elements with local dark (or light) patches of colour, which do not detract from the overall appearance.*

3.4.7 Test panels for colour control

Test panels may be used to identify and record in the project documentation the acceptable range of contiguous tones, based on the maximum number permitted for the specified class (see Clause 3.4.3), from within the tonal range given in Figure 3.4.4 or its equivalent.

Test panels shall not be used for comparison to evaluate colour control of the completed work.

NOTE: Test panels should be provided irrespective of whether or not details of the test panels have been specified in the project documentation (see Clause 3.7.2).

***C3.4.7** Test panels for colour control perform two main functions. In the first instance, they validate that the construction methods and materials can achieve the level of colour control required. Second, by comparison with the tonal range in Figure 3.4.4, they allow selection of the particular contiguous tones, based on the number permitted for the specified class. It should be noted that this does not necessarily involve approval of the whole panel. In some cases it may be practicable to approve, and mark, part of the panel as representative of the tonal range to be achieved on the permanent structure.*

3.5 SURFACES PRIOR TO TREATMENT

3.5.1 General

Details of any surface treatment shall be specified in the project documentation, including details of—

- (a) off-form measurable tolerances and deviations (see Clause 3.5.2); and
- (b) test panels (see Clause 3.7).

NOTE: Surface treatment may be specified for the whole of Class 2 and Class 3 surfaces, but for only part of a Class 1 surface, see Table 2.2.3 Item 7.

3.5.2 Tolerances

The acceptable tolerances and dimensional deviations specified in Table 3.3.4.1 and Table 3.3.5.1 or in the project documentation shall apply to the concrete surface finish prior to surface treatment (see Clause 3.3.5.2).

NOTE: Recognition should be made of the facility for the surface treatment to remove irregularities. Tolerances and deviations less stringent than specified in Table 3.3.4.1 or Table 3.3.5.1 may then be appropriate, in which case the suffix 'X' would apply [see Clause 2.2.3(b)].

3.5.3 Colour control

The requirements of Clause 3.4 shall apply prior to surface treatment, where applicable.

3.6 REPAIRS

3.6.1 General

Where the surface does not achieve the specified quality of finish, repairs are acceptable for all classes, except for the case where the project documentation states that repairs to Class 1 are not permitted (see Table 2.2.3 Item 12).

The surface repair shall conform with the project documentation, the visual characteristics specified in Table 3.2.1, acceptable physical quality specified in Clause 3.3 and shall have acceptable surface details, appearance and, if applicable, colour within the selected tonal range specified in Clause 3.4.

Repairs should be carried out as soon as practical after form removal. The extent of repairs shall not exceed any limits specified in the project documentation.

NOTE: Where the project documentation specifies that blow hole, form tie holes or honey combing be repaired [see Clause 2.2.3(d)(iv)], the repairs shall satisfy the requirements of Clause 3.6.2. Although repairs are acceptable, they may not be judicious as the repaired surface may further compromise the specified quality of finish, colour control or durability.

C3.6.1 *This Standard is a performance document and, as such, it is focussed on the quality of the end product. The Clauses on 'Evaluation' make no distinction as to whether the product has needed repair to achieve acceptance or note. High-quality repairs are possible, and permission to repair defects is an opportunity to avoid rejection of the element in question.*

Consequently, in accordance with the requirements of this Standard, repairs to all classes of surface finish are acceptable. However, for Class 1 surfaces, the project documentation may include a statement prohibiting repairs (see Table 2.2.3 Item 12). It is recommended that such a decision be not made lightly. Even in a surface of the high quality of Class 1 it is possible to make minor repairs successfully.

3.6.2 Repair technique

The proposed repair technique shall conform with the requirements of the project documentation and be satisfactory in the following respects:

- (a) Structural characteristics.
- (b) Durability.
- (c) Durability of adhesion.
- (d) Appropriateness of materials.
- (e) Appearance (including surface finish, colour and texture).
- (f) Permeability of water retaining structures.
- (g) Any additional criteria, specified in the project documentation, prior to the performance of the repair work.

C3.6.2 *In this Clause the criteria relates to the evaluation of the proposed repair technique prior to its application. The purpose of this evaluation is to stop the repair work being undertaken prior to the detailed assessment of the problem.*

It would be usual for this proposal to be prepared and submitted by the site for consideration and permission. The wording of this Clause is not intended to place any responsibility for the success of the repair on those granting permission for the repair work. As in most cases, it is the work at the site that has created the need for repair, therefore it is the site that is expected to propose the repair technique and be responsible for its success.

3.6.3 Evaluation

The repair technique shall demonstrably conform with Clause 3.6.2 and the requirements of the project documentation (see Clause 2.2.3).

When repaired, the concrete surface finish shall satisfy the criteria for the specified concrete surface finish and shall be evaluated in accordance with Clauses 3.3.3.2, 3.3.4.2 and 3.3.5.2, as applicable.

3.6.4 Test panels to validate proposed repairs

Test panels should be provided for proposed repair (see Clauses 2.2.3 and 3.7).

NOTE: Repairs to form tie holes should be incorporated in test panels specified in Clauses 3.3.7 and 3.4.7, where applicable.

3.7 TEST PANELS

3.7.1 General

Test panels shall be provided as specified in Clauses 3.3.8, 3.4.7 and 3.6.4.

3.7.2 Application

Test panels shall be provided to validate the feasibility of design details and suitability of construction materials and processes to achieve acceptable standards for the physical quality, colour, colour control and repair of the concrete surface.

Test panels shall not be used—

- (a) to establish standards of acceptance which are more stringent than that specified Clauses 3.3, 3.4 and 3.6, or the project documentation; or
- (b) for evaluation of colour control of completed work (see Note 2).

NOTES:

- 1 Test panels may be used to establish agreed standards of acceptance or rejection for concrete surface features that are beyond the scope of this Standard.
- 2 Over time the colour of the test panel concrete will gradually change.
- 3 Where the mandatory test panels for the intended class of surface finish (see Table 2.2.3) has not been specified in the project documentation, in the event of a dispute, the maximum surface class applicable to the project should be assigned as the next lower class as defined in Table 2.2.3 where test panels are not required.

C3.7.2 The functions of the test panels to be produced as a preliminary part of the construction of the permanent structure are as follows:

- (a) *To check the feasibility of the design details. However, if the designer intends to use such test panels to evaluate appearance or performance characteristics, which may lead to redesign or change in design details, then he or she should allow adequate time in the preparation of the documentation to effect such design changes.*
- (b) *To check the builder's competence.*
- (c) *To check the suitability of materials and processes of construction which are to be used.*
- (d) *To establish standards for acceptance and rejection of the permanent work.*
- (e) *To give an opportunity for the evaluation of proposed repair techniques.*

In the design stage, before completion of the project documents, 'laboratory' samples may be needed to check that the specified concrete mix will produce the colour and surface texture envisaged. The need for this is covered in Clause 3.4.4. Laboratory samples are usually quite small, rarely exceeding 500 mm × 500 mm × 100 mm and often much smaller. Concrete testing laboratories can economically produce these in a range of concrete mixes, to aid the project designer in the preparation of the specification of 'special class concrete' which is almost always required for the cases where test panels are also needed. It should be pointed out that such samples are handmade in a laboratory and are therefore only representative of the aggregate and matrix proposed. The actual product will be manufactured using bulk materials and merchandised production methods and may vary to some degree from the sample.

For Classes 1 and 2, treated or not, involving work with colour control and areas with surface treatment, test panels are mandatory. For Class 3 areas the option is available to specify test panels. For Classes 4 and 5 the specification of test panels for surface quality purposes is specifically excluded. This does not, however, exclude test or prototype units for purposes other than surface quality.

3.7.3 Number of test panels

If there are no details given in the project documentation, a single test panel, or separate test panels, conforming with this Standard and consistent with the relevant surface area shall be provided.

Test panel(s) shall either be—

- (a) a single panel to serve more than one application (see Clause 3.7.1); or
- (b) separate panels for each application covered in Clause 3.7.1.

Project concrete elements may be used in lieu of discrete test panels.

C3.7.3 It is a matter for the project designer's judgement whether there are to be separate test panels, or if some of the functions are to be incorporated in the one test panel.

3.7.4 Test panel design and construction

Test panels shall contain accurate representations of the completed work and conform with the details given in the project documentation [see Clause 2.2.3(e)].

The test panel(s) shall incorporate all relevant features of the surface (e.g. the form tie pattern and type, face steps, joints to adjacent elements, grooves, rebates, cast-in items, openings and corners) and shall be consistent with the requirements of the project documentation. The test panel(s) shall be of similar thickness and reinforced in a manner similar to the permanent concrete.

The design and construction of the test panel(s) shall take account of: the concrete constituent materials and admixtures; form face material; form reuse; release agent; application of release agent; rate and method of concrete placement; vibration; stripping; and repairs, where applicable.

C3.7.4 If a test panel is required to be held alongside the final work for its evaluation, this implies that it needs to be portable. This usually means being within the site crane's capacity but, in some cases, may mean being light enough to be carried by other means.

3.7.5 Evaluation of test panels

Test panels shall be evaluated in accordance with requirements of Clauses 3.3, 3.4 and 3.6, as applicable.

NOTE: Test panels may need to be used to evaluate several variants and combinations before arriving at an acceptable system.

C3.7.5 For surfaces with colour control, the appropriate test panel is used to fix the standard required of the final work. This test panel, when accepted by the project designer, fixes the maximum tonal (colour) range that will be accepted. However, it cannot be used in the future for that evaluation. In addition to the effects of pollution, the test panel will gradually change colour and the extent of colour change varies over time. Its use for evaluation of final work would lead to the imposition of gradually changing standards and unfair demands on the formworker. Also, the variations would be obvious in the final work.

3.7.6 Validity of test panels

The representations resulting from test panels only remain valid where there has been no substitution of materials, changes in design or construction practices. Test panels shall be repeated in the event of changes to materials, changes to design or construction practices.

NOTE: Substitution of materials may include changes in suppliers, sources of raw materials or types and grades of materials.

SECTION 4 STRUCTURAL REQUIREMENTS

4.1 SCOPE OF SECTION

4.1.1 General

The project documentation shall include all structural information necessary to design and construct the formwork.

