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Australian Standard®

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Formwork for concrete

Part 2: Design and construction



AS 3610.2 (Int):2023

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- Engineered Wood Products Association of Australasia
- Engineers Australia
- Forest and Wood Products Australia
- Master Builders Australia
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Formwork for concrete

Part 2: Design and construction

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Preface

This Interim Standard was prepared by the Standards Australia Committee BD-043, Formwork. AS 3610—1995 and AS 3610 SUPP2—1996 will also remain current for the duration of this Interim Standard and after this time they will be superseded or revised accordingly.

This Interim Standard will have a currency of two years from its date of publication. At the conclusion of that period it will be superseded by another document, confirmed as an interim Standard in its present form for a further two year period or withdrawn.

The objective of this document is to provide architects, engineers, builders and construction contractors, and formwork designers, suppliers and contractors, with design information that will enable them to produce formwork that will adequately and safely support fluid concrete until it is self-supporting.

This document provides a design document to achieve the objectives of AS 3610.1 with regard to the quality of finish of formed concrete surfaces.

This document does not cover project documentation, construction documentation, formwork documentation, proprietary documentation, surface finish and colour control, which are covered by AS 3610.1.

The major changes in this edition are as follows:

- (a) Formwork actions have been substantially updated.
- (b) A section specific to structural analysis methods for falsework has been added.
- (c) A section for special formwork, such as single sided wall forms, jump/climb forms, and slip forms, has been added.
- (d) The testing of formwork and its components has been expanded from the earlier versions of this document, with new Appendices detailing specific tests.

The terms “normative” and “informative” are used in Standards to define the application of the appendices or annexes to which they apply. A “normative” appendix or annex is an integral part of a Standard, whereas an “informative” appendix or annex is only for information and guidance.

This document includes a 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 and does not form part of the Standard.

Standards Australia welcomes comments on this Interim Standard. Please contact Standards Australia at success@standards.org.au for a copy of the commenting template and return the completed form to the same email address. Standards Australia Committee BD-043 will review comments received.

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Australian Standard®

Formwork for concrete

Part 2: Design and construction

Section 1 Scope and general

1.1 Scope

This document sets out the minimum requirements for the design, erection and, where applicable, removal of formwork and the supporting falsework for cast *in situ* concrete.

This document applies to the design of the form that contains and moulds the cast *in situ* concrete to the required dimensions. This document also includes the design of the falsework that supports the form and transfers all the loads to a stable surface(s) and/or to multiple levels prior to, during and following placement of concrete into the form, and supporting equipment used as falsework.

This document includes specific tests for adjustable props and shoring frames.

This document does not cover project documentation, construction documentation, formwork documentation, proprietary documentation, surface finish and colour control, which are covered by AS 3610.1.

1.2 Application

The design, documentation and verification of formwork shall conform to [Section 2](#).

Procedures to be followed during construction shall conform to [Section 6](#).

Special formwork shall conform to [Section 7](#). The term “special” is intended to apply to formwork such as tunnel forms, jump/climb forms, slipforms, and permanent forms.

1.3 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document.

NOTE Documents referenced for informative purposes are listed in the Bibliography.

AS 1170.4, *Structural design actions, Part 4: Earthquake actions in Australia*

AS 1720.1, *Timber structures, Part 1: Design methods*

AS 2082, *Timber — Hardwood — Visually graded for structural purposes*

AS 2858, *Timber—Softwood—Visually stress-graded for structural purposes*

AS 3600, *Concrete structures*

AS 4100, *Steel structures*

AS 5100, *Bridge design (series)*

AS 5216, *Design of post-installed and cast-in fastenings in concrete*

AS 6669, *Plywood — formwork*

AS/NZS 1170.2, *Structural design actions, Part 2: Wind actions*

AS/NZS 1170.3, *Structural design actions, Part 3: Snow and ice actions*

AS/NZS 1576.1, *Scaffolding, Part 1: General requirements*

AS/NZS 1576.2, *Scaffolding, Part 2: Couplers and accessories*

AS/NZS 1576.6, *Scaffolding, Part 6: Metal tube-and-coupler scaffolding—Deemed to comply with AS/NZS 1576.3*

AS/NZS 1664.1, *Aluminium structures, Part 1: Limit state design*

AS/NZS 1892.1, *Portable ladders, Part 1: performance and geometric requirements*

AS/NZS 4600, *Cold-formed steel structures*

AS/NZS 4994.1, *Temporary edge protection, Part 1: General requirements*

AS/NZS 4994.4, *Temporary edge protection, Part 4: Perimeter protection screens*

1.4 Terms and definitions

For the purpose of this document, the definitions in AS 3610.1 and the following apply.

1.4.1

jump formwork

combined formwork and falsework systems that relocate vertically

Note 1 to entry: Also known as a *jump-form* or a *climb-form*.

1.4.2

travelling formwork

combined formwork and falsework systems that relocate horizontally

1.5 New designs and innovations

This document does not prevent the use of materials, methods of assembly, procedures and the like that do not conform with the specific requirements of this document, or are not mentioned in it, provided the minimum dimensional and performance requirements specified herein are met.

1.6 Notation

The following notation is used in this document:

A_b	=	brace member gross cross-sectional area (see Clause 4.3.4.2)
$A_{b,red}$	=	brace member reduced cross-sectional area (see Clause 4.3.4.2)
C_1	=	coefficient dependent on the size and shape of formwork (see Appendix E)
C_2	=	coefficient given in Table E.1 for the constituent materials of the concrete (see Appendix E)
d_i	=	the nominal inner diameter of the outer tube (see Clause 4.3.4.3)
d_o	=	the nominal outer diameter of the inner member (see Clause 4.3.4.3)
E_b	=	brace member modulus of elasticity (see Clause 4.3.4.2)
E_d	=	design action effect due to the most adverse limit state design load (see Clause 3.3.3)
$E_{d, dst}$	=	stability limit state combination for destabilizing actions (see Clause 3.3.2)
$E_{d, stb}$	=	stability limit state combination for stabilizing actions (see Clause 3.3.2)

E_u	=	ultimate earthquake action (see Clause 3.2.3.6.4)
e	=	total eccentricity (see Clause 4.3.4.1)
e'	=	a fixed eccentricity (see Clause 4.3.4.1)
e''	=	the maximum possible unintentional eccentricity (see Clause 4.3.4.1)
e_j	=	offset between two spigot-joined compression members (see Clause 4.3.4.3)
F_d	=	The force due to accumulated debris against the formwork, in kilonewtons (see Clause 3.2.3.6.5)
F_{sn}	=	ultimate snow action (see Clause 3.2.3.6.3)
F_w	=	The force due to the water flowing around the formwork, in kilonewtons (see Clause 3.2.3.6.5)
G_c	=	permanent action, weight of placed concrete (see Clause 3.2.2.2)
G_f	=	permanent action, weight of formwork (see Clause 3.2.2.1)
G_p	=	permanent action, weight from additional concrete due to deflection of supporting member, referred to as ponding (see Clause 7.2.4.4.3)
G_s	=	permanent action, weight of elements of the permanent structure (see Clause 3.2.2.3)
H	=	vertical form or concrete discharge height, whichever is greater, in metres (see Appendix E)
h_c	=	vertical pour height, in metres (see Appendix E)
I_h	=	unintended action, horizontal impact (see Clause 3.2.4.1)
I_v	=	unintended action, vertical impact (see Clause 3.2.4.2)
K	=	temperature coefficient (see Appendix E)
k_1	=	factor for the effect of load duration on timber strength (see Table 3.3.2)
k_b	=	axial stiffness of the brace connector (see Clause 4.3.4.2)
k_d	=	modification factor to allow for the strength variations (see Clause A.5.5)
k_{d1}	=	modification factor for duration of load (see Clause A.4.4.3)
k_s	=	sampling factor using a coefficient of variation (see Clause A.4.4)
L	=	actual length of the member under consideration between node points (see Clause 5.3.2.2.4)
L_b	=	brace member length (see Clause 4.3.4.2)
l_e	=	effective length of the member under consideration between node points (see Clause 5.3.2.2.4)
l_o	=	overlap length (see Clause 4.3.4.3)
N^*	=	design value of vertical action on falsework (see Clause 4.3.6)
N_{cr}	=	elastic critical buckling value of the vertical action (see Clause 4.3.6)
n	=	accumulated sample size or total number of units tested (see Clause A.4.4)
n_v	=	number of connected vertical compression members erected side by side (see Clause 4.3.4.3)

P_c	=	lateral concrete pressure (see Clause 3.2.3.8)
P_i	=	initial average pressure of a plastic concrete incremental layer, in kilopascal (see Clause 7.2.2.3.3)
$P_{c,hyd}$	=	plastic concrete hydrostatic lateral pressure, in kilopascal (see Clause 3.2.3.8 , 7.2.2.3.3 and Appendix E)
$P_{c,inc}$	=	lateral concrete pressure for incremental concrete pour specifically but not limited to slip-forming, in kilopascal (see Clause 7.2.2.3.3)
Q_{c2}	=	concrete variable action due to mounding for Stage 2 (see Clause 3.2.3.2)
Q_g	=	vertical and horizontal imposed action for guard railing (see Clause 3.2.3.5)
Q_h	=	horizontal imposed action (see Clause 3.2.3.4)
Q_m	=	imposed action from the weight of stacked materials at a given stage of construction (see Clause 3.2.3.3)
Q_w	=	vertical imposed action from workers, equipment and concrete placement (see Clause 3.2.3.1)
Q_{w1}	=	vertical imposed action from workers and equipment for Stage 1 (see Clause 3.2.3.1(a))
Q_{w2}	=	vertical imposed action from workers, equipment and concrete placement for Stage 2 (see Clause 3.2.3.1(b))
Q_{w3}	=	vertical imposed action from workers and equipment for Stage 3 (see Clause 3.2.3.1(c))
Q_x	=	imposed other actions that occur concurrently with other construction activities (see Clause 3.2.3.6)
(ϕR)	=	the strength limit state capacity (see Appendix A)
R_d	=	design capacity of the formwork, or components, or members or connections, as appropriate, equals ϕR (see Clauses 2.3.4 , 2.3.5 and Section 5)
r	=	rate at which the concrete rises vertically up the formwork in metres per hour (see Clause 7.2.2.3.3 and Appendix E)
S_u	=	design situation combination of destabilizing effects (see Clause 3.3.2)
S_v	=	slip-form slide speed (see Clause 7.2.2.3.4)
S_t	=	the test load (see Appendix A)
s	=	standard deviation of a finite population of units tested (see Clause A.4.4.2)
T	=	concrete temperature at placement, in degrees Celsius (see Clause 7.2.2.3.3 and Appendix E)
V	=	coefficient of variation for the failure load of the units tested (see Clause A.4.4.2)
W_s	=	environmental action, service wind (see Clause 3.2.3.6.2)
W_u	=	environmental action, ultimate wind (see Clause 3.2.3.6.2)
$\bar{x}$	=	mean value of the test results of the units tested (see Clause A.4.4.2)
X_f	=	friction due to a slip-form form-face pressing against concrete (see Clause 7.2.2.3.2)
x_i	=	test result of each individual unit of the sample (see Clause A.4.4.2)

γ_d	=	variable partial load factor for unanticipated load redistribution (see Clause 2.3.4.2)
γ_p	=	variable partial load factor for lateral concrete pressure (see Clause 3.3.2 and 3.3.3)
γ_{WLL}	=	limit state conversion factor (see Clause 5.3.3)
δ_o	=	member out-of-straightness (see Clause 4.3.3.2)
ρ	=	wet density of concrete, in kilograms per cubic metre (see Appendix E)
φ	=	angle of deviation for a series of connected parallel compression members, in radians (see Clause 4.3.4.3)
φ_j	=	angular change between two compression members connected end to end with a spigot, in radians (see Clause 4.3.4.3)

Section 2 Design requirements

2.1 Scope of section

This Section sets out the minimum design requirements for formwork.

