PART IX. RELATED SITE PRACTICES

FORMWORK

CEMENT CONCRETE & AGGREGATES AUSTRALIA

Formwork has a dual function in concrete construction – it supports the plastic and hardening concrete until it is sufficiently strong to support the actions/loads imposed upon it, and it imparts a finish to the concrete surface. This Section describes the different types of formwork used in modern concrete construction and outlines the requirements which must be met for formwork to perform satisfactorily. The special requirements associated with the achievement of visually satisfying surface finishes are discussed in Part V, Section 16 *'Control of Surface Finishes'* in this Guide.

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1. INTRODUCTION

Formwork is the temporary structure which (a) moulds concrete into the desired shape and (b) holds it in the correct position until it is able to support the loads imposed upon it. It also imparts the required surface finish. Importantly, formwork also provides safe working areas and access ways for construction personnel. Formwork and its supports (known as falsework) is a structural system and must be designed and built accordingly. The actions (loads) imposed on it may be temporary, but they can be extremely large. Frequently they are different in nature to those imposed on the finished concrete structure.

Concrete is an extremely plastic and mouldable material which will accurately reflect the shape, texture and finish of the surface against which it is cast. Any imperfection or inaccuracy in this surface will be indelibly inscribed onto the concrete surface. Form-face materials must therefore be chosen both to achieve the required surface finish and, in conjunction with all the supporting elements, to maintain accuracy and stability under all of the loads imposed during erection and placing – typically for at least several days into the life of the concrete structure.

At early ages, the concrete will not be able to support the loads imposed on it. Until the concrete is able to support the imposed loads the formwork (and falsework) will be the primary loadbearing structure. Only when the concrete has achieved sufficient strength can the formwork be removed without detriment to the safety or performance of the concrete structure.

Failure to meet accuracy, stability and strength requirements will lead to formwork failures in the form of bowing, warping or misalignment which will be reflected in the final structure. Such problems could even lead to the catastrophic collapse of part (or all) of the formwork.

The cost of formwork is generally a very significant item in the overall cost of a project. The formwork system should be the most economical available – but cost concerns should never be permitted to overrule the criteria governing safety, strength and stability. In reality, the initial cost of formwork may be a very poor guide to its suitability for a project. Multiple uses of good quality formwork can result in improved overall project economies. Formwork design and selection of materials should therefore always be approached on the basis of 'cost per use'.

2. BASIC COMPONENTS OF FORMWORK

The basic components of formwork for typical concrete elements are shown in **Figures 27.1** to **27.4**.

The basic structure of almost all formwork is the same. It comprises:

- Form-face – which creates the surface finish e.g. metal or plywood sheet, sawn timber;
- Studs, or joists – lengths of sawn timber or (sometimes) metal sections which support the form-face and prevent it from bulging or bowing in one direction; and
- Walers or bearers – which brace the studs or support the joists and prevent bulging or bowing in the other direction.

An important facet of formwork design and construction is the choice of spans (or centres) between studs, and also centres between walers or bearers – both of which are important in preventing bulging and bowing.