This Section sets out the requirements for specifying—

- (a) limitations on construction loads (see Clause 4.2);
- (b) multistorey shoring (see Clause 4.3);
- (c) minimum stripping times and procedures (see Clause 4.4);
- (d) construction sequence (see Clause 4.5); and
- (e) specific information (see Clause 4.6).

4.2 CONSTRUCTION LOADS

4.2.1 General

The magnitude and distribution of vertical and horizontal construction loads imposed on the partially completed structure shall be assessed taking account of the minimum concrete strength and stiffness achieved prior to the application of the loads.

Formwork shall be designed to resist action combinations that arise during construction and act on the partially completed structure taking account of the minimum concrete strength and stiffness achieved.

The following shall be specified in the project documentation:

- (a) The loads for which the permanent structure is designed.
- (b) Permission to use parts of the structure or elements of the structure to support or restrain the formwork, including any limitations.
- (c) Maximum permitted construction loads and any limitations on the locations of these loads.
- (d) Information on the redistribution of construction loads on the formwork.

NOTE: See Clause 2.2.4(a).

C4.2.1 *The intention of Clause 4.2 is to specify information required to ensure the formwork designer is properly briefed regarding the permanent structure capacity to resist imposed construction loads without overload.*

Communication of the loads for which the structure is designed provides important information for the design of the formwork.

To avoid possible overload, permission needs to be granted in the project documentation to apply vertical and horizontal construction loads directly on the structure (not necessarily by the formwork), including the maximum permitted load and any limitations on where it can be imposed, e.g. loads from stacked materials, fork lifts, formwork hoists, etc. Otherwise, the permanent structure cannot be used as it may be inadequate for the purpose and lead to formwork instability or the permanent structure may be damaged in an unexpected manner.

4.2.2 Post-tensioning and pre-stressing

The magnitude and location of any redistribution of vertical and horizontal construction loads the formwork shall support, as well as any concrete movements that may occur as a result of the effects of post-tensioning or prestressing shall be specified in the project documentation.

In addition, the project documentation shall specify any formwork provisions necessary to avoid restraint to the contraction of the concrete or compression of the forms.

C4.2.2 During construction, formwork loads may be redistributed from the formwork to other parts of the permanent structure still supported by formwork. In these circumstances, without specific information in the project documentation overload may occur, e.g. during post-tensioning or release of prestress.

Prior to stressing, members to be post-tensioned may be more vulnerable to damage by cracking, by virtue of the relatively low content of unstressed reinforcement compared with reinforced concrete. It is recommended that particular attention be devoted to this aspect, if it is required that forms be stripped in accordance with Clause 4.4.3.2. For the same reason, reshoring is not recommended prior to stressing.

Post-tensioned and prestressed members are frequently design with tendons profiled to balance deflections due to gravity loads. On stressing, an upwards camber, lifting the member free of the forms, may result. Particularly in slabs, attention needs to be paid to the sequence of stressing, and the effects on the member and its supports. For example, if a slab were stressed first in one direction only, lifting from the forms could leave it unsupported in the other direction, yet to be stressed, with a consequent risk of cracking.

To avoid restraints to the contraction of the concrete, it is often necessary to remove or relieve forms before stressing. Also, stressing may compress the forms and render them difficult to strip, unless due provisions such as sliding joints have been specified.

4.3 MULTISTOREY SHORING

4.3.1 General

In multistorey construction, where one slab does not have adequate strength to support the loads imposed by construction of the next slab, multistorey shoring shall be provided to share the construction load, either—

- (a) to a rigid base; or
- (b) between an adequate number of suspended slabs.

The method (i.e. undisturbed shoring or reshoring) and details of multistorey shoring (i.e. minimum number of levels, layout and specific supports), as well as the anticipated load distribution between the slabs and the assumptions upon which the multistorey shoring design is based, shall—

- (i) conform with the requirements of AS 3600;
- (ii) conform with the requirements of Clauses 4.3.2, 4.3.3 and 4.3.4;
- (iii) be based on information provided in the construction and formwork documentation; and
- (iv) be specified in the project documentation [see Clause 2.2.4(b)].

The anticipated load carried by each slab connected by multistorey shoring shall be determined from analysis of the interaction of slab deflections and multistorey support loads (see Clause 4.3.3).

C4.3.1 *In the construction of multistorey structures, estimating the load share between slabs connected by multistorey shoring is complex and requires detailed knowledge of the: early-age, short and long term behaviour and capacity of the permanent structure; construction method; loading and sequence; and strength and elastic stiffness of formwork and multistorey supports.*

Selecting the method of multistorey shoring, as well as the design and detailing of the multistorey shoring will require timely consultation and sharing of information, because it—

- (a) has significant time and cost consequences; and*
- (b) will almost certainly influence the selection and quantity of formwork and the construction schedule.*

4.3.2 Method of multistorey shoring

4.3.2.1 General

The method of multistorey shoring selected shall either be—

- (a) undisturbed shoring (see Clause 4.3.2.2); or
- (b) reshoring (see Clause 4.3.2.3).

4.3.2.2 Undisturbed shoring

Where the lowest set of undisturbed supports is seated on a rigid base, the sum of the actions on supports shall be not less than the sum of permanent and imposed actions on every level above the supports. Otherwise, the actions on the supports and connected slabs shall be determined from a rational analysis (see Clause 4.3.3).

4.3.2.3 Reshoring

The actions on the supports and connected slabs shall be determined from a rational analysis (see Clause 4.3.3).

4.3.3 Imposed construction load

In addition to the load imposed by multistorey shoring, the imposed construction load on any slab may include—

- (a) the weight of the formwork and multistorey supports; and
- (b) imposed variable actions from—
 - (i) workers and their equipment on the formwork;
 - (ii) stacked materials; or
 - (iii) other actions.
- (c) Combination of both (a) and (b) above.

NOTES:

- 1 Loads from workers and their equipment on the formwork are not considered to act concurrently at the same location with stacked materials.
- 2 Loads from concrete mounding may be neglected.

C4.3.3 *The weight of construction material or equipment stacked on soffit formwork or on any of the slabs carrying a share of the load is likely to increase the number of levels of shoring and needs to be taken into account. This may be achieved economically by limiting the magnitude of the load from stacked materials and locations where stacking material is permitted.*

Additional multistorey shoring may be required to share the load imposed by construction equipment, such as loading platforms, forklifts, elevated working platforms, perimeter screens, personnel and material hoists, formwork hoists and concrete pump booms and concentrated buildings materials such as stacked plasterboard and stacked glazing. Where the location of the construction equipment is fixed, specific multistorey shoring may be introduced to share the imposed load; otherwise, the load from construction equipment should be considered to act concurrently with other construction loads and in the most adverse location.

4.4 MINIMUM STRIPPING TIMES AND PROCEDURES

4.4.1 General

Stripping of forms and removal of formwork supports from members cast in situ shall be in accordance with the requirements of AS 3600.

In addition, stripping procedures shall conform with Clause 4.4.2 and minimum stripping times shall conform with Clause 4.4.3.

Stripping procedures and times shall also be in accordance with the requirements for curing and protection of the concrete specified in AS 3600.

NOTE: Where forms are stripped before the end of the specified curing period, exposed concrete surfaces shall be cured until the end of the specified period.

4.4.2 Stripping procedure

Formwork stripping procedures shall be specified in the project documentation, where otherwise they have the potential to cause damage, unnecessary deformation, impact, eccentric loads or overload of the permanent structure or existing structure [see Clause 2.2.4(b)].

Forms shall not be stripped or any formwork supports removed until the concrete has attained sufficient strength to support, with safety and without detriment to its intended use, when subject to the most severe combination of imposed design actions. Except that the removal of forms or formwork supports may be acceptable, providing the forms or formwork supports are replaced by other temporary supports in a manner without detriment to safety and the concrete's intended use.

Stripping shall be carried out in a controlled and planned manner that ensures the gradual transfer of load, from the formwork or the formwork supports, to the permanent structure or existing structure.

Stripping procedures that have the potential to cause damage, unnecessary deformation, impact, eccentric loads or overload of the permanent structure or existing structure shall not be used.

When formwork is stripped in less than 18 hours after casting, extra care shall be exercised to avoid surface damage during stripping.

NOTES:

- 1 Removal of formwork supports under slabs and beams should commence at the centre of each span and progress outward to the permanent supports.
- 2 Where colour control is specified, forms should be stripped early, subject to the minimum times and procedures specified in the project documentation. Elements where colour control has been specified (see Clause 3.4) should be stripped at the same time after casting.

4.4.3 Stripping times

4.4.3.1 General

Stripping of formwork from in situ concrete shall not be undertaken earlier than as specified in the project documentation [see Clause 2.2.4(b)].

NOTE: Appendix C provides guidance for the documentation of stripping times.

In the absence of specific information in the project documentation, stripping times for formwork shall conform with—

- (a) stripping side forms of vertical faces;
- (b) stripping slab or beam soffit forms between undisturbed supports where control samples have been taken (see Clause 4.4.3.2); and
- (c) stripping slab soffit forms and removal of supports from under concrete slabs not supporting structures above—
 - (i) for reinforced concrete slabs (see Clause 4.4.3.2); and
 - (ii) for prestressed concrete slabs (see Clause 4.4.3.4).

NOTES:

- 1 Guidance is not provided for stripping times for the removal of formwork supports under slabs supporting structures above (see Clause 4.3).
- 2 The premature stripping of forms and removal of formwork supports could be detrimental to the strength and durability of the concrete.
- 3 Economies of early stripping may warrant adoption of more accurate methods of assessing concrete strength.

4.4.3.2 Stripping slab or beam soffit forms between undisturbed supports

Slab and beam soffit forms between undisturbed supports shall not be removed unless in accordance with Clause 17.6.2.3 of AS 3600.

4.4.3.3 Stripping of soffit forms and removal of supports from under reinforced concrete slabs not supporting structures above

Formwork and supports under-slabs not supporting structures above shall not be removed unless in accordance with Clause 17.6.2.5 of AS 3600.

4.4.3.4 Stripping of soffit forms and removal of formwork supports under prestressed concrete slabs and beams not supporting structures above

Formwork and supports under prestressed slabs and beams not supporting structures above shall not be removed unless in accordance with Clause 17.6.2.7 of AS 3600.

NOTE: Clause 2.2.4(a)(v) requires the project documentation to provide information on the magnitude, location and any redistribution of construction loads the formwork needs to support that may occur as a result of post-tensioning or prestressing procedures.