The formwork design shall be as follows:

- (a) The project and construction requirements set out in [Clause 2.2](#).
- (b) The structural requirements set out in [Clause 2.3](#).
- (c) The formwork documentation shall conform to the requirements of AS 3610.1:2018 Clause 2.4.

The obligation, competency and minimum requirements for verifying the formwork design conforms to this document shall be in accordance with [Clause 2.4](#).

2.2 Project and construction requirements

2.2.1 General

The formwork design shall conform to the requirements specified in the —

- (a) project documentation prepared in accordance with AS 3610.1:2018 Clause 2.2; and
- (b) construction documentation prepared in accordance with [Clause 2.2.2](#) and AS 3610.1:2018 Clause 2.3.

2.2.2 Additional construction requirements

2.2.2.1 General

The formwork shall conform to the following requirements:

- (a) Provide space for access and working.
- (b) Designed to permit inspection, adjustment and stripping.
- (c) Provided with means to resist movement and misalignment at construction joints in the concrete.
- (d) Fitted with mechanisms to facilitate adjustment of the formwork and to permit the controlled movement of formwork during stripping.
- (e) The installation of all adjustment mechanisms shall be such that the anticipated actions cannot dislodge them. The adjustment mechanisms shall not be subject to uncontrolled movement under load.
- (f) Where it is possible that any movement would cause formwork components to become unstable, dislodged or to collapse, there shall be positive means to prevent that consequence.
- (g) Provided with bracing to ensure that the formwork can be safely erected and stripped.

NOTE 1 The design should be based on concepts and details whose realization is achievable and can be checked on site.

NOTE 2 Some authorities may require the design to conform to other criteria, e.g. additional provisions for safe working.

2.2.2.2 Foundations and footings

Elements of the permanent structure intended to be used or existing structures shall not be used to support the formwork unless permitted by the project documentation, in accordance with AS 3610.1:2018 Clause 2.2. Elements of the permanent structure to be used as a footing for the falsework may require additional support.

Where foundations and footings are used the following condition where applicable shall be met:

- (a) The foundation material beneath the footings shall be investigated to determine its bearing and settlement characteristics.
- (b) The footings shall support the falsework on the foundation material. As a result the formwork shall satisfy the requirements for stability, strength and serviceability limit states.
- (c) Movement of the footings that occurs prior to the initial set of the concrete shall not cause the tolerances on the cast *in situ* concrete to exceed the specified limit's acceptable levels.
- (d) Movement of the footings after the initial setting of the concrete shall not cause any detrimental effects to the cast *in situ* concrete. Project documentation shall allow for this design requirement.
- (e) Falsework shall be stable through stages 1, 2 and 3 and appropriately transfer the design actions to the supporting footings.

2.3 Structural requirements

2.3.1 General

Formwork shall be designed in the limit states method.

The formwork shall be analysed subject to the combinations of permanent, variable and unintended actions set out in [Section 3](#), taking account of the applicable importance level given in AS 3610.1:2018 Appendix A.

To determine the relevant design serviceability parameters and action effects, the formwork (including, components, members and connections) shall be analysed in accordance with [Section 4](#).

The design resistance of the formwork (including, its components, members and connections) shall be determined in accordance with [Section 5](#).

The design of the formwork (including, its components, members and connections), for the duration of its design working life (job duration), shall conform to the following:

- (a) Serviceability requirements set out in [Clause 2.3.2](#).
- (b) Stability requirements set out in [Clause 2.3.3](#).
- (c) Strength requirements set out in [Clause 2.3.4](#).
- (d) Structural integrity requirements set out in [Clause 2.3.5](#).
- (e) Deterioration requirements set out in [Clause 2.3.6](#).

NOTE Formwork may be designed not only by calculation but also by empirical methods which involve various forms of testing on full-scale assemblies or components. See [Appendix A](#) for relevant testing requirements.

2.3.2 Serviceability

Formwork deformations shall not exceed the limits and tolerances in AS 3610.1, unless otherwise stated in project documentation.

Serviceability limit states shall be satisfied in accordance with [Equation 2.3\(1\)](#) as follows:

$$\delta \leq \delta_1 \quad 2.3(1)$$

where

δ = values of the serviceability parameter (deflection, deformation or vibration) determined by analysis (in accordance with the requirements of [Sections 4](#) and [5](#)) of the action combinations specified in [Section 3](#)

δ_1 = limiting value of the serviceability parameter (for surface finish refer to AS 3610.1:2018 Clause 3.2)

Any effects of vibration detrimental to the functioning of the formwork shall be taken into account.

The formwork shall have sufficient stiffness, mass, or both, to avoid any detrimental effects of vibration on its structural capacity, tolerances and surface finish.

For multiple-use formwork, deformations shall remain elastic.

2.3.3 Stability

The formwork shall resist over-turning, uplift and sliding without external restraint or support from the permanent or any existing structure, unless such restraint is permitted and within the limitations permitted in the project documentation (see Figure C2.3.3 and refer to AS 3610.1:2018 Clause 2.2.4).

The stability limit state of the formwork shall be satisfied in accordance with [Equation 2.3\(2\)](#) as follows:

$$E_{d,stab} + R_d \geq E_{d,dst} \quad 2.3(2)$$

where

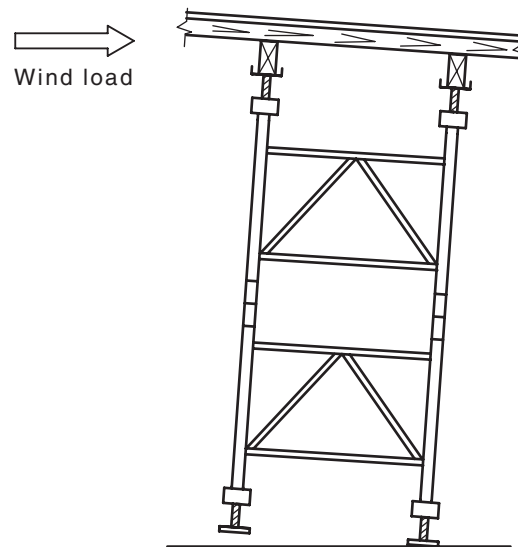
$E_{d,stab}$ = design effect of stabilizing actions (see [Section 3](#))

R_d = design capacity (equal to ϕR) of any stabilizing formwork, component or connection (see [Section 5](#))

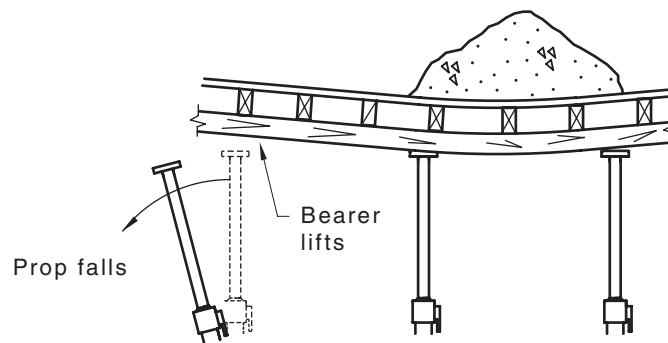
$E_{d,dst}$ = design effect of destabilizing actions (see [Section 3](#))

C2.3.3 Formwork assemblies are generally lightweight structures and are therefore susceptible to stability problems. Consequently, when analysing the structure, the direction of placement of the concrete should be considered, in addition to the loads specified in this document, in order to avoid instability problems such as that shown in Figure C2.3.3. Unless strict control of the sequence of placement of the concrete is feasible, the worst direction of placement should be assumed.

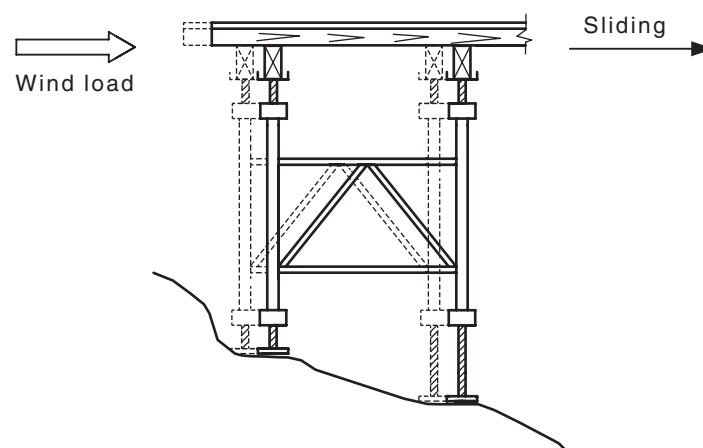
Similarly, tall formwork assemblies may require supports to be adequately anchored to temporary footings or to the permanent structure in order to avoid the problem of overturning or sliding.

(continued)

(a) Overturning



(b) Uplift



(c) Sliding

Figure C2.3.3 — Instability

2.3.4 Strength

2.3.4.1 General

The formwork, its components, members, connections, foundation and any points of resistance shall not collapse, rupture or deform excessively. The strength limit state of the formwork shall be in accordance with [Equation 2.3\(3\)](#) as follows:

$$\gamma_d E_d \leq R_d \quad 2.3(3)$$

where

γ_d = partial load factor for unanticipated load redistribution (see [Clause 2.3.4.2](#))

E_d = design action effect (see [Clause 3.3.3](#))

R_d = design capacity (equal to ϕR_n) (see [Section 5](#))

2.3.4.2 Unanticipated load redistribution factor (γ_d)

For members whose failure could result in the collapse of the formwork, the effects of unanticipated load redistribution shall be taken into account by increasing the design action effect by a factor, $\gamma_d = 1.3$. This factor shall apply to critical members, which include, but are not limited to, primary bearers, falsework and form ties.

For non-critical formwork members, such as the form face and secondary members, the global load factor shall be equal to $\gamma_d = 1.0$.

Refer to [Table 3.3.1](#) for application of the unanticipated load redistribution factor.

C2.3.4.2 While the load-carrying capacity of formwork support structures (falsework) can be determined accurately using tests or advanced numerical methods, the loads applied to falsework structures in the field are highly unpredictable. Studies of conventional formwork support systems have determined a high variance between predicted support load and actual support load. Factors such as discontinuities in the formwork and imperfections in the support structure such as drift in set-out, jacks not in contact with bearers, out-of-plumb shores, eccentric bearers, form ties with uneven adjustment and variable foundation conditions all contribute to unanticipated load redistribution.

In design practice, the loads acting on shores are commonly calculated using the tributary area method with continuity effects. The applied loads are the weight of the newly poured slab and the code-specified formwork design live load. Construction site studies have shown a coefficient of variation over 35 % of the predicted tributary load occurring [1].

