

- Insufficient allowance for eccentric loading due to placement sequences;
- Failure to investigate bearing stresses in members in contact with shores or struts;
- Failure to provide proper lateral bracing or lacing of shoring;
- Failure to investigate the slenderness ratio of compression members;
- Inadequate provisions to tie corners of intersecting cantilevered forms together;
- Failure to account for loads imposed on form hardware anchorages during closure of form panel gaps when aligning formwork; and
- Failure to account for elastic shortening during post-tensioning.

2.1.5 Formwork drawings and calculations—Before constructing forms, the formwork engineer/contractor may be required to submit detailed drawings, design calculations, or both of proposed formwork for review and approval by the engineer/architect or approving agency. If such drawings are not approved by the engineer/architect or approving agency, the formwork engineer/contractor should make such changes as may be required before the start of construction of the formwork.

The review, approval, or both of the formwork drawings does not relieve the contractor of the responsibility for adequately constructing and maintaining the forms so that they will function properly. If reviewed by persons other than those employed by the contractor, the review or approval indicates that no exception is taken by the reviewer to the assumed design loadings in combination with design stresses shown; the proposed construction methods; the placement rates, equipment, and sequences; the proposed form materials; and the overall scheme of formwork. All major design values and loading conditions should be shown on formwork drawings. These include assumed values of live load; the compressive strength of concrete for formwork removal and for application of construction loads; rate of placement, minimum temperature, height, and drop of concrete; weight of moving equipment that can be operated on formwork; foundation pressure; design stresses; camber diagrams; and other pertinent information, if applicable.

In addition to specifying types of materials, sizes, lengths, and connection details, formwork drawings should provide for applicable details, such as:

- Procedures, sequence, and criteria for removal of forms, shores, and reshores;
- Design allowance for construction loads on new slabs when such allowance will affect the development of shoring, reshoring schemes, or both (refer to [Sections 2.5 and 3.8](#) for shoring and reshoring of multistory structures);
- Anchors, form ties, shores, lateral bracing, and horizontal lacing;
- Field adjustment of forms;
- Waterstops, keyways, and inserts;
- Working scaffolds and runways;
- Weepholes or vibrator holes, where required;
- Screeds and grade strips;

- Location of external vibrator mountings;
- Crush plates or wrecking plates where stripping can damage concrete;
- Removal of spreaders or temporary blocking;
- Cleanout holes and inspection openings;
- Construction joints, contraction joints, and expansion joints in accordance with contract documents (also refer to ACI 301);
- Sequence of concrete placement and minimum elapsed time between adjacent placements;
- Chamfer strips or grade strips for exposed corners and construction joints;
- Camber;
- Mudsills or other foundation provisions for formwork;
- Special provisions, such as safety, fire, drainage, and protection from ice and debris at water crossings;
- Formwork coatings;
- Notes to formwork erector showing size and location of conduits and pipes projecting through formwork; and
- Temporary openings or attachments for climbing crane or other material handling equipment.

2.2—Loads

2.2.1 Vertical loads—Vertical loads consist of dead and live loads. The weight of formwork plus the weight of the reinforcement and freshly placed concrete is dead load. The live load includes the weight of the workers, equipment, material storage, runways, and impact.

Vertical loads assumed for shoring and reshoring design for multistory construction should include all loads transmitted from the floors above as dictated by the proposed construction schedule. Refer to [Section 2.5](#).

The formwork should be designed for a live load of not less than 50 lb/ft² (2.4 kPa) of horizontal projection. When motorized carts are used, the live load should not be less than 75 lb/ft² (3.6 kPa).

The design load for combined dead and live loads should not be less than 100 lb/ft² (4.8 kPa) or 125 lb/ft² (6.0 kPa) if motorized carts are used.

2.2.2 Lateral pressure of concrete—Unless the conditions of [Section 2.2.2.1](#) or [2.2.2.2](#) are met, formwork should be designed for the lateral pressure of the newly placed concrete given in Eq. (2.1a) or (2.1b). Minimum values given for other pressure formulas do not apply to Eq. (2.1a) and (2.1b).

Worst

case:

$$p = wh \text{ (lb/ft}^2\text{)} \quad (2.1a)$$

$$p = \rho gh \text{ (kPa)} \quad (2.1b)$$

where

p = lateral pressure, lb/ft² (kPa);

w = unit weight of concrete, lb/ft³;

ρ = density of concrete, kg/m³;

g = gravitational constant, 9.81 N/kg; and

h = depth of fluid or plastic concrete from top of placement to point of consideration in form, ft (m).