4.5 CONSTRUCTION SEQUENCE

4.5.1 General

If critical, the sequence and any limitations on the timing of construction of concrete elements shall be specified in the project documentation [see Clause 2.2.4(c)(i)].

The location and details of any mandatory joints or delayed pour strips within a concrete element or between concrete elements shall be specified in the project documentation [see Clause 2.2.4(c)(ii)].

In addition, the details of and any special procedures for locating construction joints within concrete elements shall be specified in the project documentation [see Clause 2.2.4(c)(iii)].

C4.5.1 *Situations where the sequence of construction is critical include structural designs that involve: 'hanging' concrete elements from the structure above; coupling post-tension cables, corbels and the staged construction of large concrete elements, where the initial stages of construction are used to support subsequent stages.*

The sequence and timing of placement of concrete in adjacent elements can sometimes be critical. For example, it may be necessary to specify that columns be not poured integral with the slabs they support.

The timing of the construction may be critical where concrete needs to attain specified strengths prior to imposing additional construction loads, e.g. the strength of columns and walls before the application of vertical and horizontal construction loads and setting minimum multistorey construction cycles.

Constructions joints may be unavoidable, e.g. horizontal construction joints in lift and stair shaft wall, vertical construction joints in long walls and vertical and horizontal construction joints in large or complex elements.

If a concrete pour is interrupted it may be necessary to provide emergency construction joints in accordance with the requirements of the project documentation.

4.6 SPECIFIC INFORMATION

4.6.1 General

The project documentation shall provide specific information, where applicable, in relation to—

- (a) composite construction (see Clause 4.6.2);
- (b) permanent form systems (see Clause 4.6.3);
- (c) concrete behaviour (see Clause 4.6.4); and
- (d) foundations (see Clause 4.6.5).

4.6.2 Composite construction

For composite construction, the project documentation shall be in accordance with the requirements of AS 2327 and provide the location, layout, details, any special requirements for the erection, concreting and removal of any supports and/or bracing.

4.6.3 Permanent form systems

For permanent form systems, the project documentation shall provide—

- (a) the location, layout and details of any supports, bracing, sealing;
- (b) any limitations on deflections; and
- (c) any special requirements for the erection, concreting and removal of any supports and/or bracing.

NOTES:

- 1 Section 3 tolerances do not apply to permanent form systems and should be specified in the project documentation.
- 2 If the surface texture of the permanent form is important, information for its protection should also be provided.

4.6.4 Concrete behaviour

The project documentation shall provide information necessary to take account of the effects of concrete shrinkage, creep and axial shortening, which may include details of—

- (a) pre-camber of horizontal forms to allow for deflection or long-term creep deformation under gravity loads as specified in the project documentation;

- (b) pre-inclination of vertical forms to allow for subsequent curvature of vertical elements due to differential axial shortening;
- (c) early stripping of small areas around the tops of columns or the provision of slip joints to prevent damage to the concrete; and
- (d) early stripping of corner sections to reduce tension cracking in the concrete during curing.

C4.6.4 *Pre-inclination of vertical forms, such as lift shaft formwork on high-rise buildings, may be necessary to counterbalance curvature of the element due to differential axial shortening as a result of asymmetric loading, e.g. where lift shaft walls step in progressively from one side, the wall concrete on the tallest side is more heavily loaded and therefore subject to greater axial shortening. This can be addressed by measured pre-inclination of the formwork toward the more lightly loaded side.*

The project documentation should make provision for the effects of shrinkage and creep of concrete in the formwork. In some cases, it may be desirable to specify stripping small areas of formwork around concrete columns or to provide a slip joint to prevent damage to the concrete itself. The problem is common in the precasting of hollow cellular units for bridges. Specifying early stripping of corner sections materially assists in the reduction of tension cracking in the concrete during curing. Examples of cracking are shown in Figures C4.6.4(A) and C4.6.4(B).

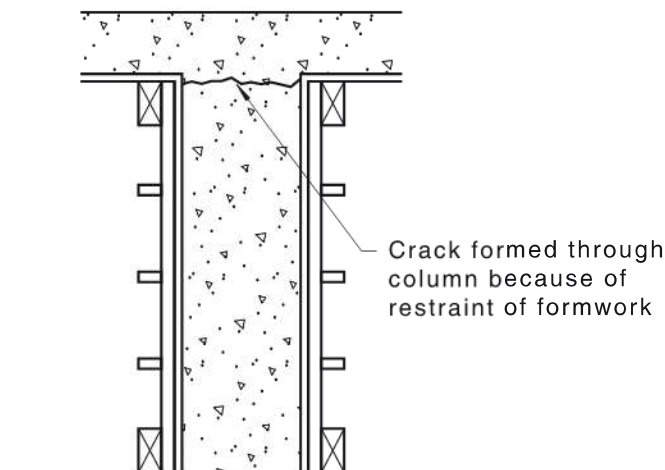


FIGURE C4.6.4(A) EXAMPLE OF SHRINKAGE OF LONG COLUMNS

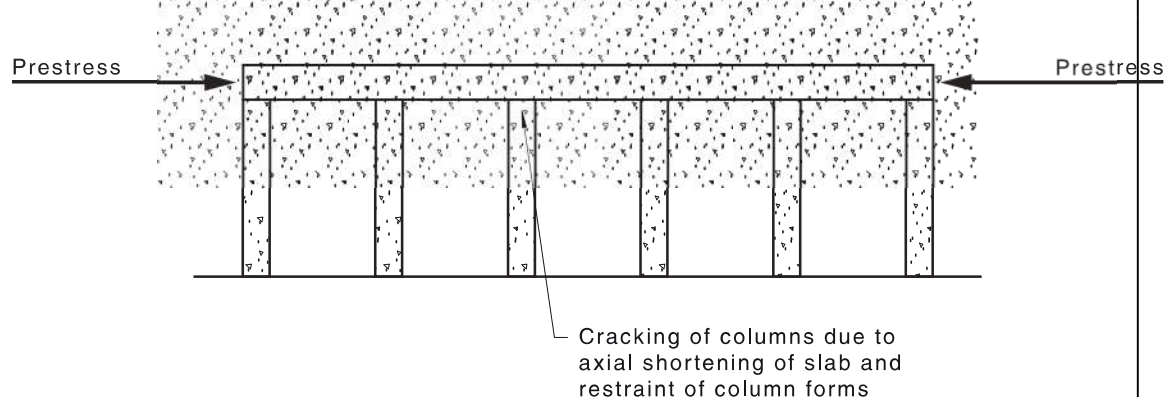


FIGURE C4.6.4(B) EXAMPLE OF AXIAL SHORTENING OF SLAB

4.6.5 Foundations

Where formwork is supported directly on the surface of foundation material and information on its bearing capacity and settlement characteristics are known, that information should be specified in the project documentation.

Where concerns relating to settlement of forms supported from the surface of the ground exist, the project documentation should specify that an alternative footing system shall be provided, e.g. piles or bridging between the footings for the permanent structure.

NOTE: A geotechnical investigation of the site may also need to address footings for formwork.

4.6.6 Inserts and penetrations

To ensure the safety and serviceability of the permanent structure is not impaired, the project documentation shall specify guidelines and limitations on the locations of inserts and penetrations to be constructed for services, e.g. plumbing, electrical, air-conditioning.

C4.6.6 Often inserts and penetrations are not specifically detailed on the structural drawings, consequently they may be inadvertently constructed in critical structural locations.

APPENDIX A
FORMWORK IMPORTANCE LEVEL
(Normative)

A1 GENERAL

Table A1 sets out importance levels that apply to formwork in different situations. Where there is a choice, or doubt, between importance levels, the highest appropriate importance level shall apply.

Where the importance level is not specified in the project documentation, the formwork designer shall make an assessment based on the available knowledge of the applicable conditions.

TABLE A1
IMPORTANCE LEVEL FOR FORMWORK IN DIFFERENT SITUATIONS

Importance level	Consequence of failure	Situations
I	Formwork, whose failure poses a risk to few people and has small or negligible economic, social or environmental consequences	Formwork to the sides of shallow footings and slabs Formwork for the side of small walls and columns, up to 2 m high Horizontal formwork that supports concrete whose soffit is less than 3 m above the lowest surrounding ground level and whose plan area is less than 16 m ² , providing the concrete to be placed has a volume of not more than 2.5 m ³ Formwork in areas where access is prevented, such that few people would be put at risk in the event of its failure
II	Formwork not in other importance levels	All formwork not in other importance levels
III	Formwork, whose failure poses a risk to people in crowds or has great economic, social or environmental consequences	Formwork on the perimeter of high-rise buildings in populated areas Formwork lifted over busy streets Bridge formwork spanning over major arterial roads Formwork in environmentally sensitive areas Suspended or cantilever formwork, e.g. formwork supported off cantilever needles, climbform, slipform, jumpform, etc. Formwork that would otherwise fall into importance level II, and whose— (a) mode of failure is sudden and without warning; or (b) design, construction or materials are new, novel or unusual.

NOTES:

- 1 Importance levels I, II and III are comparable with importance levels 1, 2 and 3 in AS/NZS 1170.0, respectively.
- 2 The obligation and competence for formwork design verification appropriate to each level of importance is given in Clause 2.4.

APPENDIX B
EVALUATION BLOWHOLE PHOTOGRAPHS
(Normative)

B1 GENERAL

The blowhole photographs in Figures B1 to B3 are intended for use in the evaluation of completed work.