The need for a partial load factor for unanticipated load redistribution, γ_d , is reliability-based and dependent on the magnitude of the partial load factors in [Table 3.3.1](#) and the imposed action for workers and equipment during Stage 2, $Q_{w2} = 2$ kPa.

By applying the unanticipated load redistribution factor, where applicable, it brings the reliability for limit state strength design of this document generally in line with the original Australian allowable stress design format standard for formworks and formwork standards of Europe and North America.

For example, the design equation for allowable stress design (ASD) equates to the following:

$$R_n/SF \geq \text{working load} \quad C2.3(1)$$

in which R_n is the nominal strength of the component or system resisting the applied loads and SF is the safety factor. Typical ASD safety factors ranged from 1.67 to 2.4 depending on material, design method or test method. This can be expressed as:

$$R_n = (1.67-2.4) G + (1.67-2.4) Q$$

(continued)
C2.3(2)

The limit state design method (LSD) has two gravity design cases expressed as the following:

$$\varphi R_n = (1.2 G + 1.5 Q) \cdot 1.3$$

C2.3(3)

and

$$\varphi R_n = (1.35 G + 0.0 Q) \cdot 1.3$$

C2.3(4)

where $\varphi = 0.9$.

Equations C2.3(3) and C2.3(4) rearranged as pure partial load factor equations are as follows:

$$R_n = 1.73 G + 2.17 Q$$

C2.3(5)

and

$$R_n = 1.95 G + 0.00 Q$$

C2.3(6)

Comparing equations C2.3(2) to C2.3(5) and C2.3(6) shows the partial load factors for LSD fit within the partial load factor range of ASD, thus giving an equivalent structural reliability between ASD and LSD.

Note that $\gamma_d = 1.3$ has been in use with AS 3610:1995 since an amendment in 2003. This version of AS 3610 seeks to clarify its required use of γ_d .

Research into the structural reliability of temporary and slender structures continues and further adjustments of the partial load factors and redistribution factors may occur.

2.3.5 Structural integrity

The design of the formwork shall provide load paths to the foundations or the permanent structure, where permitted in the project documentation, for forces generated by all types of actions from all parts of the formwork.

The formwork shall be connected in both the horizontal and vertical planes so that the formwork can withstand an event without being damaged to an extent disproportionate to that event (not disproportionate to the cause).

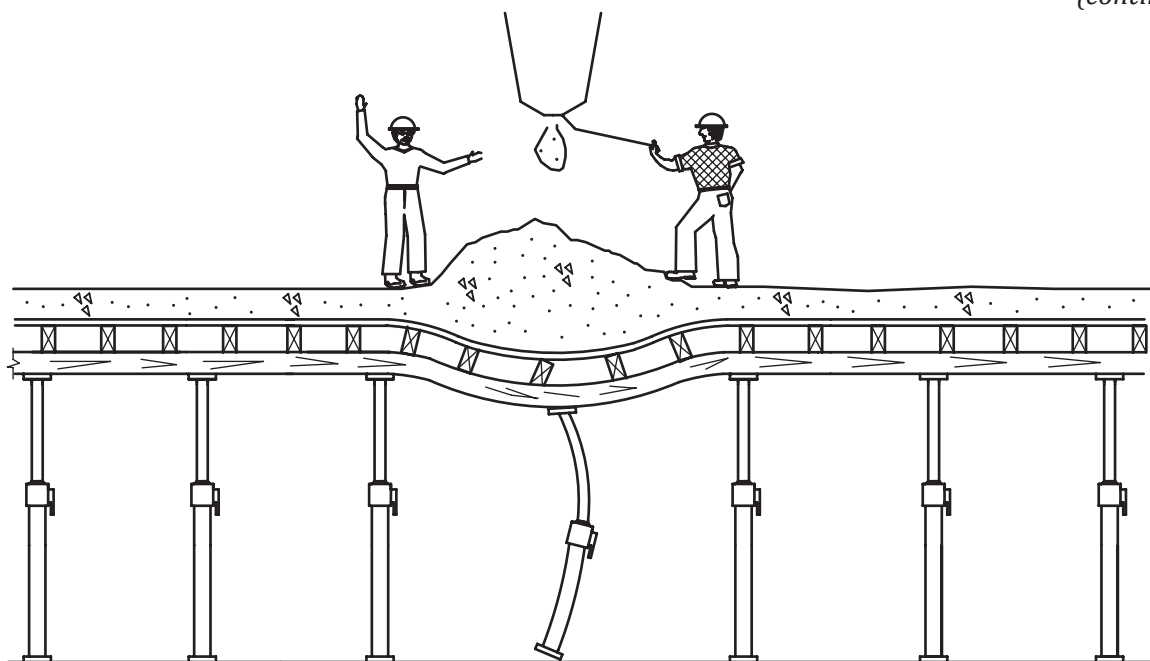
The formwork, its members and connections shall be designed to prevent progressive collapse.

The design of the formwork shall not rely on any part of the permanent or any existing structure to provide restraint, a point of resistance or support, unless permitted by, and within the limitations specified in, the project documentation (refer to AS 3610.1:2018 Clause 2.2).

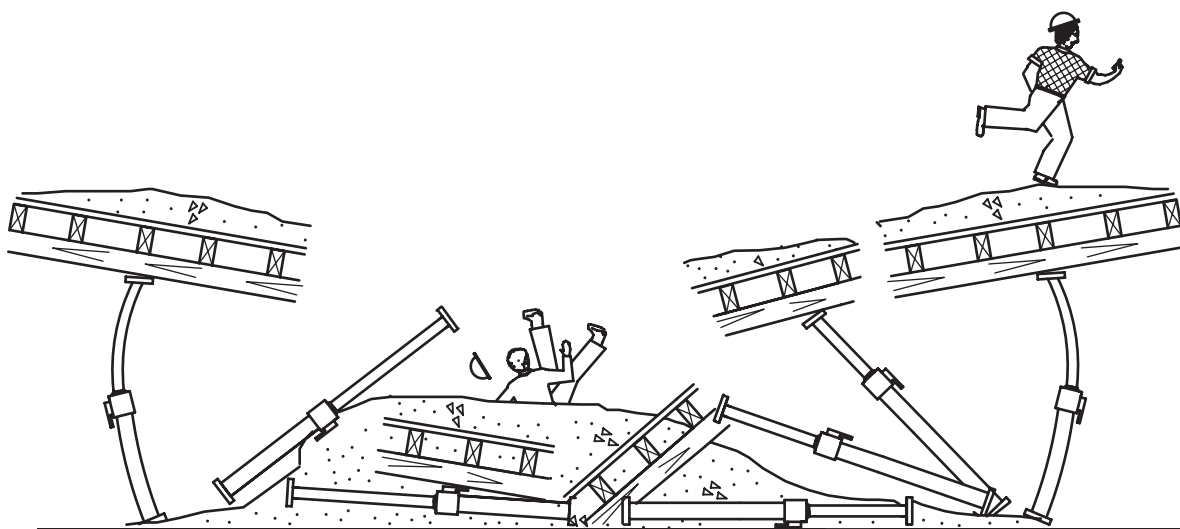
NOTE Where not specified in the project documentation, it may be necessary to seek permission from the developer of the project documentation to use the permanent or any existing structure for restraint or support of the formwork, as well as any limitations applicable.

C2.3.5 Progressive collapse is a problem which can be encountered more frequently in formwork assemblies than in most structures. Progressive collapse occurs when the collapse of one component results in adjacent components becoming overloaded and, in turn, collapsing. An example of the onset of progressive collapse is shown in Figure C2.3.5

(continued)



(a) Stage 1: Overload of a single prop causes it to buckle
This places additional load on adjacent props



(b) Stage 2: The adjacent props buckle, in turn overloading other props which in turn buckle and collapse

Figure C.2.3.5 — Progressive collapse

2.3.6 Deterioration

Formwork components and assemblies of formwork components shall be designed for the acceptance criteria specified in [Table 6.3.1](#).

The design of formwork shall make an allowance for the deteriorating effects of environmental conditions, unless documented control measures mitigate the effects.

A reduction in the formwork capacity shall be used where control measures are not possible.

NOTE 1 Environmental conditions are not to be confused with environmental actions, see [Clause 3.2.3.7](#).

NOTE 2 See [Clauses 6.3.4](#) and [6.3.5](#) for acceptance criteria of formwork components and materials.

C2.3.6 *The effects of environmental conditions will determine the life expectancy of formwork components and materials. Components set up in aggressive environments (e.g. bridges, wharfs, jetties, chemical plants, oil refineries, marine tidal zones, tropical climates) or undergoing adverse activities (materials in transit, stripping, impact, prolonged weather exposure) require a level of durability or an allowance for loss of strength.*

Durability may be attained through greater wall thicknesses with components, coated protection such as galvanising, or material selection such as stainless steel. However, where economics or formwork availability preclude the use of directly improving durability, then an allowance for designed deterioration is necessary. No more than 5 % material loss should be considered, but in a situation with an extreme environment, operating with an allowance of approximately 10 % material loss due to corrosion may be appropriate, when allowed for.

For steel members resisting predominantly axial loads (commonly falsework), a 5 % reduction in surface area (or cross-sectional area) correlates to a 5 % reduction in section capacity and a slightly smaller reduction in buckling capacity (4 % to 5 %). A reduction factor of 0.95 can be used for the simulation of 5 % material loss in an axially loaded component. For material losses greater than 5 %, or members resisting bending actions, rigorous design and/or satisfactory proof testing should be used in determining the allowable percentage of material loss.

A component and assembly of components should be designed for the acceptance criterial specified in [Table 6.3.1](#). This simulates construction site tolerances, usage, and abuse of formwork equipment.

With timber, the load carrying capacity is adversely affected by weathering and mechanical damage. This clause intends to qualify timber capacity when weathered. However, it should be noted that no reliable research information could be sourced. The amount of time exposed, greatly influences the weathering effects. Without accurate data on exposure, or control measures for materials on construction sites then it is very difficult to provide guidance on the effects of weathering. Direct testing of a representative sample of severely weathered timber elements would be required to determine degraded capacity. For a timber product degraded by mechanical damage only, then design for the reduced cross-section can be undertaken for determining the capacity.

2.4 Formwork design verification

2.4.1 General

The obligation and competency to verify the formwork design conforming to this document shall be in accordance with [Table 2.4](#).

The minimum requirements for verification of the formwork design are set out in [Clause 2.4.2](#).

The details of the design verification shall be documented, including providing —

- (a) reference to the specific formwork design documentation verified;
- (b) reference to all project, construction, formwork and technical documents, Standards, testing, and information upon which the verification is based; and
- (c) all assumptions upon which the verification is based, including both the assumptions made by the designer and the verifier.

Table 2.4 — Formwork design verification obligation and competency

Importance level	Formwork design verification	
	Obligation	Competency
I	Optional	Experienced Experienced in formwork design of the type being assessed and in terms of its magnitude
II	Mandatory	Qualified Knowledge, skills and training in the aspects of that type formwork design
III	Mandatory	Independent The skills of a qualified competency above, who is experienced in the design of formwork of that type and not involved in the design of that project

NOTE 1 For [Table 2.4](#), descriptions of formwork systems for the given formwork importance levels are set out in AS 3610.1:2018 Table A.1.

NOTE 2 It is expected that a competent person will complete formwork design verification.

