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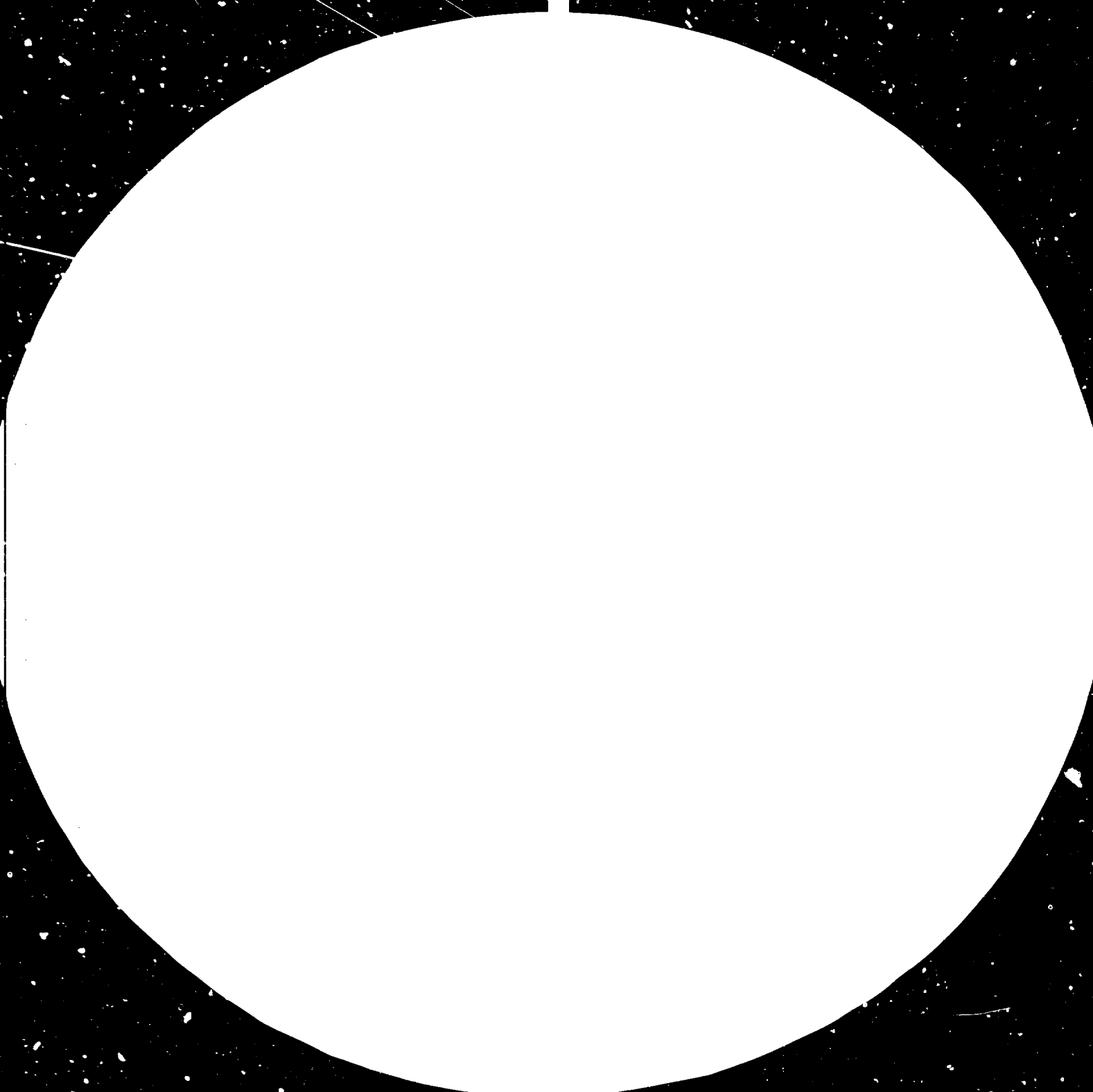

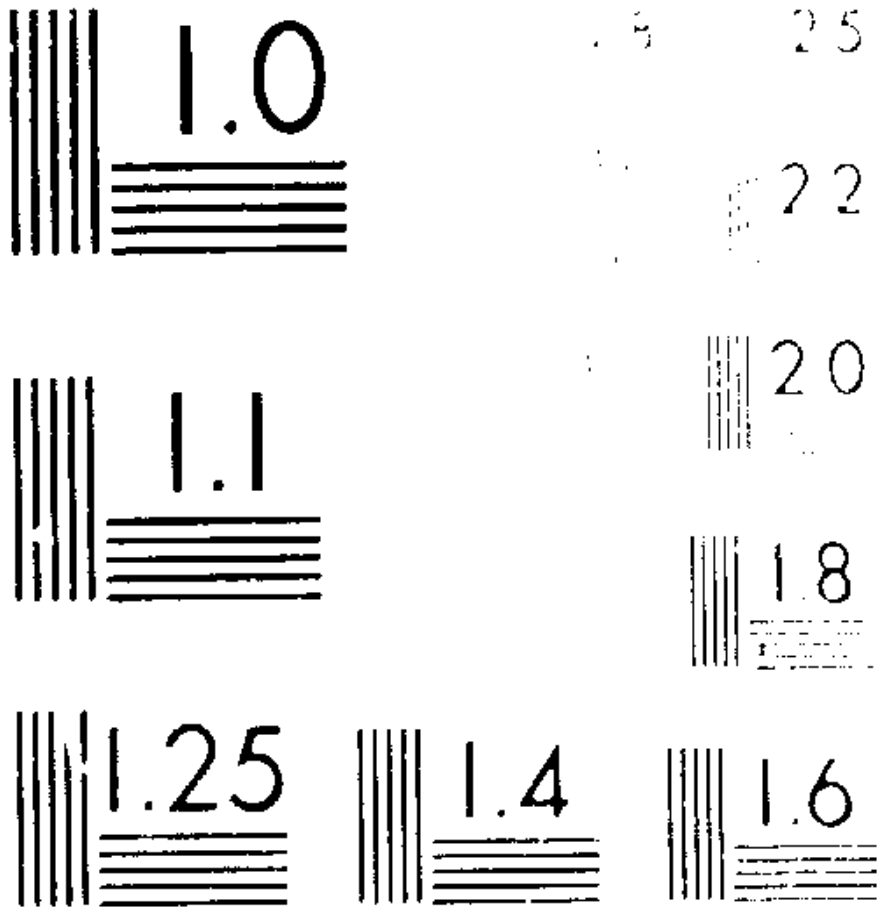
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FORMWORK AND FORMWORK SYSTEMS IN AUSTRALIA*