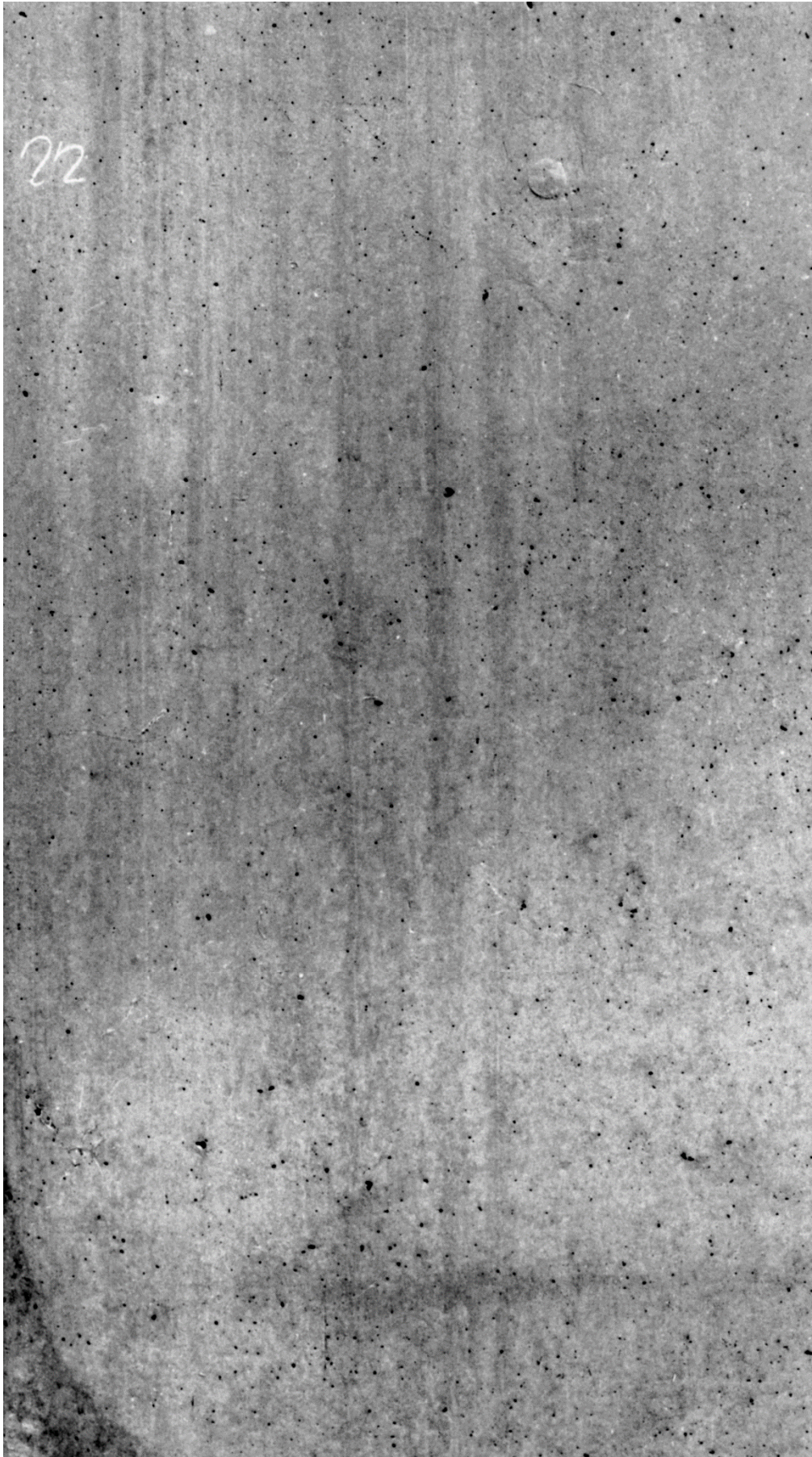
B2 BLOWHOLE EVALUATION PHOTOGRAPHS

The photographs in Figures B1 to B3 illustrate the acceptable limits for blowhole size and distribution for Classes 1, 2 and 3, as specified in Clause 3.3.2 and shall be used only for evaluating the completed work in accordance with Clause 3.3.3.2(a).

Photographs are in pairs consisting of—

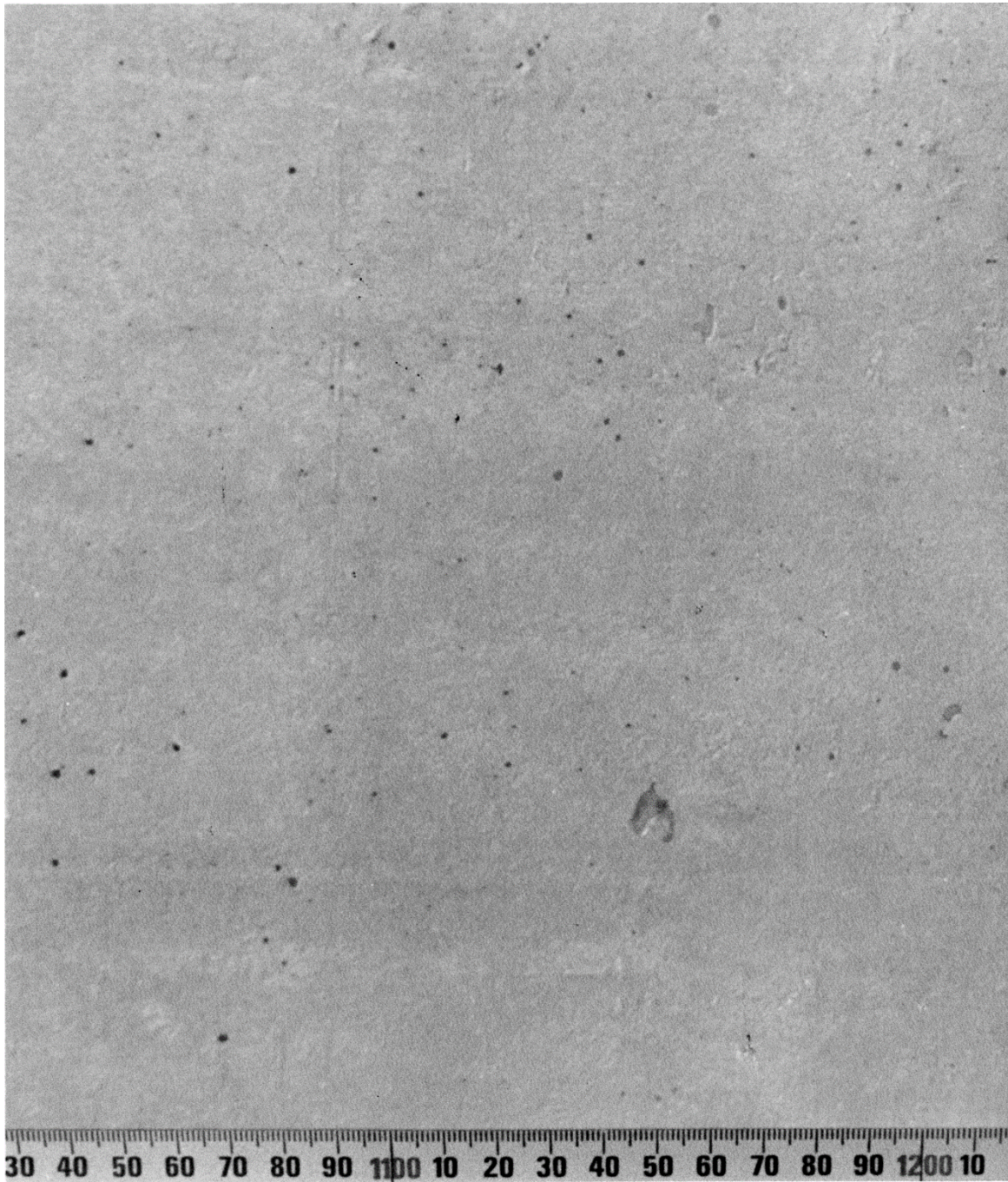
- (a) a general photograph at scale 1:5, which gives a clear example of expected variation in blowhole size and distribution; and
- (b) a close-up photograph at scale 1:1, which shows an area that is representative of the general photograph.

NOTE: It is possible that there will be small sections of the 1:5 scale photograph that exhibit a greater concentration of blowholes, or ones of larger size than are shown in the 1:1 scale photograph. This is consistent with the intention of Table 3.3.2.