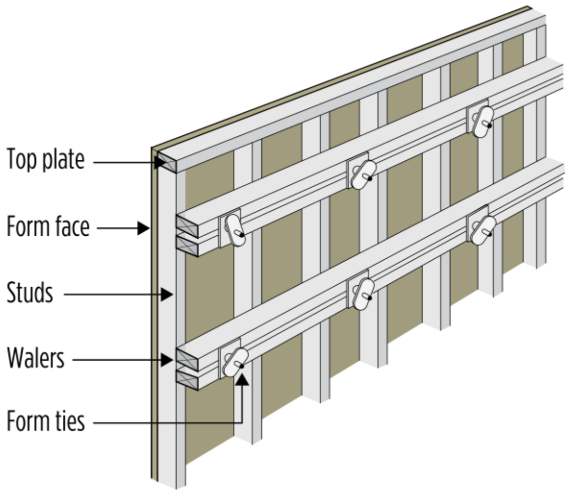


Figure 27.1 – Wall Forms

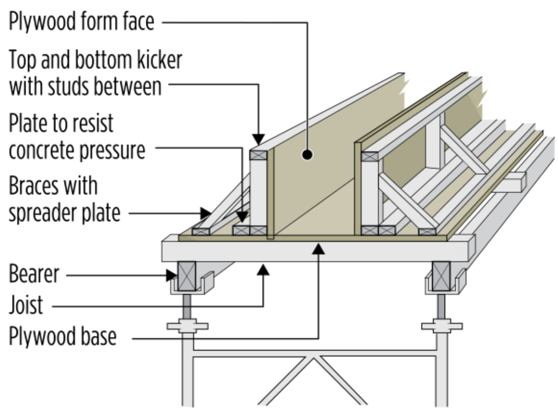


Figure 27.2 – Beam Form and Supports

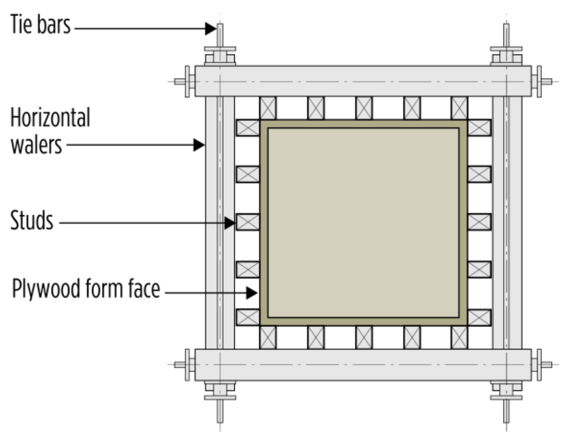


Figure 27.3 – Column Forms

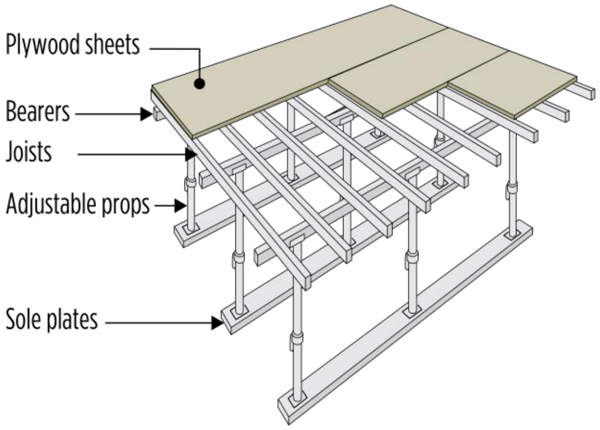


Figure 27.4 – Typical Soffit Forms and Falsework (diagrammatic only; bracing not shown)

3. REQUIREMENTS FOR FORMWORK

3.1 GENERAL

Although formwork is constructed only to contain and support concrete until the cast structure is strong enough to support the imposed loads itself, it must provide a safe environment for all those working on or around it. In addition to being strong enough, it must also be stable against overturning, uplift, and sideways movements. It must also meet all statutory requirements for access ladders, guardrails, working platforms, etc. Where Importance Level II and Importance Level III criteria (see AS 3610.1 – Appendix A) are met, formwork documentation that (a) sets out the requirements of the formwork design, (b) states that the design conforms with AS 3610 requirements, and (c) allows the formwork to be verified and inspected, is a mandatory requirement of AS 3610. Where proprietary formwork systems are used, formwork documentation can contain brochures describing the formwork – provided these contain a suite of information described in AS 3610 (see also sub-section 9).

The general requirements for formwork are summarised in **Table 27.1**. Additional information is contained in AS 3610.

With new materials, these requirements may be readily met. With re-use, all materials (except perhaps metal components) may be weakened. However, even metal components may become loose fitting or broken due to wear. All formwork materials and components must be checked regularly to ensure that they are sound and safe.

Table 27.1 – Requirements for Formwork

Property	Purpose
Strength	Carry imposed loads
Stiffness	Maintain specified shape and avoid distortion of concrete elements
Accuracy	Ensure shape and size of concrete elements; Ensure specified cover to reinforcement.
Watertightness	Avoid grout loss and subsequent honeycombing of the concrete
Permeability	When used, permeable formwork allows water and air to be removed from the formed surface
Robustness	Enable re-use
Ease of stripping	Avoid damage to concrete surfaces
Standardisation	Promote economy
Safety	Ensure a safe working environment

3.2 STRENGTH

All components should be designed to cater for the most severe loads that are likely to be imposed on the formwork. To achieve this, the formwork design should be carried out by a person experienced and competent in such design.

Care should then be taken to ensure that the design details are met and that the construction loads imposed on the formwork are within the limits nominated by the designer.

Sound materials should always be used. Re-used material may be satisfactory but should be checked regularly to ensure it is in good condition and adequate for the job in hand. The strength of each item of formwork material contributes to the overall safety of the temporary structure.

Particular care is required with formwork design and application where flowing concrete (also known as Super Workable Concrete or Self Compacting Concrete – see Section 22 *'Super-Workable Concrete'* in this Guide) as these materials can exert full hydrostatic pressure on the formwork, resulting in significantly higher pressures on the formwork than are seen with conventional 'slumped' concrete. This is particularly the case for formwork in vertical structures such as columns and walls.

3.3 STIFFNESS

Formwork should not bow, bulge, sag or otherwise move to the extent that the completed concrete element falls outside the tolerances specified for the work.

The formwork designer should detail the formwork elements to have adequate stiffness, but site personnel are responsible for ensuring that (a) the correct materials are used, (b) they are of adequate quality, and (c) they are used in the proper manner. For example – plywood sheeting for general formwork use has a greater strength in one direction relative to the other. It should always be used in the correct orientation, as shown in **Figure 27.5**.

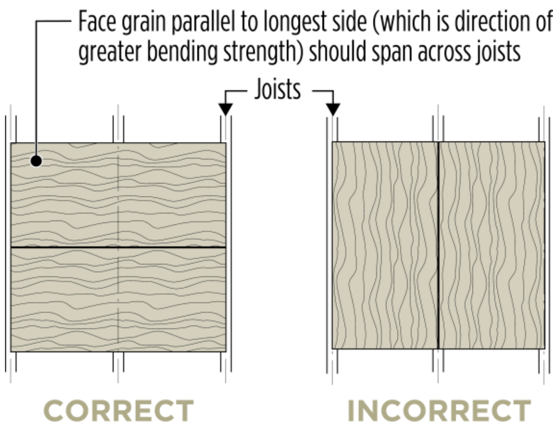


Figure 27.5 – Orientation of Plywood

3.4 ACCURACY

In general, formwork should always be built to an accuracy greater than that desired in the finished concrete structure or element. All support structures should be sufficient to ensure that this accuracy is maintained until the concrete has hardened.