C2.4.1 *Where a person is not comfortable with the given formwork system, then it is expected that they recognize that they are not experienced enough to provide design verification, no matter their qualification level. Nominating a time period of experience for a given competency is difficult as it requires similar recognition in confirming the said experience. No formal registry to record experience with formwork systems currently exists. Safety codes of practice for some States specifically nominate required experience and qualifications for formwork verification.*

2.4.2 Minimum requirements

The design verification shall ensure the formwork design conforms with this document, as follows:

- (a) The formwork documentation conforms to the requirements of AS 3610.1:2018 Clause 2.4.
- (b) The formwork design conforms to the project and construction requirements set out in [Clause 2.2](#).
- (c) The formwork design conforms to the structural requirements set out in [Clause 2.3](#).

Where design or design verification is assisted by testing, the testing conforms to the requirements of [Appendix A](#) of this document.

Section 3 Design actions and action combinations

3.1 Scope of section

Formwork shall be designed for the permanent, variable and unintended actions specified in [Clause 3.2](#), combined in accordance with [Clause 3.3](#).

C3.1 *It is not intended that the requirements of this Section will comprehensively cover all eventualities in formwork design. Where an unusual formwork assembly is to be designed, care is necessary to assess whether the requirements of this document are adequate in themselves to constitute an adequate design.*

3.2 Actions

3.2.1 General

The actions on formwork shall be determined in accordance with [Clauses 3.2.2](#) to [3.2.4](#), taking into account each of the following stages in the construction cycle:

- (a) Stage 1 — Prior to placement of concrete. Includes the period —
 - (i) during handling and erection of the formwork; and
 - (ii) once the formwork is erected, but prior to placement of concrete.
- (b) Stage 2 — During placement of concrete.
- (c) Stage 3 — After placement of concrete, and until the formwork is removed.

These actions shall take precedence over those defined in other relevant Standards.

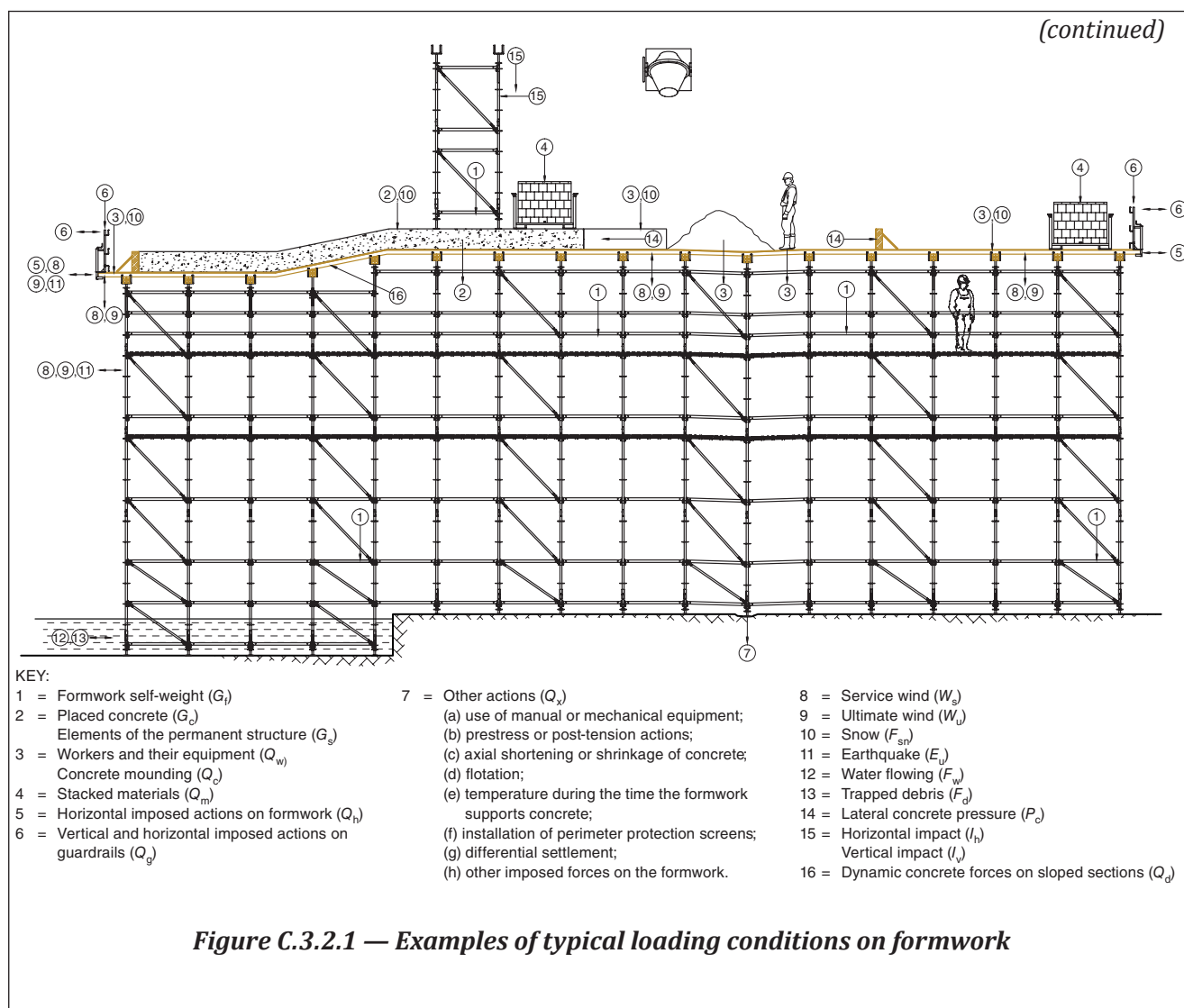
NOTE 1 See Figure C3.2.1 for examples of typical actions that may occur in formwork.

NOTE 2 Typically, actions on formwork during Stage 3, include those arising during curing, post-tensioning, relaxation of prestress, as well as landing and stacking materials, loading or operating plant or machinery, construction of subsequent elements, such as walls and plinths.

NOTE 3 See [Clause 6.4](#) for further commentary on the stages of construction for formwork.

C3.2.1 *The three stages in the construction cycle are clearly defined. However, attention is drawn to the fact that during the construction of some structures, the three stages may overlap. After completion of Stage 3 at a certain level in the building, Stage 1 may commence adjacent or at the level above. Where this occurs, it is essential that the formwork designer recognize the various stages and make adequate provision for the load effects of each in turn.*

Figure C3.2.1 depicts various actions that can take place over the three stages of the formwork construction cycle. It is a diagrammatic representation of the actions described in this Section and does not represent safe work practices or a realistic construction site.



3.2.2 Permanent actions

3.2.2.1 Formwork (G_f)

Permanent actions shall include the weight of formwork, including where applicable, the weight of —

- (a) any part of the permanent structure forming part of or supported by the formwork;
- (b) any ancillary structure connected to the formwork;
- (c) forms;
- (d) falsework;
- (e) multistorey shoring and
- (f) footings.

3.2.2.2 Placed concrete (G_c)

Permanent actions shall include the weight of concrete as placed, plus an allowance for the weight of reinforcement.

NOTE 1 For dense aggregate unreinforced concrete 24.0 kN/m³ should be used, plus an allowance of 0.6 kN/m³ for each 1 % of reinforcement by volume. Typically 25 kN/m³ for soffit formwork.

NOTE 2 Specialists installations may use high density concrete. For example, concrete elements of bridges can have densities of 26.5 kN/m³.

3.2.2.3 Elements of the permanent structure (G_s)

Permanent actions shall include the weight of elements of the permanent structure supported directly or indirectly by formwork, including but not limited to, where applicable, the weight of —

- (a) plinths, upstands, spandrels, columns and walls; and
- (b) plant or machinery.

3.2.3 Variable actions

3.2.3.1 Workers and their equipment (Q_w)

For formwork, the value for the imposed action from the weight of workers and equipment shall be taken as the most severe of the following:

- (a) For Stage 1, either —
 - (i) $Q_{w1} = 1.0$ kPa; or
 - (ii) $Q_{w1} = 0$ kPa.
- (b) For Stage 2, either —
 - (i) $Q_{w2} = 2.0$ kPa, which includes an allowance for localized mounding during concrete placing; or
 - (ii) $Q_{w2} = 0$ kPa.

NOTE 1 In some circumstances, once the concrete has reached its full height, the effects of concrete mounding may exceed 2.0 kPa, e.g. excessive mounding of concrete for manual distribution or kibble delivery, see [Clause 3.2.3.2](#).

NOTE 2 It is recognized that $Q_{w2} = 2.0$ kPa may be too severe for long span systems. However, vertical deflection of long span systems typically governs, and short-term variable actions are not considered when determining serviceability deflection. See [Section 7](#) for Stage 2 variable actions applicable to long span systems such as precast, large span formwork and permanent formwork in composite structures..

Commentary C3.2.3.1(a) *A more severe but transient load can occur at the point of discharge of the concrete onto the forms. While it is desirable not to mound the concrete in one location and then use the vibrators to transport the concrete horizontally, in practice this occurs frequently, and is independent of whether discharge is from a kibble or a pump. As the majority of concrete pours are delivered via a concrete pump the mounding and dynamics are not as severe as that of kibble delivery, but the effect is present.*

Instead of complicating Stage 2 with separate workers and concrete mounding loading conditions, it was determined that it was equally reliable to take account of the effect with a uniformly distributed

(continued)

load of $Q_{w2} = 2.0$ kPa. This has the added benefit of aligning this document more closely with the EN and ACI live loads.

- (c) For Stage 3, either of the following load conditions:
- (i) Where there is only one floor level to be supported, either —
 - (A) $Q_{w3} = 1.0$ kPa; or
 - (B) $Q_{w3} = 0$ kPa.
 - (ii) Where there is more than one floor level to be supported, the topmost level shall be taken as 1.0 kPa, and the other levels taken as 0.25 kPa.

For formwork acting as an access platform, the value for the imposed action from the weight of workers and equipment (Q_w) shall be not less than 2.5 kPa at any stage of the construction cycle.

For formwork acting as a working platform, the value for the imposed action from the weight of workers and equipment (Q_w) at any stage of the construction cycle shall be the most adverse of either a —

- (1) 1.0 kPa uniformly distributed load; or
- (2) 2 kN point load at the most adverse location.

Commentary C3.2.3.1(b) It is important to be aware that the most adverse action combination may occur with $Q_w = 0$ kPa. For example, with $Q_{w1} = 0$ kPa, a maximum uplift due to a horizontal wind action would occur if the design wind action is applied during Stage 1. The stability combination, with $Q_w = 0$ kPa, is also critical whenever cantilevers are used in formwork construction. $Q_w = 0$ is applicable in all stabilizing effects used for stability limit state design and $Q_w > 0$ is applied in destabilizing effects.

Concrete mounding (Q_c)

Concrete variable action due to mounding for slabs less than 250 mm thickness shall be added as follows:

- (a) $Q_{c2} = 1.0$ kPa when kibble is used applying to a $1.6 \text{ m} \times 1.6 \text{ m}$ area.
- (b) $Q_{c2} = 0$ kPa when concrete pump is used.

NOTE 1 Concrete mounding only applies at Stage 2.

NOTE 2 See [Section 7](#) for concrete mounding variable actions applicable to long span systems such as precast and permanent formwork in composite structures.