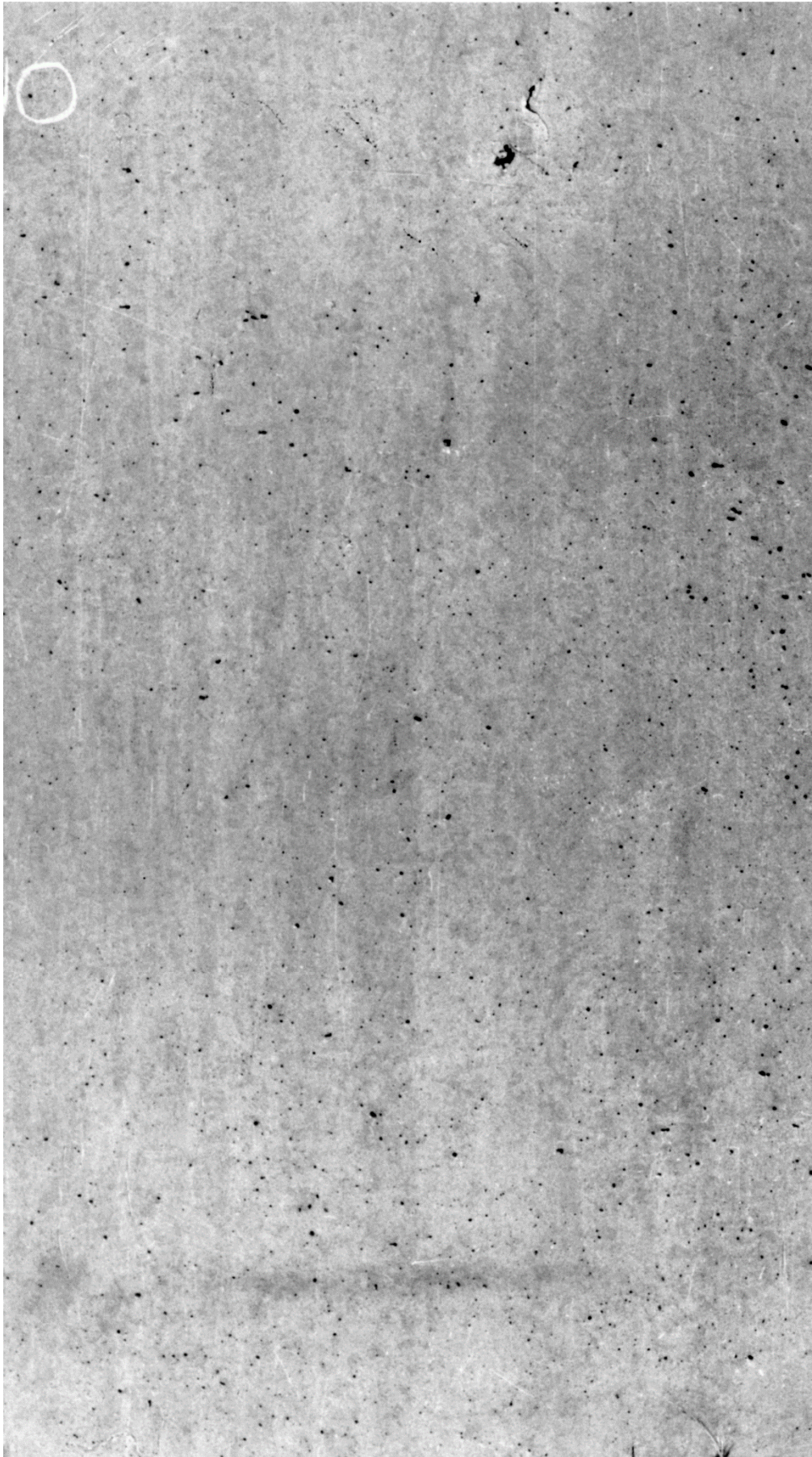
(a) Scale 1:5

FIGURE B1 (in part) CLASS 1 FINISH



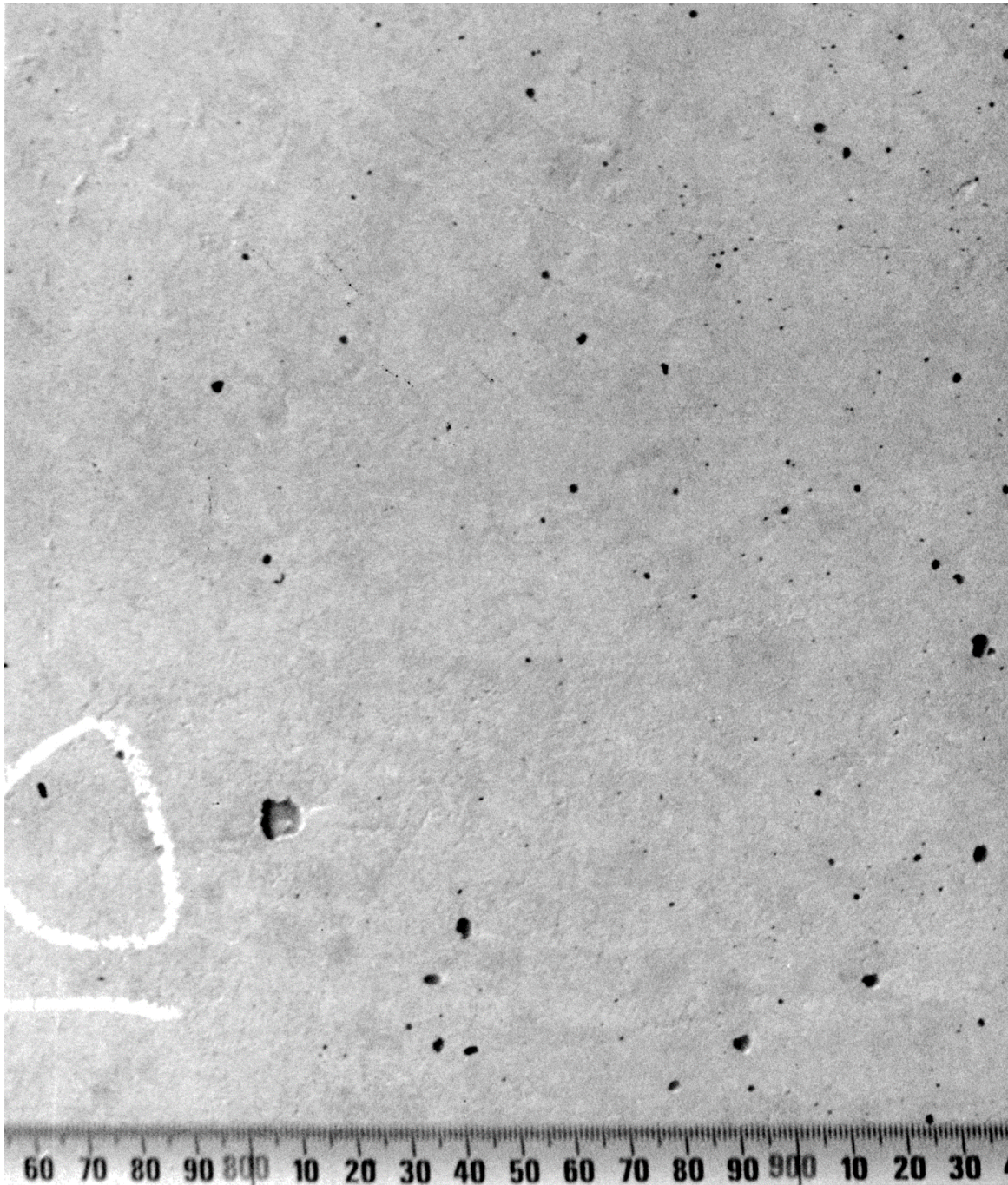
(b) Scale 1:1

FIGURE B1 (in part) CLASS 1 FINISH



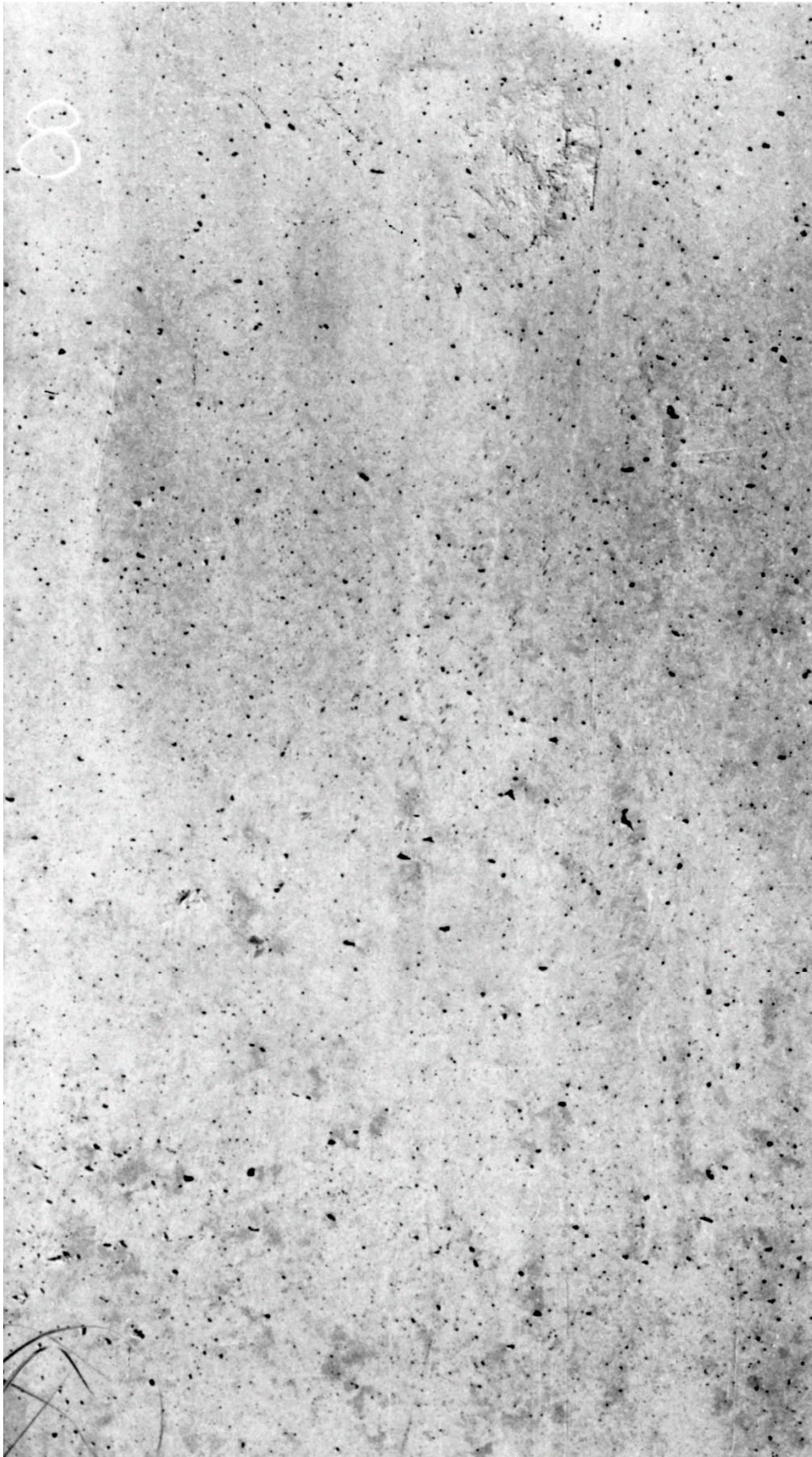
(a) Scale 1:5

FIGURE B2 (in part) CLASS 2 FINISH



(b) Scale 1:1

FIGURE B2 (in part) CLASS 2 FINISH



(a) Scale 1:5

FIGURE B3 (in part) CLASS 3 FINISH



(b) Scale 1:1

FIGURE B3 (in part) CLASS 3 FINISH

CB2 Experience has shown that the evaluation of surface quality is difficult when the requirements are expressed as written descriptions of acceptable defects, or as stated levels of various-sized blemishes per unit area.

The visual effect of any defect relates to the proximity to other defects as well as to its size and nature.

To answer this problem, the method adopted in this Standard has been the use of pairs of photograph, at 1:5 and 1:1 scales, i.e. examples of the maximum level of defects permitted in each class. The photograph should be held up against the area being evaluated to determine whether the surface of the element reaches its specified standard. This still involves the subjective comparison of the photograph and the work, but is considered to be a fairer and more accurate assessment than the use of numerical parameters.

One problem that cannot be adequately addressed by the use of these photographs is the grouping of blowholes. Small blowholes that would be difficult to see from a distance as individual defects, become very obvious when they are clustered in small groups. This is a case where subjective judgement is applicable.

APPENDIX C
STRIPPING CRITERIA
(Informative)

C1 SCOPE

This Appendix may be used as a guide for the documentation of stripping times for the following formwork:

- (a) Side forms of vertical faces—stripped in accordance with Paragraph C2.
- (b) Soffit forms spanning between undisturbed supports—stripped in accordance with Paragraph C3, provided the supports remain undisturbed.
- (c) Soffit formwork (forms and supports)—stripped in accordance with Paragraph C4.