The accuracy required may affect the selection of the material from which the formwork is to be built, as some materials may be able to be assembled to tighter tolerances than others.

3.5 WATER-TIGHTNESS

All joints should be sealed to stop grout (cement and water) leaking from the formwork. Grout loss causes ragged edges, hydration staining and honeycombing which can affect strength, durability and appearance in the final structure. These issues can be exacerbated when using flowing concretes of the types described in sub-section 3.2.

3.6 PERMEABILITY

Systems using formwork with high permeability have some advantages. There are several systems available, but they may be as simple as a fabric material attached to plywood backing which contains drain holes. This type of formwork allows 'bleed' water and air to escape through the formed faces with the effects of (a) lowering W/C ratio in the areas adjacent (to a depth of about 20 mm) to the formwork, (b) increasing the strength and reducing sorptivity and permeability in these outer areas, and (c) improving the finish at these surfaces.

3.7 ROBUSTNESS

Formwork should be robust enough to withstand repeated stripping, storing and erection. Re-use of formwork is an important element in improving the overall economy of the structure. The extent of possible re-use varies with formwork materials – with ranges from 'up to 5 times' for plywood to 20-30 times for fibreglass and 50-100 times for steel. For form liners (see 4.3), re-use can vary from 1-20 times for timber (with varying surface treatments) to up to 100 times for rubber.

3.8 EASE OF STRIPPING

Formwork should be easy to remove – to avoid or minimise damage to the concrete and/or to the forms. Consideration should therefore be given to providing adequate draw (taper) on vertical faces and also to the movement which must be allowed in supports to facilitate easy removal of horizontal soffit forms and specialist systems such as table forms.

3.9 STANDARDISATION

As far as possible, formwork components should be standardised in size to avoid unnecessary cutting. They should be able to be stripped, shifted and re-erected rapidly if speed of construction is to be maintained. This necessitates a system that comes apart easily, has a minimum of elements needing to be replaced (i.e. those damaged during removal) and is easily shifted with the available equipment. On small jobs this will involve 'manhandling', but on large jobs crane capacity may be used to improve efficiencies.

Standardisation for speed of construction frequently requires more expensive formwork but, once re-use is taken into account, lower overall project costs can be achieved.

3.10 SAFETY

Formwork must provide a safe working environment for all those working on and around it. In addition to being of adequate strength, it must also be stable against overturning, uplift, and sideways or sliding movements. Properly guarded walkways should be provided around all areas of suspended work to provide safe access to them during construction, as should a safe means of withdrawal as concreting progresses. All statutory requirements must be met.

The tightness of all components must be thoroughly checked prior to pouring concrete.

The stripping procedures (see 8.4) specified must not be modified and limits placed on stacked materials anywhere on the formwork must not be exceeded.

4. MATERIALS FOR FORMWORK

4.1 GENERAL

Formwork can be constructed in a variety of ways and from a number of materials. The size and nature of the project will most likely determine which materials and which systems are likely to maximise technical and economic imperatives. For example, on some projects, particularly small ones, certain formwork elements are likely to be used only a relatively small number of times. Considerable cutting and fitting may be involved with consequent wastage of materials. The use of lower grade/cost materials may then be justified – provided safety is not jeopardised.

On larger projects, or with multiple projects, the use of specifically designed and constructed formwork elements can lead to improved economy. Standardisation and interchangeability then become particularly important selection criteria.

4.2 CHOICE OF MATERIALS

Many materials may be used for formwork. **Table 27.2** provides a brief overview of the characteristics of those in common use.

Before the final selection of the formwork material is made for a particular project, a number of factors should be considered, including:

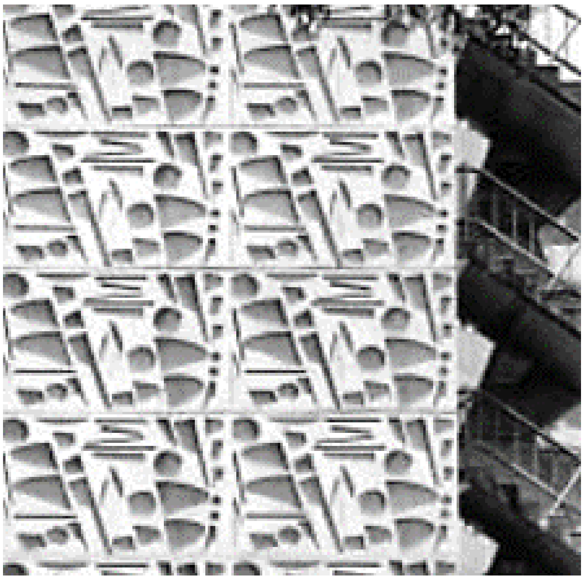
- The size of the forms;
- The shape of the forms;
- The surface finish quality required;
- The accuracy required;
- The number of re-uses required;
- The handling methods proposed;
- The methods of compaction proposed;
- The methods of curing proposed; and
- Safety.

The weighting given to each factor will vary from project to project. On small projects, where multiple uses of formwork elements are unlikely and a great deal of cutting and fitting may be required, timber sections may well be appropriate. On major projects, where standardised components can be employed and multiple re-use achieved, heavier steel sections may well be warranted. Modular units may also be viable in such circumstances. In the final analysis, the choice of formwork materials is a matter of cost, suitability and availability. Most of the commonly accepted materials can be made to work in most situations. The quality of the finish required, and the overall cost of the formwork, are likely to be the principal determinants in choosing materials.