NOTE 3 [Figure 3.2.3.1](#) is an example of mounding due to the kibble pour.

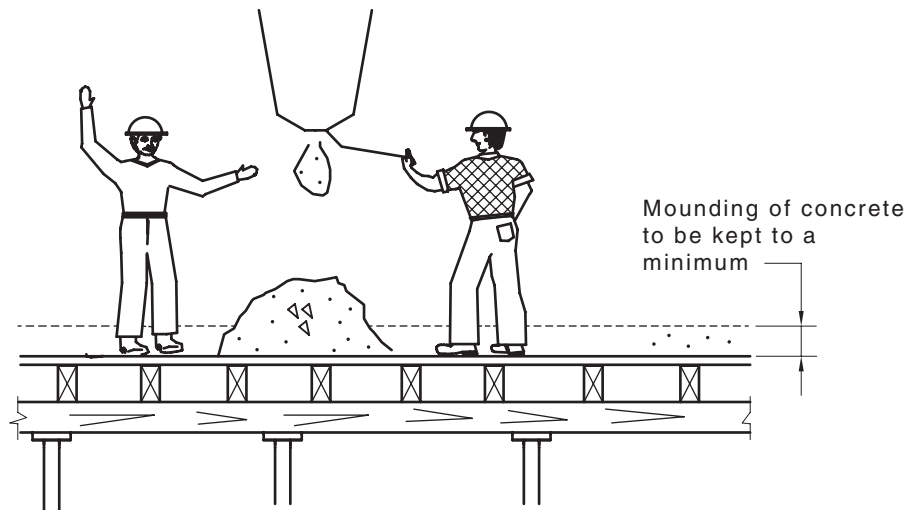


Figure 3.2.3.1 — Example of mounding due to kibble pour

3.2.3.2 Stacked materials (Q_m)

The imposed action from the weight of stacked materials may occur at any stage of construction and shall conform to the requirements of the construction documentation or AS 3610.1:2018 Clauses 2.2.4(a) (iii) and 2.4.2(h). The imposed action shall not be less than 2.5 kPa, where applied.

The weight of stacked materials shall be taken into account in the design. Any limitations on its location shall be clearly indicated in the formwork documentation.

The weight of stacked materials (Q_m) does not act concurrently with the allowance for workers and equipment (Q_w).

NOTE 1 Caution should be taken of high concentrations of stacked material loads around material hoist and load bays.

NOTE 2 Materials should be stacked or stored adjacent to columns or walls to reduce displacement of newly poured slabs.

NOTE 3 Stacked material allowance can be zero. For example, materials not placed during Stage 2 or certain locations cannot support materials. This needs to be clearly documented.

NOTE 4 Stacked materials may be placed on floors supporting the slab to be constructed. Strict control measures will be necessary if stacked materials are not allowed on supporting floors for multi-storey supports.

C3.2.3.2 *An understanding of the construction materials being used and stacked is essential for determining an appropriate magnitude for stacked materials. This Clause provides guidance for an appropriate minimum magnitude of stacked materials. In practice, stacked materials can be highly concentrated, especially adjacent to material hoists and load bays.*

Analysis of data from site surveys that weighed and mapped stacked materials determined that with tributary areas less than 28 m² the weight of stacked materials could be considered equivalent to a uniformly distributed action of not less than 2.4 kPa. For formwork with tributary areas greater than 28 m², it was found that the design load could be reduced (but not less than 2.0 kPa).

For some stability limit state cases, it may be appropriate to presume stacked materials are not present at all. However, whatever the design magnitude of the stacked material and its location, it needs to be clearly indicated in the formwork documentation.

Stacked materials typically occur in Stages 1 and 3 but can occur in Stage 2. An example for Stage 2 would be when concrete is being placed up to a construction joint, while materials are stacked adjacent

(continued)

to the construction joint yet share the same formwork support area. Another example is materials present on jump/climb and slip form systems; they are present throughout all stages.

Rapid cycle construction for tall buildings (consecutive pours every 3 days to 5 days with small slab areas) commonly have materials placed within hours of the concrete pour with formwork being constructed for the next floor level imprinting the concrete.

The total combined formwork actions, including stacked materials, needs to not exceed the maximum permitted construction loads of the supporting structure. Additional propped floor levels may be required if large stacked materials are present or the magnitude of the stacked materials may have to be reduced.

It may be required that stacked materials are not permitted until a newly poured slab reaches a certain strength.

For examples of stacked materials at each stage, see Figure C3.2.3.2.

Stage 1 — Materials placed directly on the formwork: Bundled reinforcement bars, stressing cable coils, stressing duct, set-down frames, packs of ply and timber, toolboxes, skips and bins.

Stage 2 — Commonly zero but overlap from an adjacent pour may contribute. Materials similar to Stages 1 and 3.

Stage 3 — Materials placed on newly poured slab while still supported by formwork: Stage 1 stacked materials plus stacked falsework, formwork, scaffold, and building materials (pallets of bricks, sand, etc.).

Many of the items listed above exceed 2.5 kPa and building materials such as pallets of bricks and stressing coil will exceed 5.0 kPa. Specific propping is often required for heavy items such as stressing coils.

Be aware that stacked materials can become left behind or trapped on supporting floors during multi-storey support construction.

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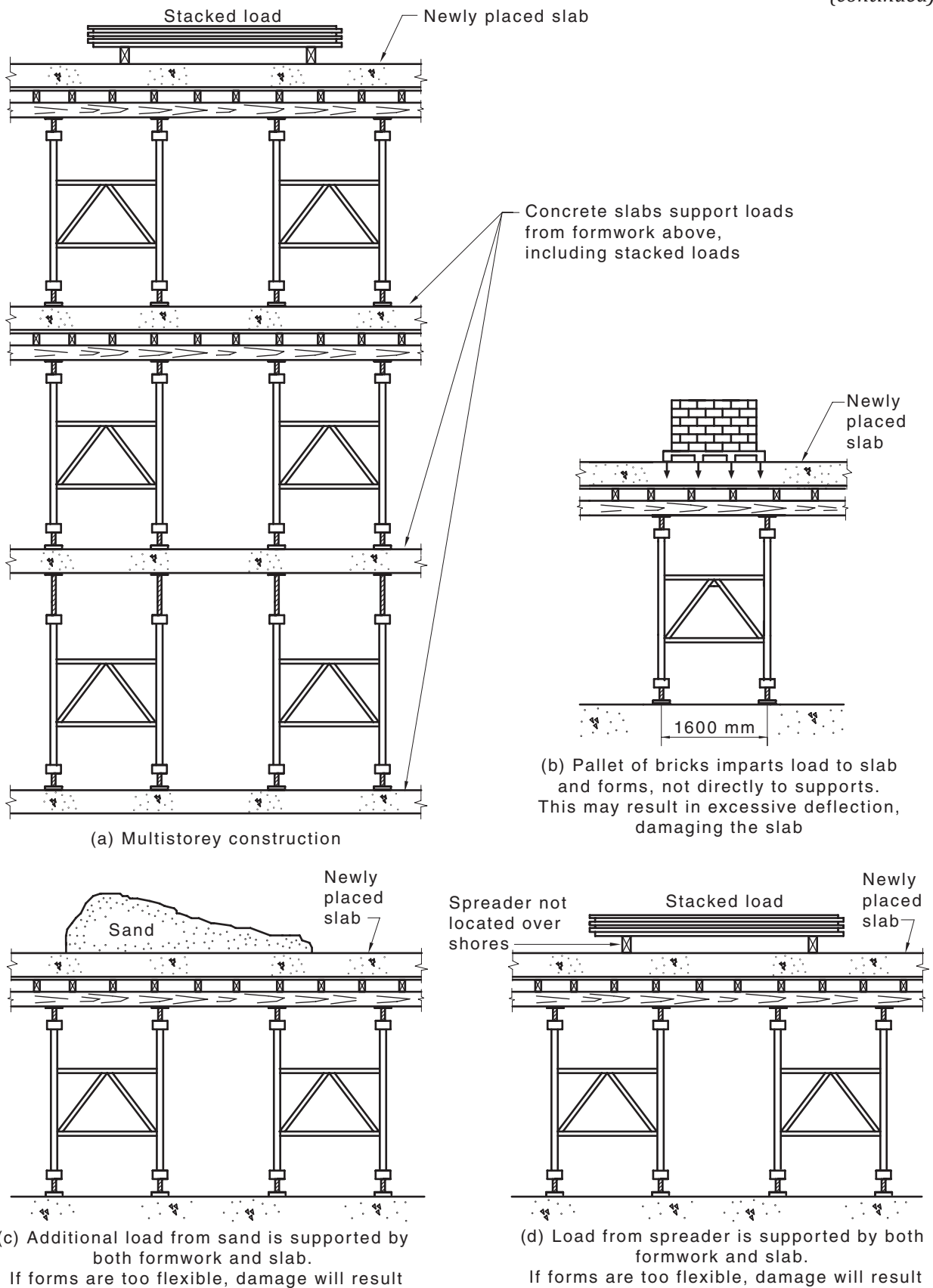


Figure C.3.2.3.2 — Examples of stacked material

3.2.3.3 Horizontal imposed actions on formwork (Q_h)

The value of the horizontal imposed action (Q_h) shall be the sum value of the horizontal imposed actions and shall not be less than —

- (a) 5 kN; or
- (b) 1 kN/m of form edge.

NOTE These actions do not occur concurrently with notional actions of [Section 4](#).

The following other imposed actions shall be taken into account:

- (i) Forces in concrete pumping systems.
- (ii) Braking of trolleys, skips or other vehicles.
- (iii) Cable tensions.
- (iv) Action of workers and equipment.

3.2.3.4 Vertical and horizontal imposed actions on guardrails (Q_g)

The imposed actions on edge protection fixed to the formwork shall be designed as specified in AS/NZS 4994.1. The load shall be taken into account as part of the loads in [Clause 3.2.3.4](#).

3.2.3.5 Other actions (Q_x)

Where additional actions occur concurrently with the formwork construction, these and any other anticipated actions shall be taken into account in the design. Additional imposed actions may include —

- (a) use of manual or mechanical equipment;
- (b) prestress or post-tension actions;
- (c) axial shortening or shrinkage of concrete;
- (d) flotation;
- (e) temperature during the time the formwork supports concrete;
- (f) Installation of perimeter protection screens;
- (g) differential settlement; and
- (h) other imposed forces on the formwork.

NOTE See AS 3610.1:2018 Section 2 for additional information that may be required to be inserted into project documentation.

3.2.3.6 Environmental actions

3.2.3.6.1 General

During all stages of the construction cycle, the effects of imposed horizontal and vertical actions from wind, snow, earthquake and flowing water acting on the formwork and falsework shall be taken into account based on the appropriate annual probability of exceedance for ultimate limit states specified in [Table 3.2.6\(A\)](#).

Table 3.2.6(A) — Annual probability of exceedance for ultimate limit states

Formwork importance (refer to AS 3610.1:2018 Appendix A)	Wind	Snow	Earthquake
I	1/25	1/25	Not required (See Note)
II	1/100	1/50	Not required (see Note)
III	1/250	1/100	1/250

NOTE Earthquake loads in Australia are low and the formwork is designed for robustness. [Clause 3.3.5](#), and other actions will provide sufficient resistance.