NOTES:

- 1 Guidance is not provided for stripping times for formwork and supports under slabs supporting structures above or post-tensioned concrete slabs.
- 2 The stripping times set out in this Appendix may be less than those specified in AS 3600.
- 3 The early stripping of formwork could be detrimental to the strength and durability of the concrete.

CC1 Economic considerations often determine that it is necessary to remove the formwork soffit as early as possible. This is usually achieved by either a single or a two stage process such as undisturbed supports or backpropping. These processes are defined in Section 1. The safe ages for both the initial soffit form stripping and the later support removal needs to be determined.

For the first stage, initial soffit form stripping, Paragraph C3 neglects the influence of reinforcement and specifies the minimum concrete strength that ensures the slab section remains uncracked.

For slabs not supporting structures above, Paragraph C4 provides guidance for removal of formwork for a single stage or the removal of supports for the second stage of a two-stage process.

It is commonplace to stack materials for later activities on the surface of newly cast slabs, often before the next set of formwork is constructed. Prior to stripping, this load is supported by the formwork, and after stripping it is carried by the concrete structure. Particular attention is required in determining stripping times where stacked materials are present.

C2 VERTICAL FACE FORMWORK

Table C2 may be used in the case of stripping forms from vertical faces.

TABLE C2
VERTICAL FACE FORMWORK MINIMUM STRIPPING TIMES
AFTER CASTING

Classification	Average temperature		
	Greater than 20°C	Between 12°C and 20°C	Between 5°C and 12°C
Class 1, Class 2 or Class 3 (see Note 1)	1 d	2 d	3 d
Class 4 or Class 5	9 h	12 h	18 h
All	A minimum of 1 d applies to the stripping of vertical faces where frost damage is likely		

NOTES:

- 1 In the absence of site recording, local temperatures are usually available from the Australian Bureau of Meteorology.
- 2 Where colour control is specified, it is advisable to strip forms early, subject to the limitations given. Elements intended to have the same colour should be stripped at the same time after.
- 3 Generally, vertical forms should not be stripped before the concrete has reached a minimum mean compressive strength of the following:
 - (a) Class 1, Class 2 or Class 3 formwork—5 MPa.
 - (b) Classes 4 and 5 formwork—2 MPa.
- 4 Forms should not be left unstripped for an extended period of time.
- 5 Ideally, formwork should be stripped from vertical surfaces normal to the surface. For large forms this is impractical and a ‘peeling’ action should be adopted.

C3 SLAB OR BEAM SOFFIT FORMS BETWEEN UNDISTURBED SUPPORTS WHERE CONTRL SAMPLES HAVE BEEN TAKEN

Slab and beam soffit forms between undisturbed supports should not be removed unless in accordance with Clause 17.6.2.3 of AS 3600.

The requirements of Clause 17.6.2.3(b) of AS 3600 may be met if the following inequality in Equation C3 is satisfied:

$$f'_{ce} \geq \left(\frac{W_d}{600} \right)^2 \left(\frac{l}{d_c} \right)^4, \text{ MPa} \quad \dots \text{ C3}$$

where

- W_d = most severe combination of strength limit states design loads due to construction activity on the slab at time of stripping, in kilopascals
- l = span between undisturbed supports, in mm
- d_c = the depth of the slab, in mm
- f'_{ce} = minimum early age characteristic compressive strength of the concrete required before stripping, in megapascals

C4 REMOVAL OF FORMWORK FROM UNDER-SLABS NOT SUPPORTING STRUCTURES ABOVE

The requirements of Clause 17.6.2.5(a) of AS 3600 may be met provided the following inequalities in Equations C4(1) and C4(2) are satisfied:

$$\left(\frac{w_c}{w_s} \right) \leq 1.0 \quad \dots \text{C4(1)}$$

and

$$\left(\frac{w_c}{w_s} \right) \leq \left(\frac{f'_{ce}}{f'_c} \right)^{0.6} \quad \dots \text{C4(2)}$$

where

w_c = most severe combination of unfactored loads due to construction activity on the slab at time of stripping, in kilopascals

w_s = unfactored design service load for the permanent structure taking account of any applicable reduction factors, in kilopascals

= sum of permanent and imposed loads (specified in the project and construction documentation) on the permanent structure

f'_{ce} = minimum early age characteristic compressive strength of the concrete required before stripping, in megapascals

f'_c = 28 day characteristic compressive strength of the concrete, in megapascals

At the time of stripping (less than 28 d), usually only the mean grade compressive strength is known. Typically, the mean grade compressive strength is determined from testing cylinder specimens, but may be converted to a characteristic strength by the following criterion in Equation C4(3):

$$f'_{ce} = f'_{cm} - k_c s \quad \dots \text{C4(3)}$$

where

k_c = an assessment factor determined on the basis of the number of samples

s = standard deviation of the specimens tested

Appropriate values for k_c and methods for determining s are set out in AS 1379.

APPENDIX D
ARCHITECTURAL REQUIREMENTS
(Informative)

D1 SCOPE

This Appendix may be used as a guide to understanding Section 3, Architectural Requirements, in particular surface finish and colour control or plain concrete surfaces left off-form prior to surface treatment or coating.

D2 CLASSES OF SURFACE FINISH AND COLOUR CONTROL

In most cases the concrete in the permanent work has more than just a load-bearing function—it is also required to have a visual quality that will contribute to the aesthetic value. Clause 3.2 and its sub-Clauses are concerned with guiding the project designer in the selection, specification and detailing of surface classes and features that are appropriate to the intent and purpose of the permanent structure. Specifying more stringent requirements than are realistic for a particular class, especially Class 1, will be counterproductive because they are not achievable.

The clear and lucid communication of the project designer's intentions does not automatically make them practicable and achievable. The size of each concrete element, the details of its shape, reinforcement arrangement and access for concrete placement needs to be compatible with concrete pouring, its free movement and thorough compaction. Thin sections, congested reinforcement and large pours all inhibit the consistent achievement of quality of finish. For example, the shape of precast bridge girders, combined with the limitation on concrete access, due to ducts and reinforcements, makes the achievement of a high-quality surface finish almost impossible.

Where surfaces are designed to have a pattern of grooves, some of these can be used as locations for construction or control joints. Construction joints in plane surfaces are usually visible from a great distance, but when placed in grooves they are rarely obvious, being dominated by the stronger visual effect of the grooves.

The project designer has an obligation to be aware of contemporary and local construction practices, and to tailor his or her designs to suit the available materials, technology and accepted standards of workmanship. One example is the use of slipform construction for concrete walls in high-rise construction. For building work, the usual standard achieved with slipform is Class 4. Only in particular cases where there is a very 'clean' shape and stringent supervision can Class 3 be achieved. The problem is not only one of wider tolerances, but also one of surface texture. The banding effect in the surface colour also makes it unsuitable for colour control.

Another simple example is found with circular columns constructed with spirally wound forms. These create a spiral groove on the surface. Checking this groove under the provisions of Clause 3.3.5 will show that it is not a face step, but can be regarded as a 'surface pattern detail'. For Classes 2 and 3 these spiral forms needs to be specified (Table 2.2.3 Row 4) if they are to be acceptable. For Class 4, where no specification of surface patterns is permitted, these forms could be used without restriction.

Even if all the above matters are thoughtfully incorporated in the design, the final product can be marred by difficulties in stripping the forms. The need to forcibly strip forms often results in tool marks and surface damage on what could have been high-quality surfaces.

This Standard is not limited to in situ concrete. Special Clauses relating solely to precast concrete are provided in addition to the general clauses, covering both forms of construction.

The requirements of this Standard are based on a realistic appraisal of the achievable standards of contemporary workmanship. Project designers are advised not to seek a quality of work which is beyond reasonably achievable standards. This theme runs consistently through this Standard. An example of this is the restriction placed on the method of specifying exceptions and extras to the surface classes. This effectively precludes the specification of anything more stringent than the Class 1 defined in this Standard.

This Standard recognizes that much of the concrete work that is visual has some type of surface treatment, e.g. grit blasting, bush hammering, jack picking. Clauses are given that cover specification details, test panels and evaluation. However, the selection of the type of treatment is not considered other than in Table 3.2.3, as this is at the project designer's discretion. Table 3.2.3 notes that Class 1 is only recommended for use in very special features of buildings of a monumental nature and is not to be specified where the whole surface of an element is to be treated.

The project designer should select a surface class appropriate to the selected treatment. For light grit blasting Class 2 is appropriate, but for heavier processes such as deep tooling, Class 3 would be adequate.