4.3 FORM LINERS

Form liners are effectively a mould placed on the inside of formwork and are used to create simple or complex designs or textures on the surface of concrete (**Figure 27.6**). The use of form liners has expanded the architectural applications of concrete hugely, and it is really open to the designer to create as complex a pattern as can reasonably be imposed on a concrete surface. When combined with coloured concrete the architectural scope expands even further. A wide variety of materials can be used as form liners, with important considerations being (a) the complexity of the design required, and (b) the extent of re-use of the form liner that is required. For low levels of re-use materials like cardboard, rigid plastics, polystyrene or tempered hardboard have been used. These will generally only provide one or two castings. For high levels of re-use, rubbers and synthetic polymers are common. Patterns can also be created when form liners are coated (partially) with a retarding agent to create different textures and patterns on the concrete surface – typically a scene or portrait.

(a)



(b)

Figure 27.6 – Variety of Textures and Patterns achieved by Using Form Liners

Detailed information on the use of form liners and their range of applicability is given in the CCAA Briefing 06 *'Form Liners – Achieving Surface Relief and Texture'* (June 2002).

Table 27.2 – Formwork Materials

Material	Uses
Timber	Commonly used for studs, bearers, joists, walers etc. as it is readily available and easily worked with conventional tools. Has good load-carrying capacity and some suitable species are relatively light-weight, e.g. Oregon. Australian hardwoods tend to be heavier and more susceptible to warping. Some species of pine also tend to splinter or split when nailed.
Steel	Steel sections are used in formwork framing, particularly in patented systems. Strong and robust, steel-framed formwork is capable of multiple re-uses but requires a degree of standardisation to warrant its additional cost. It is commonly used in precasting yards, particularly for repetitive work.
Coated plywood	Commonly used for soffits or as form liners in beams, columns and similar elements. Readily worked, coated plywood (properly handled) is capable of multiple re-uses.
Cardboard	Has been used in column and waffle forms. Normally suitable for one-off use only.
Glass reinforced concrete (GRC) or plastic	Commonly used as permanent formwork, where it provides a decorative finish, or in moulds to achieve intricate shapes – particularly for precast elements. Generally, it is relatively durable and capable of multiple re-uses.
Concrete	Precast concrete elements are used as permanent formwork – where the precast element is exposed to view in the completed structure. Also used to provide permanent forms in precast concrete factories where it is very economical for standard elements or components.
Rubber, thermoplastic and polystyrene materials	Used as form liners to provide intricate effects and for decorative finishes. Rubber and thermoplastic sheeting are used for decorative finishes and are suitable for multiple uses.

5. FORMWORK SYSTEMS

5.1 MODULAR FORMWORK

A number of formwork systems comprising modular units are available on a sale or hire basis. The systems generally incorporate modular panels so that they can be re-used on a wide variety of jobs. Panels may use a steel frame with plywood facing which can be replaced when necessary. Generally, such systems incorporate simple but effective means of support and fixing.

5.2 GANG FORMS

Gang forms are individual components, often modular, made up into large panels that are then tied and braced so that they can be moved as a complete unit.

Adequate cranage is essential for handling gang forms but the cost of the cranage is offset by the increased speed of construction offered by moving large units of formwork from one location to another.

5.3 TABLE FORMS

Table forms are a type of gang form used to form soffits. Large sections of soffit form, complete with propping and bracing elements, can be fabricated into a single unit which, after use, can be lowered from the soffit, transported to the edge of the floor, lifted to the next level by the crane and realigned ready for the next concrete placement (**Figure 27.7**).

Figure 27.7 – Typical Use of Table Forms

A 'transporter' is often used to wheel the table forms to the edge of the building, where a special rig enables the crane to handle them efficiently.

Table form systems are of particular use in multi-storey building construction where speed is important, adequate cranage is available and the initial cost of formwork can be offset by multiple re-uses.

5.4 JUMP/CLIMB FORMS

Jump or climb forms are gang forms for casting vertical elements such as walls and shafts. They are equipped with simple and rapid mechanical means of handling, require a minimum of labour and do not rely on the availability of cranage (**Figure 27.8**).

The system strips the form, shifts it to the new position and then re-aligns it using its own inbuilt jacking system. Daily casting cycles are common.

Jump or climb form systems are capable of producing a high-quality finish with good colour control.

5.5 SLIP-FORMS

Slipform systems incorporate continuously moving formwork to speed construction and to eliminate the need for large areas of formwork. The concrete being 'extruded' must have adequate stiffness to hold its shape once it is free from the slipform. Slip-forming can be undertaken either vertically (e.g. for silos, towers and lift shafts) or horizontally (e.g. for roads and safety barriers).

Figure 27.8 – Typical Self-climbing Formwork System

On vertical elements, the slipform has shutters on both faces that are lifted vertically, at a predetermined rate by a series of hydraulic jacks (**Figure 27.9**). Typical rates of slip-forming vary from 300-400 mm per hour. Some projects are slip-formed continuously, whilst on others the free-standing height is limited to a few storeys.

Slip-forming is not recommended where a high degree of colour control on the finished surface is necessary as colour banding is very difficult to avoid.