3.2.3.6.2 Wind (W_u , W_s)

Wind actions shall include the aerodynamic effects of wind acting on the sides and soffit of the formwork, falsework, edge protection or cladding, and any stacked materials.

The wind actions shall be calculated in accordance with AS/NZS 1170.2. The calculation shall include the following:

- (a) W_u = the ultimate wind actions calculated in accordance with AS/NZS 1170.2.

For formwork that is constructed and removed within one year, the regional design wind speed specified in AS/NZS 1170.2 may be reduced by the factor given in [Table 3.2.6\(B\)](#). Interpolation is permitted for other durations not less than one week.

Formwork erected in Regions C and D (i.e. cyclonic regions as defined in AS/NZS 1170.2) and remaining erected only during the period of May to October may be designed for Region A wind speeds specified in AS/NZS 1170.2.

Formwork in Regions C and D not designed for cyclonic wind speeds shall be dismantled or have the capacity to be strengthened during a cyclonic event.

Table 3.2.6(B) — Reduction factor on regional wind speed

Wind region	6 month duration	1 month duration	1 week duration
A	0.95	0.85	0.75
B	0.95	0.75	0.55
C	0.95	0.75	0.55
D	0.90	0.70	0.50

- (b) W_s = the service wind, calculated in accordance with AS/NZS 1170.2, based on a mean wind speed at ground level of not less than 16 m/s.

C3.2.3.6.2 Wind actions calculated in accordance with AS/NZS 1170.2 require a 3 s gust speed. To convert a mean wind speed ($\bar{v}$) measured over 10 min at 10 m above ground or sea level to its equivalent to a 3 s gust speed, [Equation 3.2\(1\)](#) applies as follows:

$$V(z) = \left[\left(\frac{z}{10} \right)^{0.14} + 0.4 \right] \bar{v}, \text{ metres per second} \quad 3.2(1)$$

where $V(z)$ acts on an elevated point z (m) above ground or sea level.

3.2.3.6.3 Snow (F_{sn})

The ultimate snow actions shall be determined in accordance with AS/NZS 1170.3.

3.2.3.6.4 Earthquake (E_u)

For importance level III structures refer to Table 3.2.6 (A) the ultimate earthquake forces shall be determined in accordance with AS 1170.4.

3.2.3.6.5 Water (F_w , F_d)

Where it is necessary for formwork to be placed in flowing water, the actions caused by the flow shall be taken into account. These include the following:

- (a) Dynamic pressure of water.
- (b) Impact from floating objects.
- (c) Increased frontal area and head of water due to trapped debris.

Where applicable, the forces due to the action of any of the following shall be taken into account:

- (i) River currents.
- (ii) Tides.
- (iii) Wave action.
- (iv) Flooding.

Consideration should be given to the possible existence of buoyancy or uplift.

NOTE For further information, refer to AS 5100.

3.2.3.7 Lateral concrete pressure (P_c)

The lateral concrete pressure for vertical formwork shall be calculated in accordance with one of the following:

- (a) $P_c = \rho g h_c$.
- (b) CIRIA (See [Appendix E](#)).
- (c) DIN 18218, *Pressure of fresh concrete on vertical formwork*.
- (d) ACI 347R, *Guide to Formwork for Concrete*.

Where documented testing and measurement of a particular concrete mix's lateral pressure performance has been undertaken with conditions analogous to the given construction environment and methodologies, then those results may be used in lieu of calculated pressures.

An additional allowance for pressure should be considered for concrete made with shrinkage-compensating or expansive cements.

NOTE 1 Calculations based on DIN 18218 and ACI 347R should first establish, as applicable —

- (a) correlation between the cement type upon which the respective formulas are based and the cement used; and
- (b) on-site tests for slump and flow, or consistency and setting time, in accordance with the relevant National Standards.

NOTE 2 The above calculation methods are not suitable for use in the following cases:

- (a) Grout-injected concrete, or where the concrete is pumped from below into the forms (see [Figure 3.2.3.7](#)).
- (b) Deep re-vibration of the concrete.
- (c) External vibration.

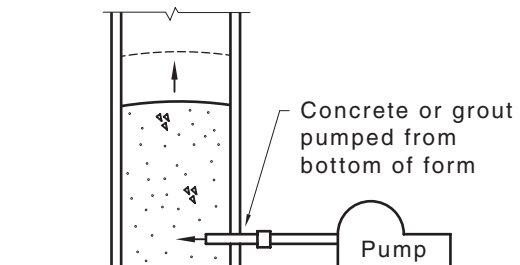


Figure 3.2.3.7 — Concrete pumped from below

C3.2.3.7 Generally, concrete lateral pressure will not reach full equivalent liquid head pressure; however, in the absence of researched data confirming this, concrete pressures should be determined with one of the methods listed in [Clause 3.2.3.8](#) based on the depth of concrete.

[Appendix E](#) details the updated CIRIA formula with SCC (Self-consolidating-concrete) considerations. The original CIRIA formula was published in previous editions of this document. Caution is advised when working with SCC as its application of pressure is contentious owing to contradictory research and advice on its performance, but, in general, its setting times are no different to other concrete mixes with similar admixtures and retarding agents. A common issue with SCC is high flow leaks through the formwork. Gaps and holes need to be tightly sealed to prevent concrete egress.

Where documented testing and measurement of a particular concrete mix's lateral pressure performance has been undertaken, then those pressure results may be used in lieu of calculated pressures. Caution is advised as the testing needs to closely match site conditions and take into account vibration and construction methodologies. Often, laboratory tests are needed as a precursor to on-site monitoring tests. The lateral pressures developed are determined by considering the rate of concrete placement relative to the rate of development of concrete stiffness/strength. Any test method has to include a measure of the stiffening characteristics and should be capable of being easily checked using on-site measurements.

Concrete pressures are challenging to measure accurately. Methods typically consist of direct pressure gauges fixed into the form face or load cells at the form ties. Pressure gauge size is an important consideration owing to concrete aggregate "bridging" over small load cells yielding misleading low-pressure readings while large gauges may compromise the formwork it is measuring.

For grout injected concrete, the form should be designed for full hydrostatic head of concrete plus a minimum allowance of 25 % for pump surge pressure. Pressure can reach as high as face pressure of the pump piston, therefore pressure should be monitored and controlled so that the design pressure is not exceeded.

Deep re-vibration is the application of vibration to concrete which has already been placed and compacted and where the first poured layer has partially hardened. The beneficial effect of this is achieving greater compaction for concrete structures requiring water resistance. However, consideration of the form is essential. Re-vibration re-excites the concrete causing a completed pour to re-plasticise producing hydrostatic concrete pressures.

Formwork systems utilizing external vibrators are typically for precast work and in situ work where internal vibrators are difficult or impossible to operate, such as culverts and tunnel linings. An

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additional allowance for pressure should be considered when using external vibration. See [Clause 7.3](#) for underground structures.

3.2.3.8 Dynamic concrete forces

The forces resulting from changes in momentum of concrete due to the impact, commencement, surge, or cessation of concrete flow shall be taken into account.

NOTE This requires attention particularly in the case of a sloping form face. See [Figure 3.2.3.8](#) as an example.

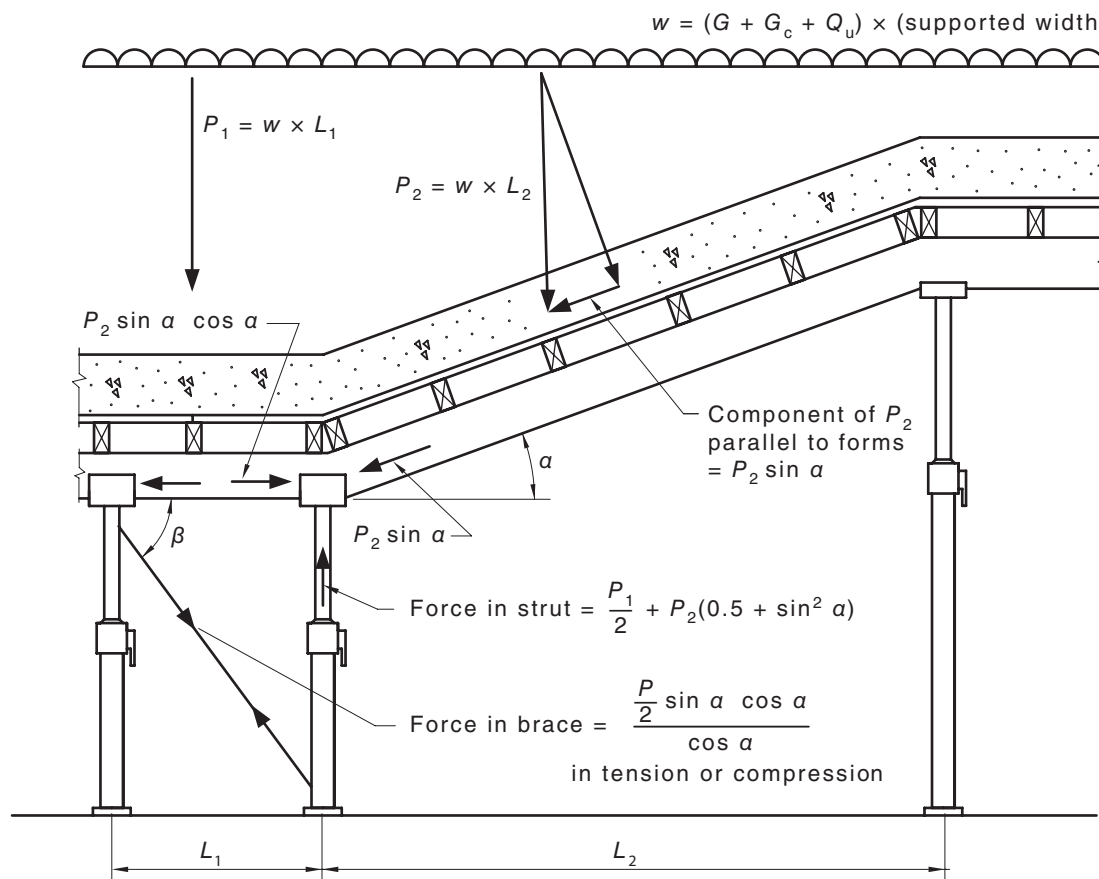


Figure 3.2.3.8 — Example of horizontal load due to sloping formwork

3.2.4 Unintended actions

3.2.4.1 Horizontal Impact (I_h)

Where construction activity is likely to cause impact to the completed formwork assembly or a formwork assembly being lifted it shall be designed to sustain a horizontal impact (I_h).

Unless the direction of the force is known it shall be taken into account to act in any horizontal direction in the horizontal plane. The force shall also be assumed not to act concurrently with the horizontal forces determined in [Clauses 3.2.3.4](#) and [3.2.3.5](#). Partial collapse, damage and deformation or deformation alone from impact is acceptable provided it does not result in collapse, detrimental or disproportionate consequences.

C3.2.4.1 The horizontal impact load has been introduced principally for reasons of safety. Figure C3.2.4.1 illustrates typical cases where this load needs to be taken into account. It is not intended.

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that wall or column forms be designed to withstand this load without damage. It is rather the intention that catastrophic collapse, which may endanger personnel, be prevented. In this respect, particular attention should be paid to connections to ensure that fixings are adequate to prevent sudden failure.