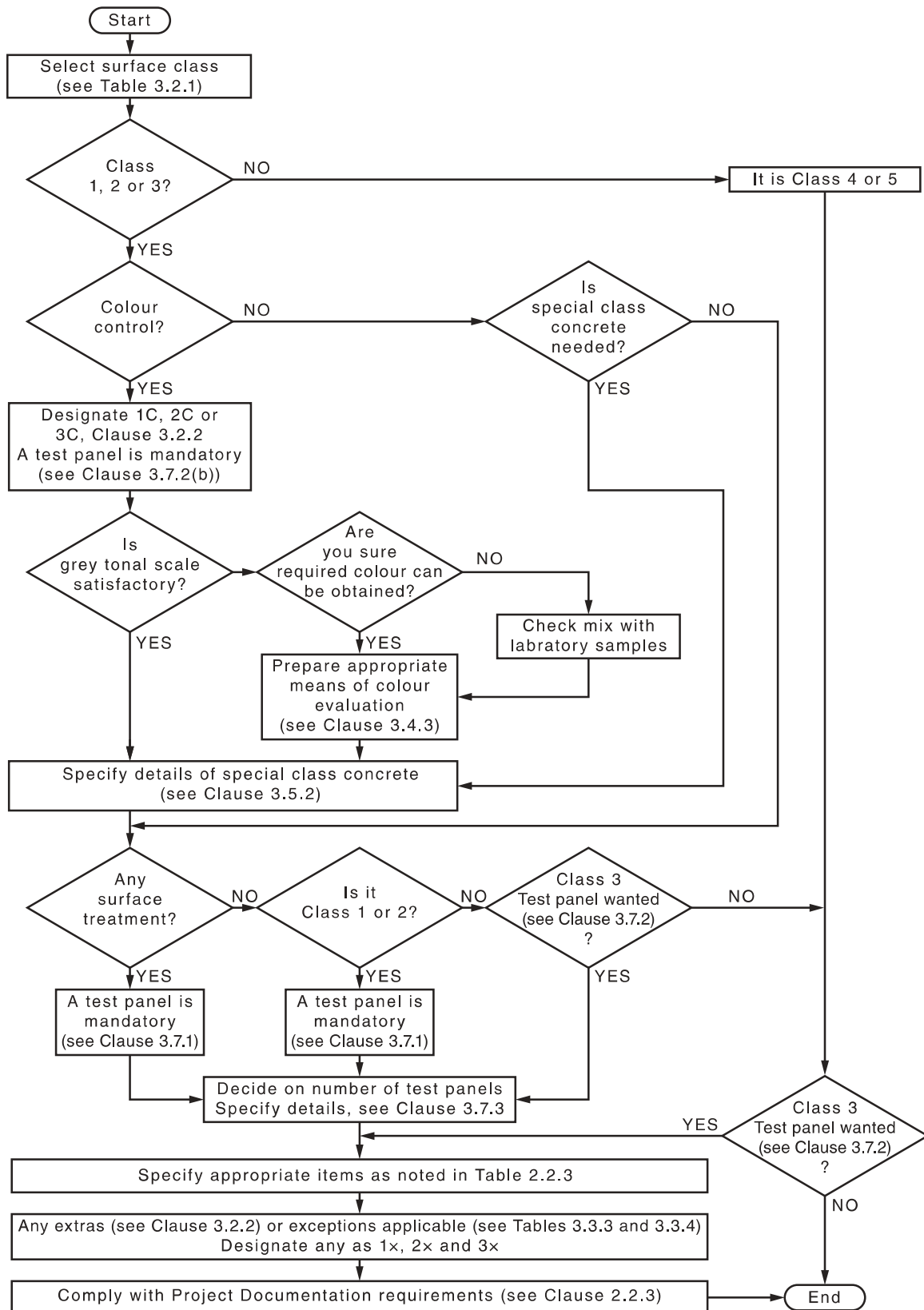
For treated surfaces, evaluation is a two-stage process. The first occurs prior to treatment, when the as cast surface is evaluated. The second occurs after treatment.

Where form liners are to be used to give a selected pattern or texture, a situation similar to that of surface treatment exists with respect to selection of surface class.

If a thin liner is used on a Class 3 surface, the permitted face step of 3 mm to 5 mm may cause an unsightly line. Class 2 would be more appropriate in this case. For thick liners, such as rope, Class 3 is suitable. However, an overriding factor could be colour control. Even where thick liners are used, it may be more appropriate to specify Class 2 because of its tighter colour control.

The concrete surface classifications can also be useful in fixing the demarcation between the concrete work and that of following trades. For example, if it were specified that a Class 2 concrete surface was to be painted, it would be the responsibility of the concreters to patch and fill all blowholes down to the sizes permitted for Class 2 work. However, it would be the painter's responsibility to patch and fill all the smaller blowholes prior to painting.

Table 3.2.3 assists the project designer in the selection of the surface class most suitable for the intended purpose. As shown in Figure D2, the subsequent Clauses cover the decisions that are to be made and communicated in the project documentation.



NOTE: This flowchart is to provide assistance on the recommended procedure to be followed.

FIGURE D2 FLOWCHART FOR SECTION 3

D3 PHYSICAL QUALITY

D3.1 General

Physical quality is concerned with accuracy, alignment, surface texture and visible features. Physical irregularities and their possible causes are listed in Table D3.1.

TABLE D3.1
PHYSICAL IRREGULARITIES AND THEIR POSSIBLE CAUSES

Common term	Description	Possible causes
Blowholes	Individual cavities usually less than 12 mm diameter	<i>Formwork:</i> Impermeable face; too flexible; poor wetting characteristics; inclined top form <i>Release agent:</i> Incorrect <i>Placing method:</i> Poor compaction; slow pour rate; external vibrators <i>Concrete mix:</i> Too lean, coarse sand; low workability
Mortar or grout loss	Sand textured areas usually associated with a dark adjoining surface	<i>Formwork:</i> Leaks at construction joints; formwork joints and tie rods
Honeycombing	Coarse stony surface with air voids, lacking in fines	<i>Formwork:</i> Joints leaking <i>Concrete mix:</i> Insufficient fines, low workability <i>Placing method:</i> Inadequate compaction; segregation <i>Design:</i> Reinforcement congestion; thin sections
Misalignment	Surface face step, wave or bulge	<i>Formwork:</i> Lack of rigid backing at joints of form face material; lack of form rigidity; distortion during form erection; damaged formwork
Plastic settlement cracking	Horizontal cracks usually located at reinforcement of changes in section	These are usually caused by plastic settlement of concrete in tall uniform elements or shorter ones at changes of cross-section, i.e. at points of restraint of settlement of concrete. Pay attention to concrete mix and workability, placing method and possible vibration
Crazing	A random pattern of fine cracks usually in a network spaced from 5 mm to 75 mm	<i>Forms:</i> Form face of low absorption, smooth or polished <i>Concrete mix:</i> High water/cement ratio and cement rich mix <i>Curing:</i> Inadequate <i>Stripping time:</i> Too early, especially in cold weather
Scaling, spalling or chipping, form scabbing	<i>Scaling:</i> Flaking off of the surface <i>Spalling:</i> Removal of surface layer <i>Scabbing:</i> Adhesion of parts of the form surface to concrete	<i>Formwork:</i> Difficult to strip; excessively rough <i>Release agent:</i> Inadequate <i>Stripping time:</i> Incorrect
Scouring	Irregular eroded areas and channels leaving exposed stone or sand particles	<i>Concrete mix:</i> Excessive water; insufficient fines; too lean <i>Placing methods:</i> Water in the forms; excessive vibration of high workability mixes
Grain imprint	The pattern of the grain of the plywood veneer is visibly imprinted on the concrete surface	<i>Formwork:</i> Inadequately sealed surface of ply formwork leading to moisture penetration of the top veneer of ply Formwork plywood is usually provided with a phenolic surface film which minimizes moisture penetration. The phenolic surface film is not impervious to moisture and to minimize moisture penetration and grain imprint, form oils or release oils needs to be applied regularly to provide supplementary protection and to seal penetrations of the phenolic surface film caused by normal construction wear. In the event of severe rain or weather events, formwork plywood needs to be protected from weather exposure. <i>Release agent:</i> Inadequate

TABLE <INSERT NUMBER> (continued)

D3.2 Colour control

Colour control is concerned with tonal ranges and gradation. Colour variations and possible causes are listed in Table D3.2.

TABLE D3.2
COLOUR VARIATIONS AND POSSIBLE CAUSES

Common term	Description	Possible causes
Inherent colour variation	Noticeable differences in the colour of areas having other similar physical characteristics	<i>Materials:</i> Change in source or type <i>Concrete mix:</i> Incomplete mixing; segregation or variation proportions; variation in water/cement ratio
Hydration discolouration	Significant variations in colour with quite dark areas caused by localized variations in water/cement ratio	<i>Formwork:</i> Variable absorbency; leaking of forms <i>Release agent:</i> Uneven or inadequate application <i>Curing:</i> Uneven, relaxation of formwork before stripping
Aggregate transparency	Dark blotches of the size similar to large aggregate	<i>Formwork:</i> Too flexible <i>Concrete mix:</i> Gap graded; low sand content <i>Placing method:</i> External vibration
Negative aggregate transparency	Light-coloured areas of the size similar to the aggregate	<i>Materials:</i> Aggregate dry or lightly porous <i>Curing:</i> Too rapid drying
Segregation discolouration	Speckled or flecked surface varying in colour	This is scouring over larger areas of the surface
Dye discolouration or contamination	Discolouration from materials in the mix, e.g. timber stains, pyrites	<i>Forms:</i> Stains on the form surface—sawdust; timber stains; hardwood forms; rust <i>Release agent:</i> Impure or incorrect <i>Materials:</i> Contaminated <i>Protection:</i> Inadequate <i>Curing materials:</i> Contaminated
Release agent discolouration	Cream or brown discolouration sometimes showing sand or coarse aggregate	<i>Release agent:</i> Excessive amount; low viscosity; impure; applied unevenly
Dusting	Light coloured, dusty surface which may weather to expose surface aggregate	<i>Curing:</i> Inadequate (rapid-drying) <i>Release agent:</i> Incorrect agent; excessive application <i>Stripping of forms:</i> Too early
Retardation	Matrix near the colour of sand and lacking durability	<i>Formwork:</i> Retarder on surface; reaction with timber constituents <i>Release agent:</i> Incorrect agent; incorrect application
Line bloom or efflorescence	White powder or bloom on the surface	<i>Release agent:</i> Incorrect type <i>Curing:</i> Uneven

D3.3 Evaluation of completed work and repairs

D3.3.1 General

It is not the intention that all concrete work should automatically be evaluated. It is expected that these procedures will only be used when there is some doubt about the acceptability of the completed element.

The comments here relate to the methods to be used in the evaluation of the completed concrete elements for acceptance or rejection. This applies to work that has been repaired as well as to the elements that may not require any rectification to reach the specified standard. This Standard does not limit the number of times that evaluation may be carried out after repair.

The intention of the requirements is to lay down fair procedures for the evaluation of the completed work, and to minimize the number of situations where subjective judgement is required.

Experience has shown that situations where judgement is based on personal opinion, rather than quantitative measurement, are those that lead to disputes and accusations of unfair treatment.

However, no set of requirements can possibly cover every circumstance. It is recommended that the project designer check that guidance is provided on all critical aspects of each project. For example, not all Clauses apply to precast work, and judgement needs to be used to check their suitability for each case. It may be necessary for the project designer to specify extra procedures for particular circumstances. In these cases it is recommended to avoid, wherever possible, writing specification clauses which call for the exercise of discretionary judgement.

D3.3.2 Physical quality

D3.3.2.1 General

The physical quality of the surface of concrete elements which require evaluation can be considered under the following two categories:

- (a) Those which require subjective evaluation, such as surface blemishes and texture [see Paragraphs D3.3.2.3(a) and (b)].
- (b) Those which can be evaluated dimensionally [see Paragraphs D3.3.2.3(a) to (e)].

Table D3.1 gives information on physical irregularities and their possible causes.