On horizontal construction, it can be used in its most simple form to construct kerbs and channels and, in the more sophisticated form, to construct roads or channel linings. Horizontal paving rates of up to 2 km per day have been achieved on large projects but an average rate of 300-500 m per day is more common. No edge forming is generally used for this work and the concrete must be made to a consistency sufficient to avoid slumping once it is free of the machine. Slip-forming is discussed in more detail in Section 19 *'Slip-formed Concrete'* of this Guide.

Figure 27.9 – Slip-forming a Vertical Element

5.6 PERMANENT FORMWORK

Permanent formwork is a type of formwork which is left in place to become part of the finished structure (**Figure 27.10**). It may assist in taking some of the structural load or simply provide a permanent decorative finish.

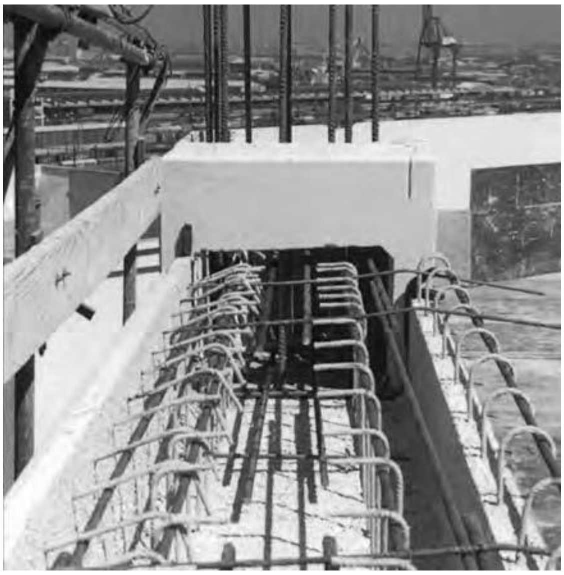


Figure 27.10 – Precast Permanent Formwork used for an Edge beam of a Multi-storey Building

Precast concrete and glass reinforced concrete (GRC) are commonly used for permanent formwork – the former being used where the form takes part of the structural loads and the latter where decorative finishes only are required. The use of permanent forms minimises subsequent finishing operations and often reduces the scaffolding and falsework required for these operations.

6. DESIGN OF FORMWORK

6.1 GENERAL

The design of formwork, particularly on large projects, calls for a considerable degree of skill and experience. Not only can the loads on it be both large and complex, but stripping procedures, and the way they cause loads to be transferred to the concrete structure, are of considerable complexity and importance.

Whilst the actual design should always be undertaken by a specialist formwork designer, all involved with either the erection or removal of formwork on the construction site should be aware of the factors which affect its performance, and in particular its strength and stability – and hence its safety. AS 3610.1 sets out requirements for the design and construction of formwork which are aimed at ensuring its effectiveness and safety.

6.2 LOADS ON FORMWORK

Formwork should be designed to support both the vertical and horizontal loads which are imposed on it whilst it is being erected and while it is in position. In supporting these loads, the formwork should not deflect excessively, buckle, bulge or otherwise move out of position.

The most severe loading generally occurs when the concrete is being placed. However, this is not always the case, so it is common to consider the loads on formwork at three stages of construction:

During Erection – Loads on formwork during erection can arise from two principal sources, (a) the weight of material, equipment etc. which may be stacked on it prior to concreting; and (b) the effect of wind which may exert both vertical and horizontal forces on the formwork and its supports. Care should therefore be taken to avoid excessive load concentrations and to ensure that bracing is installed as early as possible, and certainly before the formwork is used as a working platform (**Figure 27.11**).

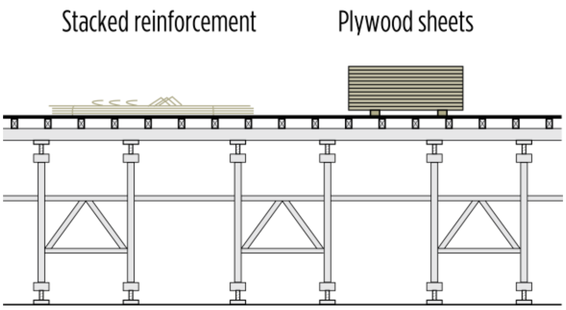


Figure 27.11 – Loads on Formwork prior to Construction

During Concreting – During concreting, the concrete itself imposes a considerable dead weight on the forms. In addition, the weight of men and equipment on the platform should be taken into account. At this stage, lateral stability should also be considered. The formwork with its load of plastic concrete is inevitably top-heavy and therefore particularly susceptible to sideways movement. The possibility of impact arising from a wayward concrete bucket or similar mishap should also be considered (**Figure 27.12**).

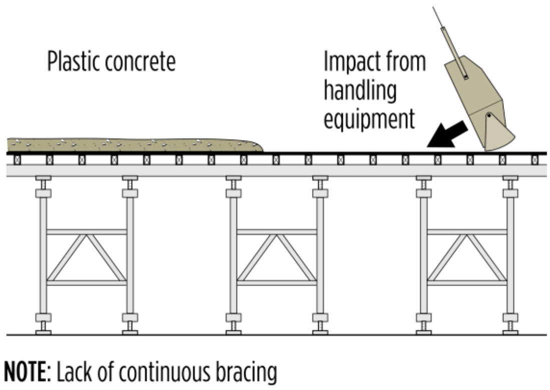


Figure 27.12 – Loads on Formwork during Construction

After Concreting – On multi-storey projects, it is usual for work to proceed on upper floors while the concrete structure below is still gaining strength. Consideration should therefore be given to these additional loads being imposed on the formwork, and particularly on the props supporting lower floors (see 7.3).