The [set](#) characteristics of a mixture should be understood, and using the rate of placement, the level of fluid concrete

Table 2.1—Unit weight coefficient C_w

Inch-pound version		SI version	
Unit weight of concrete	C_w	Density of concrete	C_w
Less than 140 lb/ft ³	$C_w = 0.5[1 + (w/145 \text{ lb/ft}^3)]$ but not less than 0.80	Less than 2240 kg/m ³	$C_w = 0.5[1 + (w/2320 \text{ kg/m}^3)]$ but not less than 0.80
140 to 150 lb/ft ³	1.0	2240 to 2400 kg/m ³	1.0
More than 150 lb/ft ³	$C_w = w/145 \text{ lb/ft}^3$	More than 2400 kg/m ³	$C_w = w/2320 \text{ kg/m}^3$

can be determined. For columns or other forms that can be filled rapidly before stiffening of the concrete takes place, h should be taken as the full height of the form or the distance between horizontal construction joints when more than one placement of concrete is to be made. When working with mixtures using newly introduced admixtures that increase set time or increase slump characteristics, such as self-consolidating concrete, [Eq. \(2.1a\)](#) [[\(2.1b\)](#)] should be used until the effect on formwork pressure is understood by measurement.

2.2.2.1 Inch-pound version—For concrete having a slump of 7 in. or less and placed with normal internal vibration to a depth of 4 ft or less, formwork can be designed for a lateral pressure as follows, where p_{max} = maximum lateral pressure, lb/ft²; R = rate of placement, ft/h; T = temperature of concrete during placing, °F; C_w = unit weight coefficient per Table 2.1; and C_c = chemistry coefficient per Table 2.2.^{2,1}

For columns:

$$p_{max} = C_w C_c [150 + 9000R/T] \quad (2.2)$$

with a minimum of $600C_w$ lb/ft², but in no case greater than wh .

For walls with a rate of placement of less than 7 ft/h and a placement height not exceeding 14 ft

More likely case:

$$p_{max} = C_w C_c [150 + 9000R/T] \quad (2.3)$$

with a minimum of $600C_w$ lb/ft², but in no case greater than wh .

For walls with a placement rate less than 7 ft/h where placement height exceeds 14 ft, and for all walls with a placement rate of 7 to 15 ft/h

$$p_{max} = C_w C_c [150 + 43,400/T + 2800R/T] \quad (2.4)$$

with a minimum of $600C_w$ lb/ft², but in no case greater than wh .

2.2.2.1 SI version—For concrete having a slump of 175 mm or less and placed with normal internal vibration to a depth of 1.2 m or less, formwork can be designed for a lateral pressure as follows, where p_{max} = maximum lateral pressure, kPa; R = rate of placement, m/h; T = temperature of concrete during placing, °C; C_w = unit weight coefficient per Table 2.1; and C_c = chemistry coefficient per Table 2.2.^{2,1}

For columns

Table 2.2—Chemistry coefficient C_c

Cement type or blend	C_c
Types I, II, and III without retarders*	1.0
Types I, II, and III with a retarder	1.2
Other types or blends containing less than 70% slag or 40% fly ash without retarders*	1.2
Other types or blends containing less than 70% slag or 40% fly ash with a retarder*	1.4
Blends containing more than 70% slag or 40% fly ash	1.4

*Retarders include any admixture, such as a retarder, retarding water reducer, retarding midrange water-reducing admixture, or high-range water-reducing admixture (superplasticizer), that delays setting of concrete.

$$p_{max} = C_w C_c \left[7.2 + \frac{785R}{T + 17.8} \right] \quad (2.2)$$

with a minimum of $30C_w$ kPa, but in no case greater than ρgh .

For walls with a rate of placement of less than 2.1 m/h and a placement height not exceeding 4.2 m

$$p_{max} = C_w C_c \left[7.2 + \frac{785R}{T + 17.8} \right] \quad (2.3)$$

with a minimum of $30C_w$ kPa, but in no case greater than ρgh .

For walls with a placement rate less than 2.1 m/h where placement height exceeds 4.2 m, and for all walls with a placement rate of 2.1 to 4.5 m/h

$$p_{max} = C_w C_c \left[7.2 + \frac{1156}{T + 17.8} + \frac{244R}{T + 17.8} \right] \quad (2.4)$$

with a minimum of $30C_w$ kPa, but in no case greater than ρgh .

2.2.2.1.1—The unit weight coefficient C_w is determined from Table 2.1.

2.2.2.1.2—The chemistry coefficient C_c is determined from Table 2.2.

2.2.2.1.3—For the purpose of applying the pressure formulas, columns are defined as vertical elements with no plan dimension exceeding 6.5 ft (2 m). Walls are defined as vertical elements with at least one plan dimension greater than 6.5 ft (2 m).

2.2.2.2—Alternatively, a method based on appropriate experimental data can be used to determine the lateral pressure used for form design ([References 2.2 to 2.7](#)).