D3.3.2.2 Surface appearance

Surface appearance is assessed in terms of the following:

- (a) *Blowholes* Experience has shown that the evaluation of surface quality is difficult when requirements are expressed as—
 - (i) written descriptions of acceptable defects; or
 - (ii) stated levels of various sized blemishes per unit area.

The visual effect of any defect relates to its proximity to other defects as well as to its size and nature.

To answer this problem the method adopted in this Standard has been the use of pairs of photographs, at 1:5 and 1:1 scales of examples of the maximum level of defects permitted in each class. The photograph should be held up against the area being evaluated to determine whether the surface of the element reaches its specified standard. This still involves the subjective comparison of the photograph and the work, but it is considered to be a fairer and more accurate assessment than the use of numerical parameters.

The viewing distance at which this comparison is made is very important. Defects which would be considered most unsightly on surfaces that can be examined at close quarters, for example from the platform of a façade scaffold, will become insignificant if the closest viewing distance is a lot greater such as the upper level walls of a multistorey buildings that can only be examined from similar buildings on the opposite side of the street. In this case the defects can become invisible to the naked eye.

One problem that cannot be adequately addressed by the use of these photographs is the grouping of blowholes. Small blowholes that would be difficult to see from a distance as individual defects, can become very obvious when they are clustered in small groups. This is a case where the subjective judgement of the project designer is applicable.

- (b) *Surface treatment* For work which is to have the surface treated in some way, e.g. tooled or gritblasted, there will be two stages of evaluation. The first of these will be when the concrete element has been poured and stripped. This evaluation for dimensions and colour will be prior to the surface treatment. The requirements with which element should conform are those of the specified class, usually Class 2 or Class 3.

The second evaluation, which is for textural uniformity only, is after the surface treatment. The appearance of the treated surface is greatly affected by the incidence of light on the surface. Therefore, in the comparison with the approved test panel, it is essential that the test panel be placed adjacent to the subject area in lighting situation which is the same as that of the permanent work. It may be necessary for consideration to be given to the time of day evaluation, as the incidence of the light changes at different times of the day.

D3.3.2.3 Measurable deviations

This Standard considers the dimensional aspects of concrete elements at two levels. The first, which are outer limits, are those required for structural acceptability. The second relates to the particular surface class and its project documentation as given in Table 2.2.3. If the project documentation does not specify the class of each element, then the class is to be selected from Class 3, Class 4 or Class 5 as appropriate to t_s applicability as given in Table 3.2.3.

Specific comment on individual items listed in Clauses 3.3.4 and 3.3.5 is as follows:

- (a) *Form face deflection* This matter is largely controlled by good formwork design, but can only be checked after the pour. The procedure is simple and only involves placing a straightedge across the surface and measuring the visible gap. As the deflections are the result of structural action and not workmanship it is not expected that there would be and discernible variation between readings over a span of 300 mm. The readings are spaced accordingly (see Table 3.3.4.1).
- (b) *Face steps* Face steps in the completed concrete surface generally arise from either—
- (i) misalignment at the junction of two concrete elements; or
 - (ii) within the area of a form, from misalignment of the form face materials.

Even in Class 1, a 1 mm face step is permitted in the case of Item (ii). This is due to the manufacturing tolerances of plywood being either $\pm 3\%$ of the thickness. The permitted values are given in Table 3.3.5.1.

- (c) *Surface undulations* In addition to the above deformations it is recognized that gradual, not abrupt, deviations may occur over a short distance, or may be more gradual and only discernible over 1.5 m. Accordingly, two checks are called for, one with a 300 mm straightedge and the other with a 1500 mm straightedge. In all cases random readings are taken with an offset straightedge and the difference between the maximum and minimum reading at each location is the reading. For acceptance, all readings need to be equal to or less than the higher value shown in Table 3.3.5.1 and the stated percentage needs to conform to the lower figure.

- (d) *Flatness* In addition to the above checks, there are two tests for the overall flatness of the elements as follows:

- (i) The first test is for long elements or a sequence of in situ elements that are intended to be straight. The deviation within 10 m lengths is checked by offset readings at the ends and the middle, and the net deviation taken as the difference between the mean of the readings at the ends of the 10 m length and that at the middle. To keep control of any general deviation, the 10 m lengths needs to overlap by 5 m.

These lines may be taken in any direction where the length of the line is compatible with this requirement and where there is seen to be a need for a check.

- (ii) Within these 10 m lengths the second check for flatness applies. This is carried out on a 1.25 m × 1.25 m grid with the outer rows not closer to the edges than 300 mm. As before, the offset readings are related to those at the corners of the 5 m grid to obtain the deviation.

The check on flatness gives the deviations of a continuous grid of surface locations. Within these grid lines the other checks for deviation apply, i.e. face span and deflection, face steps and surface undulations.

- (e) *Out-of-plumb* The important aspect here is the determination of the critical face (see Clause 3.3.2). For walls, the critical face should be one face as nominated in the project documentation. For rectangular or square columns, the critical faces should be two elected adjacent faces. In this way the out-of-plumb check also monitors the possibility of a spiral twist but does not conflict with the tolerances on thickness of elements.

D3.3.3 *Physical quality of precast concrete*

It is important to check the dimensional accuracy of precast concrete in the order specified as each of the subsequent types of deviations can affect the resulting measurement of the preceding ones.

The angular dimensions [see Clause 3.3.7(d)] need only to be checked if the unit is acceptable for surface finish [see Clause 3.3.7(a)] and linear dimensions [see Clause 3.3.7(b)]. The tolerances in profile [see Clause 3.3.6.2(c)] need only to be checked if the unit is acceptable for both linear and angular dimensions.

The age of a unit at which checks are made is most important and needs to be arranged between the project designer and the precaster. Obviously the acceptance/rejection criteria needs to be imposed at the earliest possible time after production of the unit. For tooled surfaces, they need to be checked prior to tooling. However, there are many practical situations in a precast yard that need consideration, and for reasons of damage and economy it is recommended that matters such as multiple handling of panels to enable the checks to be done are avoided. Improper storage of panels and different temperature movements during storage will have a considerable effect on profile tolerances and need to be taken into account as part of the evaluation.

Where a test panel has been used, it is recommended that the tolerances be assessed on that element and approved before site work commences.

It is also recommended that, wherever possible, tolerances are checked with the unit orientated and supported in the same attitude as in the completed structure. If this cannot be done, then the method may need to be determined by arrangement between the project designer and the precaster before the work commences.

D3.3.4 *Colour evaluation*

The evaluation of the colour for acceptance is described in Clause 3.4. It will be carried out by comparison of the elements with the grey scale. The test panel should not be used to directly assess colour.

When evaluating a finished plane surface which is to have some surface treatment after this colour check, some extra latitude can be extended with regard to minor colour variations. Such matters as light hydration staining or light release-agent stains can be minimized by grit blasting or the like.

D3.3.5 *Repairs*

D3.3.5.1 *General*

This Standard is a performance document and, as such, it is focussed on the quality of the end product. The clauses on 'Evaluation' make no distinction as to whether the product has needed repair to achieve acceptance or not. The recent advances in the range and quality of repair techniques support the validity of this approach. High-quality repairs are possible, and permission to repair defects is an opportunity to avoid rejection of the element in question.

Consequently, in accordance with the requirements of this Standard, repairs to all classes of surface are acceptable. However, for Class 1 surfaces, the project designer may include a statement prohibiting repairs (see Table 2.2.3 Item 12). It is recommended that such a decision be not made lightly. Even in a surface of the high quality of Class 1 it is possible to make minor repairs successfully.

D3.3.5.2 *Repair technique*

Clause 3.6.2 relates to the evaluation of the repair proposal prior to its application. The purpose of this evaluation is to prevent the repair work being commenced prior to the detailed assessment of the problem by the project designer.

It would be usual for the proposed repair procedure to be submitted by the contractor for consideration by the project designer. The wording of the Clause is not intended to place any responsibility for the success of the repair on the project designer once permission for the repair work is granted. As in most cases, it is the work at the site that has created the need for repair, therefore it is the site that is expected to propose a repair technique and be responsible for its success.

Prior to the repair work being undertaken the project designer may nominate criteria in addition to those of structural characteristics, durability, durability of adhesion, appropriateness of materials and appearance.

APPENDIX E
GLOSSARY OF TERMS
(Informative)

E1 GENERAL

The following are common terms used within the industry.

E1.1 Access platform

A platform that is only used or intended to be used to provide access for persons, or for persons carrying material moving to and from places of work.

E1.2 Adjustable prop

A structural member whose length may be varied.

NOTE: Also known as ‘telescopic prop’.

E1.3 Authorities

Bodies having statutory powers to regulate the design and erection of formwork.

E1.4 Climbing formwork

Repetitive formwork for vertical or near vertical structures which are constructed in successive lifts, usually without dismantling of the formwork. It is supported by the previously placed lift.

E1.5 Collapsible forms

Forms that are activated by mechanical means to reduce their volume or surface area to facilitate stripping.

E1.6 Column clamp

A yoke or other device which holds column forms tightly against the force of plastic concrete.

E1.7 Design working life

The period for which the formwork is designed to be in use.

E1.8 Dressed concrete

Concrete that has been cut back to correct size when it has been made oversize resulting from movement of forms.

E1.9 Drop panel

The structural portion of a flat slab which is thickened throughout an area surrounding a column.

E1.10 Green concrete

Concrete which has recently set but has not achieved any design strength.

E1.11 Hog

Negative deflection of a concrete element.

E1.12 Structural infill panel

A panel that does not require backing rails to transfer edge protection design loads to the supporting posts.

E1.13 Supplementary reinforcement

Reinforcement, additional to the structural reinforcement, provided to resist forces caused by manufacturer, handling, transport, construction and erection loads.

E1.14 Table form

Soffit formwork which is built up into the form of a table. It stands on the floor previously cast, is moved into place and raised to the final position to receive fresh concrete.

E1.15 Trapped form

A form which is lost when no opening is left in the permanent structure through which the form can be removed, or which has to be destroyed in stripping because of the configuration of the concrete.

E1.16 Travelling form

Formwork, such as that form walls and tunnel linings, carried on wheels or rollers so that it may be stripped and moved without dismantling.

E1.17 Upstand

A small block of concrete cast above floor level to position wall or column forms for the next pour and to assist the prevention of grout loss.

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