Of prime importance, however, is the lateral pressure exerted on side forms during and after concrete compaction. Vibration liquefies the concrete and increases the pressure exerted on the forms (**Figure 27.13**). Due allowance should be made for this, particularly with deep pours, such as columns.

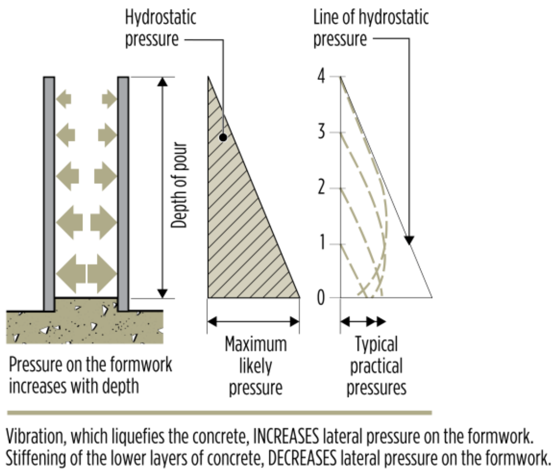


Figure 27.13 - Lateral Pressures on Formwork during Compaction

The lateral pressure exerted by fluid concrete during compaction is by far the most severe loading experienced by vertical forms. Problems such as form liners bulging and deflecting between supports frequently arise because the magnitude of the lateral pressure is underestimated. This is particularly the case with deep narrow forms, where it is often assumed the loads will be less than in (say) heavy columns. In fact, the width of formwork has little influence on lateral pressure, with the principal consideration being the height of the fluid concrete. Factors influencing lateral pressure are set out in **Table 27.3**.

In general terms, any factor which increases the fluidity of the concrete, or the height of fluid concrete, increases the lateral pressure on the formwork (see also comments about flowing concrete in sub-section 3.2). Conversely, any factor which reduces these, reduces lateral pressure (**Figure 27.13** and **Table 27.3**).

Table 27.3 – Formwork Materials

Factor	Effect on lateral pressure
Increasing concrete density	Increases
Increased rates of placing	Increases
Increased heights of pour	Increases
Internal vibration	Increases
Increased slump	Increases
Increased fluidity, e.g. flowing concrete	Increases
Increased concrete temperatures	Decreases
Faster setting cements (including use of accelerators)	Decreases

7. FALSEWORK

7.1 DESIGN OF SUPPORT STRUCTURES

All propping, bracing and fixing elements (collectively the 'falsework') that support the formwork and transmit load to the supporting foundation (usually the ground) – should be considered as part of the total formwork system.

***NOTE**: The term 'shoring' used below refers to the process of temporarily supporting a building or structure with 'shores' or props to prevent the structure from collapsing during construction or renovation.*

Falsework must also be able to resist any tendency to overturn, i.e. the formwork system must be kept stable during erection and concrete placement. Assessments of falsework failures during construction show that the majority of failures occur during concrete placement. These failures can be a result of designers not properly estimating the loads (both live and dead loads) that the falsework structure must support – including additional loads and vibration effects that are experienced during the placing activities. Problems during reshoring operations and premature falsework or formwork removal have also been significant causes of structural failures.

All support systems should be adequately braced to ensure stability and prevent progressive collapse. Bracing should be provided in two directions at right angles to each other and be provided near the edges of the system where concrete placement is likely to commence. All bracing should be between 30° and 60° to the horizontal.

Design of falsework systems should also take account of the final support conditions (e.g. the ground) and detail the size of base plates/spreader beams needed to take the loads without sustaining excessive deflections.

In multi-storey construction, the propping should extend down a sufficient number of floors to ensure the loads are supported without excessive stress on, or deflection of, the recently cast structure. This design should take account of the rate of concrete strength gain with age and the effect that local environmental conditions may have on it (e.g. concrete gains strength more slowly in cold weather).

The design of support structures should also consider the method to be used for stripping the formwork. It is normal practice to strip soffit formwork in two stages – (1) the sheet/form-face elements which are to be re-used quickly, and (2) the support structure which is to remain in place until the concrete can carry the loads.

7.2 UNDISTURBED SHORES

Proprietary systems are available that enable the support structure to remain in place while the form-face materials are removed for re-use.

In these systems the props (or shores) extend from the base to the soffit of the concrete slab and the deck system is removed around them. This is a preferred system, as the props remain untouched until removal at an appropriate later date. Thus, the risk of deflection and stress changes in the concrete slab during reshoring is eliminated. It also ensures that the props for successive storeys remain in vertical alignment and there is no chance of props being overtightened, causing reverse stresses in the concrete slab.

7.3 RESHORING SYSTEMS

Reshoring systems involve the removal of a section of the formwork and support structure, following which the support structure is then replaced once the formwork is clear. With proper control and good supervision these systems can give acceptable results. Props must be replaced in the original pattern and not overtightened to avoid causing undesirable stresses in the concrete.