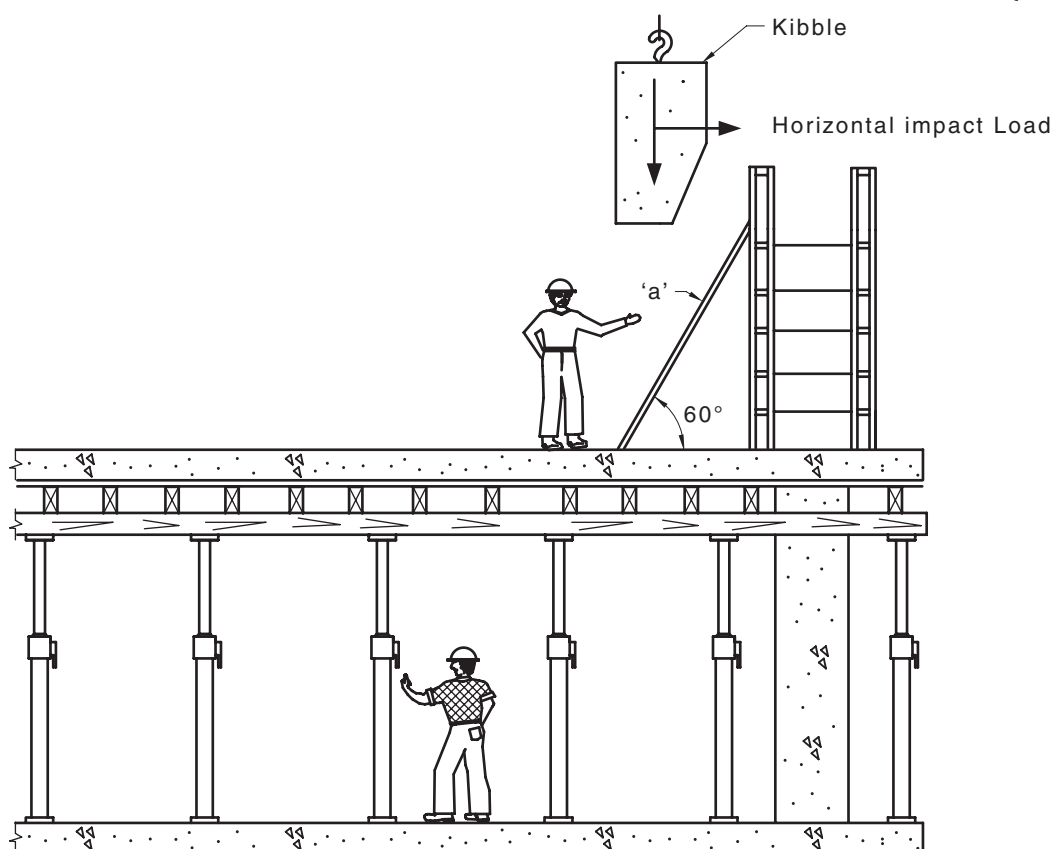
The load I_h would only be applicable to formwork projecting above the topmost level of formwork at any time, i.e. in a location where impact from a crane is possible. Where no overhead cranes are to be used during the life of the formwork, horizontal impact may be ignored.

The likelihood of the force acting simultaneously with other horizontal actions, or with wind or earthquake actions, is considered remote.

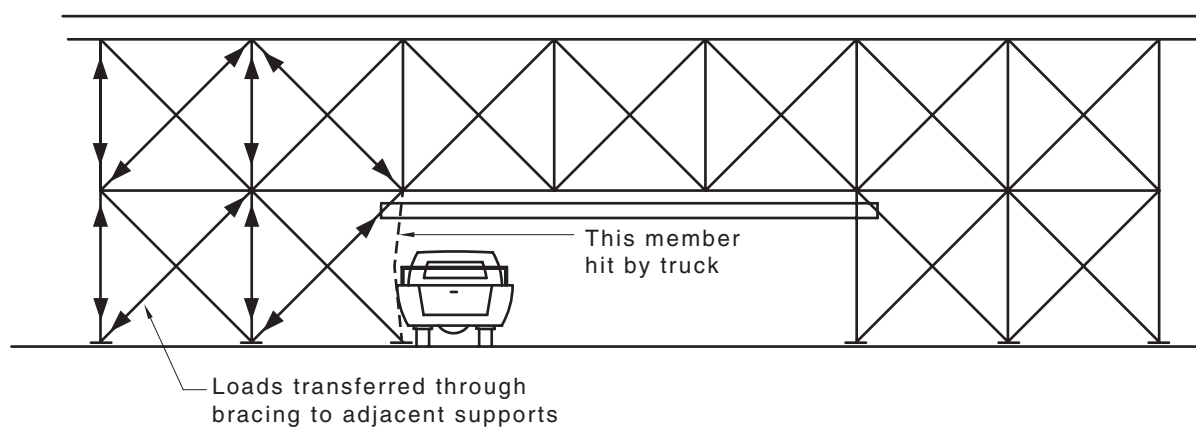
Another case where horizontal impact should be considered is in locations where the supports at ground level could be hit.

Impact needs to not lead to progressive collapse. In cases where this is possible, several load paths should be provided so that the formwork assembly, though damaged, will continue to support the applied loads, see Figure C3.2.4.1.

(continued)



(a) Impact from kibble



(b) Impact from truck

Figure C.3.2.4.1 — Horizontal impact load**3.2.4.2 Vertical Impact (I_v)**

Vertical loads in addition to those listed in [Clause 3.2.3.1](#) shall be taken into account. These include vertical impact of concrete when placed from a height greater than from a pump or typical kibble height and loads from materials placed on the formwork such as reinforcing bars, stressing coils and perimeter protection screens.

3.3 Combinations of actions

3.3.1 General

Actions shall be multiplied by the appropriate partial load factor and combined to give a “limit state” load as indicated in the equations in [Clauses 3.3.2 to 3.3.5](#). Where there is a choice of load direction or magnitude for the specified actions, the most adverse combination shall be selected.

Where imposed actions, including actions from stacked materials, occur, both full and zero values of these actions shall be taken into account to determine the most severe condition.

The magnitude of actions in this document shall take precedence over those defined in other relevant Standards.

The magnitude of the combined actions imposed by the formwork on the permanent structure, or any existing structure, shall not exceed the load limitations in the project documentation, refer to AS 3610.1:2018 Clauses 2.2.4 (a) and 4.2.

C3.3.1 *The last paragraph above is a reminder to ensure the formwork loads do not exceed the capacity of the supporting structure.*

NOTE 1 The combinations of actions in [Clauses 3.3.2, 3.3.3, 3.3.4 and 3.3.5](#) are intended to cover most situations. In some cases, other actions will be present, or the combinations shown will not produce the most severe design load.

NOTE 2 For each design situation, consideration should be given to the combinations of all vertical and horizontal actions that may act concurrently.

NOTE 3 Where impact is allowed for in the design, any assumed damage and deformation should not put at risk the health and safety of persons on or in the vicinity of the formwork. A risk assessment will assist in this regard.

3.3.2 Stability limit states

The basic combinations for the stability limit state shall be as follows in [Equations 3.3\(1\) to \(7\)](#):

- (a) For combinations that produce net stabilizing effects ($E_{d,stab}$):

$$E_{d,stab} = [0.9G] \quad 3.3(1)$$

- (b) For combinations that produce net destabilizing effects ($E_{d,dst}$):

$$E_{d,dst} = [1.35G] \quad 3.2(2)$$

$$E_{d,dst} = [1.2G, 1.5Q, W_s, \gamma_p P] \quad 3.3(3)$$

where

$$\gamma_p = 1.2 \text{ for hydrostatic concrete pressure; and}$$

$$\gamma_p = 1.5 \text{ for concrete pressure limited by setting.}$$

$$E_{d,dst} = [1.2G, W_u] \quad 3.3(4)$$

$$E_{d,dst} = [1.2G, 1.1I] \quad 3.3(5)$$

$$E_{d,dst} = [1.2G, 1.5Q, S_u] \quad 3.3(6)$$

where S_u represents, for the design situation, the appropriate combination of $1.5F_w$, $1.5F_d$ and $1.5F_{sn}$

$$E_{d,dst} = [G, Q, E_u] \quad 3.3(7)$$

3.3.3 Strength limit states

The design action effect (E_d) for strength limit state shall be determined from the basic combinations set out in [Table 3.3.1](#).

NOTE Unanticipated load factors should be applied to strength limited state load combinations for primary members in accordance with [Clause 2.3.4.2](#).

3.3.4 Serviceability limit states

The basic combination for serviceability limit states shall be as follows:

- (a) For concrete surface finish (G, P).
- (b) Otherwise, (G, Q).

3.3.5 Robustness

The connections shall be capable of transmitting notional horizontal actions of 2.5 % of the sum of the most adverse combination of permanent and variable vertical actions applied at their respective points of application. Each notional action shall be assumed to act in any direction at right angles to the axis of the compression member. However, the notional actions acting at each level are not cumulative through the bracing. A typical arrangement of notional horizontal actions is shown in [Figure 3.3.5](#). This requirement for load transmitting does not apply to connections between independent formwork structural systems but shall apply to all parts within a system. The notional actions shall be assumed to act in addition to other actions.

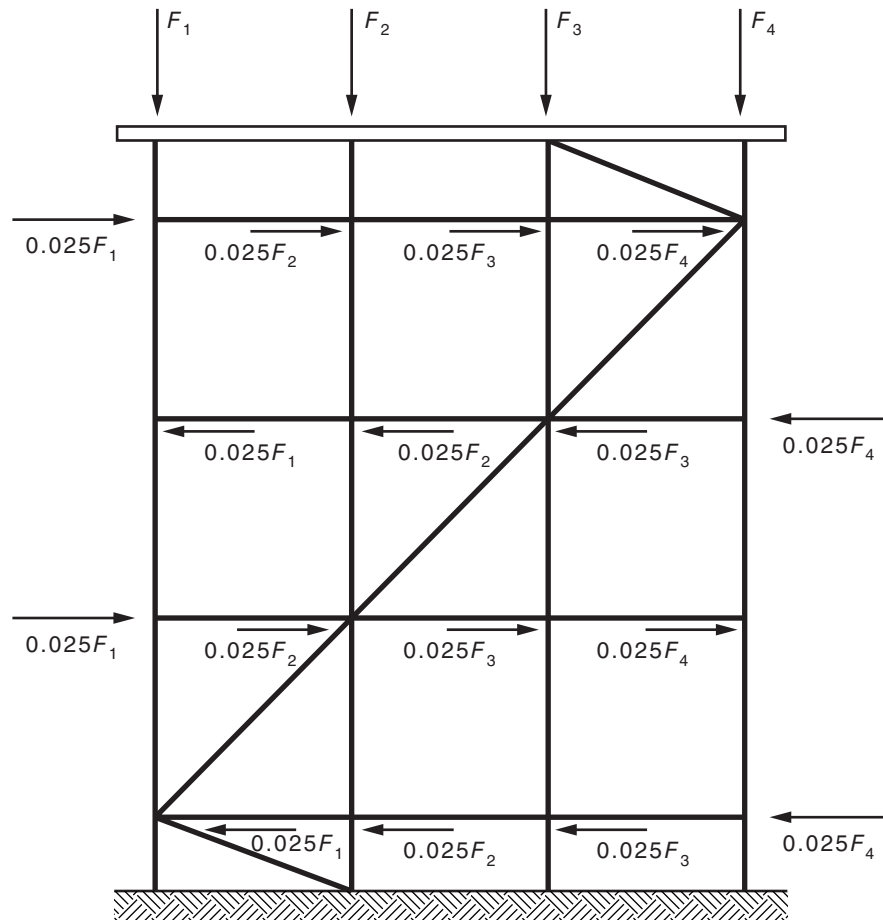


Figure 3.3.5 — Typical notional actions applied at connections

C3.3.5 The notional horizontal action of 2.5 % is required to ensure bracing members and connections have sufficient strength to transfer forces arising from out-of-straightness. The forces at a given level are cumulative when several bays are braced by the same bracing as indicated in [Figure 3.3.5](#). Because every sixth bay will be braced in case of multiple bays, the maximum accumulated notional horizontal action is 15 % of the total vertical action on the six braced bays.