Table 2.3—Minimum safety factors of formwork accessories*

Accessory	Safety factor	Type of construction
Form tie	2.0	All applications
Form anchor	2.0	Formwork supporting form weight and concrete pressures only
	3.0	Formwork supporting weight of forms, concrete, construction live loads, and impact
Form hangers	2.0	All applications
Anchoring inserts used as form ties	2.0	Precast-concrete panels when used as formwork

*Safety factors are based on the ultimate strength of the accessory when new.

2.2.2.3—If concrete is pumped from the base of the form, the form should be designed for full hydrostatic head of concrete *wh* plus a minimum allowance of 25% for pump surge pressure. In certain instances, pressures can be as high as the face pressure of the pump piston.

2.2.2.4—Caution is necessary and additional allowance for pressure should be considered when using external vibration or concrete made with shrinkage compensating or expansive cements. Pressures in excess of the equivalent hydrostatic head can occur.

2.2.2.5—For slipform lateral pressures, refer to [Section 7.3.2.4](#).

2.2.3 Horizontal loads—Braces and shores should be designed to resist all horizontal loads such as wind, cable tensions, inclined supports, dumping of concrete, and starting and stopping of equipment. Wind loads on enclosures or other wind breaks attached to the formwork should be considered in addition to these loads.

2.2.3.1—For building construction, the assumed value of horizontal load due to wind, dumping of concrete, inclined placement of concrete, and equipment acting in any direction at each floor line should be not less than 100 lb/linear ft (1.5 kN/m) of floor edge or 2% of total dead load on the form distributed as a uniform load per linear foot (meter) of slab edge, whichever is greater.

2.2.3.2—Wall form bracing should be designed to meet the minimum wind load requirements of the local building code or ANSI/SEI/ASCE-7 with adjustment for shorter recurrence interval as provided in SEI/ASCE 37. For wall forms exposed to the elements, the minimum wind design load should be not less than 15 lb/ft² (0.72 kPa). Bracing for wall forms should be designed for a horizontal load of at least 100 lb/linear ft (1.5 kN/m) of wall length, applied at the top.

2.2.3.3—Wall forms of unusual height or exposure should be given special consideration.

2.2.4 Special loads—The formwork should be designed for any special conditions of construction likely to occur, such as unsymmetrical placement of concrete, impact of machine-delivered concrete, uplift, concentrated loads of reinforcement, form handling loads, and storage of construction materials. Form designers should provide for special loading conditions, such as walls constructed over spans of slabs or beams that exert a different loading pattern before hardening

of concrete than that for which the supporting structure is designed.

Imposition of any construction loads on the partially completed structure should not be allowed, except as specified in formwork drawings or with the approval of the engineer/architect. Refer to [Section 3.8](#) for special conditions pertaining to multistory work.

2.2.5 Post-tensioning loads—Shores, reshores, and backshores need to be analyzed for both concrete placement loads and for all load transfer that takes place during post-tensioning.

2.3—Unit stresses

Unit stresses for use in the design of formwork, exclusive of accessories, are given in the applicable codes or specifications listed in [Chapter 4](#). When fabricated formwork, shoring, or scaffolding units are used, manufacturer's recommendations for allowable loads can be followed if supported by engineering calculations, test reports of a qualified and recognized testing agency, or successful experience records. For formwork materials that will experience substantial reuse, reduced values should be used. For formwork materials with limited reuse, allowable stresses specified in the appropriate design codes or specifications for temporary structures or for temporary loads on permanent structures can be used. Where there will be a considerable number of formwork reuses or where formwork is fabricated from materials such as steel, aluminum, or magnesium, the formwork should be designed as a permanent structure carrying permanent loads.

2.4—Safety factors for accessories

Table 2.3 shows recommended minimum factors of safety for formwork accessories, such as form ties, form anchors, and form hangers. In selecting these accessories, the formwork designer should be certain that materials furnished for the job meet these minimum ultimate-strength safety requirements.

2.5—Shores

Shores and reshores or backshores (as defined in [Section 1.2](#)) should be designed to carry all loads transmitted to them. A rational analysis should be used to determine the number of floors to be shored, reshored, or backshored and to determine the loads transmitted to the floors, shores, and reshores or backshores as a result of the construction sequence.

The analysis should consider, but should not necessarily be limited to:

- Structural design load of the slab or member including live load, partition loads, and other loads for which the engineer of the permanent structure designed the slab. Where the engineer included a reduced live load for the design of certain members and allowances for construction loads, such values should be shown on the structural plans and be taken into consideration when performing this analysis;
- Dead load weight of the concrete and formwork;
- Construction live loads, such as placing crews and equipment or stored materials;