The three usual methods of reshoring are:

- Secondary reshoring – in which shores are placed before any formwork or props are moved. They are placed under the soffit form as close as possible to the original props. The original props and forms are then removed, taking care to mark the location of the original elements – as the final step is to replace the original props and remove the secondary props;
- Partial reshoring – in which the soffit is stripped, bay by bay, and props are replaced on the correct grid and retightened. Typical bays are 2-3 m in width;
- Total reshoring – which involves complete stripping of the soffit and subsequent replacement of the props. This is the least desirable method as it can impose severe stresses on the relatively immature concrete and give rise to excessive deflections.

8. CONSTRUCTION OF FORMWORK

8.1 ERECTION

On many projects the formwork is supplied and erected by a specialist subcontractor. While this has many advantages, it can also cause some problems if there is not good communication between the project designer, the main contractor and the formwork contractor.

Specific matters to which attention should be given include:

- Limitations on the stacking of materials on either partially completed formwork, completed formwork, or on freshly placed concrete. These loads can be substantial and, unless controlled, can lead to overloading of partially completed structures;
- Limitations on the bracing of formwork against concrete elements of the permanent structure. Depending on the age of such elements they may not be able to support such loading without damage;
- Protection of surface finishes on existing work;
- Safety – The maintenance of a safe working environment is the responsibility of all involved with the project. Attention may therefore need to be given to such matters as (a) the provision of access ladders, guardrails and working platforms; (b) safe-load areas and overhead protection for those working below; and (c) suitable lighting and similar facilities.

8.2 PREPARATION FOR CONCRETING

Cleanliness – Once the formwork is erected and set in the correct position, all enclosed areas and surfaces should be cleaned of all foreign debris that may affect the finished surface, including timber, reinforcing steel, tie wires, sawdust, sand, mortar etc. This may necessitate a 'window' at the base of the form through which such material can be discarded.

Where form faces will be inaccessible after erection (e.g. wall forms) release agents should be applied to them before they are erected.

Immediately formwork has been stripped, it should be cleaned without damaging the form face. If necessary, any repairs should then be made to restore the surface. Formwork should be stored to avoid damage and should be stored/stacked to enable easy retrieval.

Release Agents – Most surfaces require the application of a release agent to allow the formwork to part easily from the concrete after it has hardened – without damage to either surface. However, there are a few specialist plastic form-liners that may not need a release agent.

Release agents permit easy separation of the formwork from the concrete and help to preserve the formwork. In selecting a release agent for a given project, care should be taken to check that it will not:

- Cause unacceptable discolouration to the concrete surface; and/or
- Leave any material on the concrete surface which will prevent bonding of subsequent coatings (e.g. Render, paint).

In the case of wall and column forms, release agents should be applied to clean formwork before it is erected. In the case of soffit forms, release agents are applied before the reinforcing steel is placed (**Figure 27.14**). The release agent(s) can be applied by spray, brush, roller, squeegee etc., depending on its characteristics, but on no account should it be allowed to coat reinforcing steel or any construction joint.

Figure 27.14 – Release Agent being applied to Soffit Form before Reinforcement is placed

Inspection – Formwork must be set accurately in plan and be capable of maintaining the correct line, level, plumb, shape and tolerance during concreting and until the hardened concrete can take the required loads. This requires a detailed inspection procedure to ensure that all elements of the formwork are adequate, clean, in the correct place and wedged/bolted tight.

Before the formwork is assembled it is necessary to check that:

- The forms are clean;
- Repairs have been completed;
- The correct release agent has been used and properly applied to vertical forms; and
- Joints have been sealed.

Before concreting commences it is important to check that:

- The line, level and plumb are correct;
- Dimensions are correct;
- All ties are at correct centres and tight;
- Props and supports are in the correct locations;
- All bracing systems are in place;
- All wedges are nailed;
- All clamps are tight;
- All bolts, jacks etc are tight;
- The supports are founded on a solid base;
- All foreign material has been removed from forms;
- Release agent has been correctly applied to soffits; and
- Joints are sealed and cramped/wedged tight.

During concreting checking is required for:

- Line, level, and plumb maintenance;
- Any settlement;
- Any leakage; and
- Any loosening of wedges, bolts, nails.

8.3 EXTERNAL VIBRATION

In some circumstances, external vibration may be applied to formwork – e.g. in some precast operations, or when placing concrete in thin sections. In these situations, both the formwork and the concrete are vibrated. Where external vibration is used, it is important that (a) the concrete is placed in controlled lifts so that when vibrated, the air can be expelled from the concrete, and (b) the formwork be very rigid and leak free. The formwork designer must be aware of the need to use external vibration when doing the design. External vibration can be used to obtain high quality off-form finishes and also when low slump concrete is being placed.

Vibrating tables constitute a form of 'external vibration'. In these situations, the formwork is attached to the vibrator (and not the vibrator to the formwork as above). The use of vibrating tables is common in the manufacture of concrete products (e.g. concrete blocks) and in precast operations and is used to obtain a consistent level of compaction.

8.4 STRIPPING FORMWORK

General – The project designer is normally required to provide a schedule of stripping times for formwork which is in accord with the requirements of AS 3600. Reference is also made in AS 3600 to the requirements for stripping detailed in AS 3610, and it notes that where stripping requirements in AS 3600 are more stringent than in AS 3610, then the AS 3600 requirements will prevail. The nominated times are minimum stripping times designed to ensure that the structure remains secure from collapse (under its own weight plus that from any additional super-imposed loads) and from damage which might affect its later performance (e.g. cracking or deformation in excess of that anticipated by the designer). Stripping must be carried out in a planned and controlled manner to ensure the proper and controlled transfer of loads from the formwork/falsework to the permanent or existing structure.