A key question in specifying the notional horizontal action is the extent to which out-of-straightness of adjacent standards are correlated. If they are, the notional horizontal action is cumulative, whereas out-of-straightness in opposite directions counteract each other. This is discussed in detail in [2] (see Bibliography). Data are not available for the correlation of out-of-straightness of standards in multi-bay formwork systems. However, it is conceivable that once out-of-straightness is introduced in one standard during erection, this out-of-straightness could be repeated when progressively erecting adjacent standards, therefore introducing a degree of correlation. It is also relevant that the notional horizontal action increases with the out-of-straightness (e.g. see [2], [3] and [4] in the Bibliography) and that member out-of-straightness of $L/300$ is tolerated in this document, whereas the out-of-straightness is limited to $L/1000$ in other structural standards, including AS 4100.

Table 3.3.1 — Strength limit state combinations of actions

Action group	Line No.	Action	Combination number											
			Stage 1 — prior to placement of concrete				Stage 2 — during placement of concrete				Stage 3 — after placement of concrete			
			1	2	3	4	5	6	7	8	9	10	11	12
Permanent actions	1	Formwork weight (G_f)	1.35	1.2	1.2	0.9	1.0	1.35	1.2	1.0	1.35	1.2	1.2	1.0
	2	Placed concrete (G_c)						1.35	1.2	1.0	1.35	1.2	1.2	1.0
Variable actions	3	Workers, equipment and concrete mounding (Q_w and Q_c)		1.5 ^a					1.5 ^a			1.5 ^a		
	4	Stacked materials (Q_m)		1.5 ^a					1.5 ^a			1.5 ^a		
	5	Horizontal load (Q_h)		1.5					1.5			1.5		
	6	Service wind load (W_s)		1.0					1.0			1.0		
	7	Ultimate wind load (W_u)			1.0	1.0 ^b							1.0	
	8	Flowing water (F_w), trapped debris (F_d) and/or snow (F_{sn})		1.5	1.5	1.5 ^b			1.5			1.5		
Unintended Strength	9	Other actions (Q_x)		1.5					1.5			1.5		
	10	Concrete pressure (P_c)							γ_p^c			γ_p^c		
	11	Impact (I)					1.1			1.1				1.1
	12	Unanticipated load redistribution		γ_d^d				γ_d^d	γ_d^d		γ_d^d	γ_d^d		

^a At any stage, the formwork may be subject to both imposed actions from workers and equipment (Q_w) as well as stacked materials (Q_m); however, it is unlikely that both will act concurrently at the same location. During Stage 2, it is unlikely that loads from stacked materials and concrete weight will both act concurrently at the same position.

^b May act in opposite direction to G_f .

The magnitude of the partial load factor for concrete pressure (γ_p) shall conform to [Clause 3.3.2\(b\)](#).

The partial load factor for unanticipated load redistribution (γ_d), see [Clause 2.3.4](#).

NOTE 1 Notional horizontal forces should be considered in conjunction with the appropriate load combinations, see [Clause 3.3.5](#).

Table 3.3.1 (continued)

Action group	Line No.	Action	Combination number											
			Stage 1 — prior to placement of concrete					Stage 2 — during placement of concrete			Stage 3 — after placement of concrete			
			1	2	3	4	5	6	7	8	9	10	11	12
NOTE 2 For members whose failure could cause collapse, the unanticipated effects of load redistribution, see Clause 2.3.4.2 .														
NOTE 3 The resistance of timber, plywood and LVL depends upon the duration (see Table 3.3.2) of the shortest duration load type contributing to each combination of actions. The action combination with the greatest magnitude may not be the critical case. For example, in Table 3.3.1 , the load combination number 8 may be more critical where the contribution to total load from wind, flowing water and horizontal load is neglected or their magnitude is negligible and the duration load factor for vertical permanent and variable actions applies.														

Table 3.3.2 — Duration of load factor for design in accordance with AS 1720.1

Load source	Effective duration of peak load	Modification Factor k_1^a
Permanent actions:		
Formwork weight (G_f)	5 months	0.80
Placed concrete (G_c) acting on:		
(a) Plywood	5 hours	0.97
(b) Bearers and joists (walers and soldiers)	5 days	0.94
(c) Supports	5 months	0.80
Variable actions:		
Workers and their equipment (Q_w)	5 hours	0.97
Concrete moulding (Q_c)	5 hours	0.97
Stacked materials (Q_m)	5 days	0.94
Concrete pressure (P_c)	5 hours	0.97
Service wind load (W_s)	5 hours	0.97
Ultimate wind load (W_u)	5 seconds	1.00
Snow load (F_{sn})	5 days	0.94
Flowing water (F_w and F_d):		
(a) River Currents	5 months	0.80
(b) Tidal Action	5 hours	0.97
(c) Flooding	5 days	0.94
(d) Wave Action	5 days	0.94
Unintended actions:		
Impact (I_h, I_v)	5 seconds	1.00
^a For the strength of timber.		

Section 4 Structural analysis

4.1 General

To ensure loads can be transferred to the ground or supporting structures, the load transfer shall be determined by creating representative models of formwork and supporting falsework and conducting structural analyses to determine the distribution of actions in all parts of the structure. This Section sets out the requirements for the structural analysis of formwork and supporting falsework, including the modelling of eccentricities of loading and supports, as well as unavoidable imperfections such as out-of-plumb and out-of-straightness.

Once the actions have been determined from a structural analysis, it shall be established that each part of the structure has sufficient capacity to transfer the loads. This process is referred to as design and is dependent on the materials used. [Section 5](#) sets out the requirements for the design of formwork and supporting falsework.

Specifically, formwork and supporting falsework shall be subject to structural design checks as follows:

- (a) First, a global analysis of the structure shall be made in order to determine the distribution of design actions (such as internal forces, moments or stresses) and displacements, as specified in [Clause 4.2](#) for formwork and [Clause 4.3](#) for falsework.
- (b) Subsequently, individual elements of the formwork and falsework shall be designed to ensure that the elements have adequate resistance in the ultimate limit state, and that unacceptable deformations do not develop in the serviceability limit state, as specified in [Clause 5.2](#) for formwork and [Clause 5.3](#) for falsework.

4.2 Formwork

Formwork typically consists of bearers and joists supporting plated materials onto which wet concrete is poured. The bearers and joists may be continuous or single span and are supported on the adjustable jacks of the falsework. Typical materials are LVL, timber, plywood and aluminium.

The structural analysis of formwork shall take into account the actions and action combinations specified in [Section 3](#). Distributed loads may be apportioned to supporting bearers using a statically admissible area-weighted method. The internal actions in the bearer can subsequently be obtained using linear theory for simply supported and continuous beams, as appropriate.

4.3 Falsework

4.3.1 General

For each design situation, the falsework shall be analysed to determine the action effects and serviceability response of the appropriate combinations of actions given in [Clause 3.3](#). The serviceability, stability and strength limit states shall not be exceeded.

The action effects shall be determined from an analysis of the structure taking into account the effects arising from the following:

- (a) Out-of-plumb erection tolerance (global imperfections), see [Clause 4.3.3.1](#).
- (b) Eccentricity of actions and joints, see [Clause 4.3.4.1](#).

In addition, unless taken into account in determining the falsework design capacity in accordance with [Clause 5.3](#), the structural analysis shall take into account the effects arising from compression member out-of-straightness, see [Clause 4.3.3.2](#).

A global analysis of the falsework shall be completed. Methods of structural analysis shall conform to [Clause 4.3.2](#).

NOTE 1 Elastic methods of global analysis are usually the most appropriate for cold-formed or hot-rolled steel and aluminium falsework systems. However, nonlinear connection behaviour may be incorporated in the analysis provided that the nonlinear characteristic used is based on test results that demonstrate adequate rotation capacity.

NOTE 2 Falsework is intended to be axially loaded and requires adequate bracing to maintain stability and eliminate or reduce sway to ensure that the imposed loads are primarily axial. The vertical members supporting the formwork are subject to compression and bending and are not intended to support tension loads. Additional support systems are required where vertical members develop tension.

The provisions applicable to the subsequent design check are dependent upon the method of global analysis used to determine the design actions, as specified in [Clause 5.3](#).

4.3.2 Methods of structural analysis

An analysis of a complete three- or two-dimensional frame, or representative number of bays, shall be carried out using one, or a combination, of the following methods of analysis:

- (a) Linear analysis (LA).
- (b) Linear buckling analysis (LBA).
- (c) Geometric nonlinear analysis (GNA).
- (d) Geometric and material nonlinear analysis with geometric imperfections (GMNIA).

NOTE The methods of analysis vary in complexity. It is at the discretion of the designer to choose the method. Linear analysis is the simplest and often the preferred method. Geometric nonlinear analysis more accurately predicts design actions and is the recommended method. Geometric and material nonlinear analysis with geometric imperfections (GMNIA) is the most complex method and requires competence in nonlinear finite element modelling. GMNIA is the most accurate method and may lead to higher design capacities than the simpler LA and GNA methods.

The requirements for each method of analysis in regard to geometric and material modelling are set out in [Clause 4.3.5](#). Geometric imperfections shall be taken into account in the structural model, as specified in [Clause 4.3.3](#), or indirectly in the design of members, see [Clause 5.3](#). The specified geometric imperfections depend on the method of analysis. Eccentricities at supports, joints and application of actions shall also be taken into account in the structural model, as specified in [Clause 4.3.4](#).

Structural analysis programs used to perform LA, LBA, GNA and GMNIA analyses shall be validated against benchmark analytical solutions, well-documented experimental tests, or similar benchmark results.

4.3.3 Imperfections

4.3.3.1 Global imperfections (out-of-plumb)

The effects of global imperfections (out-of-plumb) shall be accounted for by the use of notional horizontal actions.

Where the form deck is unrestrained horizontally, notional horizontal actions shall be applied at the form deck level where vertical actions are applied and be equal to 0.01 times the factored vertical permanent and variable vertical actions, as specified in [Figure 4.3.3.1\(a\)](#).

Where the form deck is restrained horizontally, notional horizontal actions shall be applied at the form deck level where vertical actions are applied and be equal to 0.005 times the factored vertical permanent and variable vertical actions. In addition, notional horizontal actions shall be applied at the joints closest to the mid-height. These actions shall be equal to 0.01 times the factored vertical