AS 3610.1 also provides guidance on stripping times, which, while compatible with AS 3600, refines the requirements to take account of the specified class of surface finish (**Table 27.4**).

The stripping times for formwork removal noted in AS 3600 and shown in **Table 27.4** shall be increased where $L_s/D > 280/\sqrt{(D+100)}$ (where L_s is the span between formwork supports and D is the overall depth of the member); and the superimposed construction load is >2.0 kPa.

Subject to these general provisions, stripping of formwork should be done at the earliest time – provided that the concrete has developed sufficient strength to prevent damage to the surface of the element. For vertical surfaces, if formwork is stripped less than 18 hours after casting then special care needs to be taken to ensure the surface is not damaged. Where it is desired to leave vertical formwork in place, either to assist in curing the concrete, or because it suits the construction sequence to do so, it is desirable to ease the forms from the concrete surface as soon as possible to minimise colour variations.

Multi-storey Construction – While the Standards provide some guidance on the minimum stripping times required for multistorey construction, they also point out that the construction and stripping of formwork systems which involve reshoring should be in accordance with the project and formwork documentation. Consequently, it is incumbent on the project designer to provide this information. Reshoring is a hazardous operation which, unless carried out in a correct and systematic manner, can lead to unacceptable loads being placed on the concrete at an early age.

This is particularly so for prestressed concrete as the stressing operations can cause quite substantial loads to be transferred to the shores, re-shores, back-props and other temporary supports.

The advice of the project designer should therefore always be sought for both reinforced and prestressed concrete construction before specified procedures are changed in any way. If specific procedures are not provided in the project documentation, they should be sought.

9. FORMWORK DOCUMENTATION

AS 3610.1 contains a number of requirements in relation to documentation including (a) documentation requirements will vary depending on the complexity of the project, (b) it is expected that all aspects of the formwork design, fabrication, stripping etc. will be included in the documentation which is to be prepared by 'competent persons' (as defined in section 1.5.1.5 of AS 3610.1), and (c) where elements of the design are done by different persons, or where proprietary information is included, all elements need to be collected and collated into a single comprehensive document that fully describes formwork requirements.

Table 27.4 – Minimum Formwork Stripping Times – In-situ Concrete (from AS 3600 and AS 3610.1)

Formed surface	Surface finish classification	Hot conditions > 20°C	Average conditions 20°C ≥ x > 12°C	Cold conditions 12°C ≥ x > 5°C
Vertical faces	Classes 1, 2, 3*	1 day	2 days	3 days
	Classes 4, 5	9 hours	12 hours	18 hours
	A minimum of one day applies to the stripping of vertical faces where frost damage is likely.			
Beam and slab soffits elements – reinforced slabs of Normal Class concrete	Formwork removal of beams and slab soffits must be in accordance with AS 3600 section 17.6.2.3 and 17.6.2.4 (and not less than 3 days) as well as conforming to AS 3610.1 Appendix C3.			

NOTE*: *Where colour control on surface finishes has been specified it is advisable to strip forms early, subject to the limitations given.*

10. SUMMARY – CONSTRUCTION CHECKLIST

- **Loads**
  - What are the stacked load limits at all stages?
  - Are the stacked materials on spreaders?
  - Will the loads be exceeded by any construction procedure?
- **Materials**
  - Are the correct form materials being used?
  - Is the form face appropriate for the finish required?
- **Position**
  - Are the forms in the correct location?
  - Are they to dimension and within tolerance?
  - Are they accurate to line, level and plumb?
- **Fixing**
  - Is the nailing/screwing adequate?
  - Are the ties the correct type?
  - Are they on the correct grid?
  - Are all ties, clamps and bolts tight?
  - Are wedges tight and nailed?
- **Bracing/Props**
  - Are the props plumb?
  - Are all loads centrally placed?
  - Are supported elements wedged and nailed?
  - Are props straight?
  - Are base plates on adequate foundations?
  - Is the bracing correct?
  - Is the bracing firmly connected?
- **Cleanliness**
  - Are the form faces cleaned?
  - Is any damage correctly repaired?
  - Is the correct release agent in use?
  - Is it being correctly applied?
  - Has all debris been removed from within the form?
- **Watertightness**
  - Are all joints properly sealed and cramped?
  - Are the construction joints sealed?
- **Reinforcing Steel/Inserts**
  - Is the reinforcement correct?
  - Are all inserts/blockouts in the correct location?
- **Concrete/Concreting**
  - Is the mix design in accordance with the specification?
  - What is the maximum rate of placement permitted?
  - Are the forms maintaining line, level, plumb, shape etc. during concreting?
- **Stripping**
  - What are the minimum stripping times?
  - Has the project designer permitted modification of these?
  - Do the procedures enable stripping without damage to form or concrete?
  - Are the provisions consistent with the re-use times required?
  - Has the crane the necessary slings etc. to move the forms quickly?
  - What curing methods are to be used once the formwork is removed?
  - Is the storage area for the formwork properly organised?
- **Safety**
  - Are there adequate guardrails, handrails, walkways, signs etc. in position?
- **Inspection**
  - Are there enough experienced inspectors on the job to provide appropriate supervision?

11. RELEVANT AUSTRALIAN STANDARDS

1) AS 3600 – *Concrete structures*
2) AS 3610.1 – *Formwork for concrete, Part 1: Specifications*

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