by
P.S. McAdam**

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CONTENTS

Formwork is rarely part of the permanent structure or fabric of a building. Its life and usefulness on site is transient and yet it can comprise up to 60% of the builder's on-site investment. It is often a critical activity that controls the total time of construction of a project.

As such, its contribution to the effective optimisation of construction costs should be recognised at the design stage of a project and consideration given to the forming methods to be adopted.

The methods of formwork available in Australia for consideration are varied but can be categorised under two broad headings: custom-made or proprietary modular systems.

As the term implies, custom-made forms are constructed to suit the particular project whilst the modular systems comprise a range of standard components that can be combined to accommodate a wide ranging, but not universal, set of concrete shapes and dimensions.

Formwork is also a work area and a scaffold: a place for site employees to work. The need for safety is obvious. It must be safe for men to work on without fear of injury and must continue to be safe during and after the placing of the concrete. To ensure this continued safety, it must be designed and constructed for all the forces that are likely to occur in the construction process and equipped with adequate guide rails, access steps and ladders.

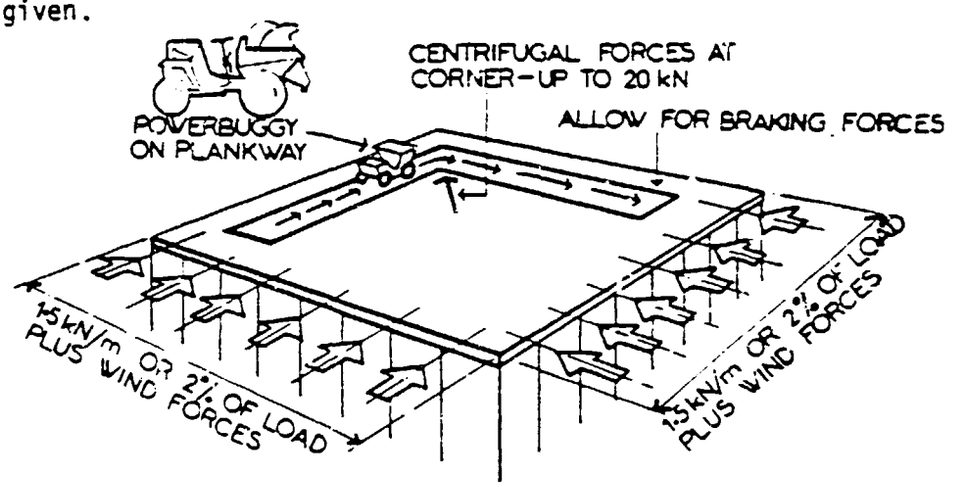
The construction of formwork in Australia is influenced by the recommendations of the Standards Association of Australia as set down in AS1509 Rules for The Design and Construction of Formwork and AS1510 Control of Concrete Surfaces - Formwork. The safety aspects are controlled by the requirements and regulations of construction legislation in the various States in Australia. In Queensland the Regulations of the Construction Safety Act 1971 - 1975 apply and give the offices of the Department of Labour Relations wide powers to control the safety of formwork.

In addition to the suitability of formwork systems for a particular project, the suitability of available materials, components and hardware are also being continually evaluated with regard to durability and safety. Regulations call for design of the formwork in accordance with the Codes and Regulations and that the design for each project be documented so that the formwork designer's intentions may be accurately transmitted to the workers on site.

1. BASIC REQUIREMENTS OF GOOD FORMWORK

The basic requirements of good formwork are Quality, Safety and Economy. Quality in strength, rigidity, dimensional accuracy and a form face giving a concrete surface to specified requirements. Safety in continuing security for workmen and construction processes, and economy of first cost, re-use and consequential effects on the time of construction.

Strength and rigidity requirements are controlled by the requirements of the SAA Codes AS1509 and AS1510. AS1509 stipulates the magnitude of the concrete, material and construction forces that formwork must be designed for. These include impact, wind and earthquake forces, as well as material loads. Bracing requirements to resist these forces and create a rigid form are given.



HORIZONTAL LOADS

AS1509 with AS1510 gives formwork tolerances for maximum deviations from design dimensions with maximum deflection of formwork face and components to control the visual quality of the resulting concrete surface.

Tight joints are needed for formwork to produce a sound concrete structure. Where the resulting product is to be part of the final decorative finish, as in "architectural concrete", the Rules of the AS1510 Code call for water-tight formwork to prevent the unsightly hydration staining that arises from the bleeding of water and fine material from open formwork joints.

The suitability of various materials to produce high quality concrete surfaces of consistent colour for "architectural concrete" are summarized in AS1510. This depends, in the main, on the characteristics of the surface as excessive absorption leads to loss of surface water at the form face and consequential hydration staining.

The AS1510 Code discusses the requirements of release/sealer agents for form surfaces to produce a form face of low absorption and which will be compatible with later surface treatments for the concrete.

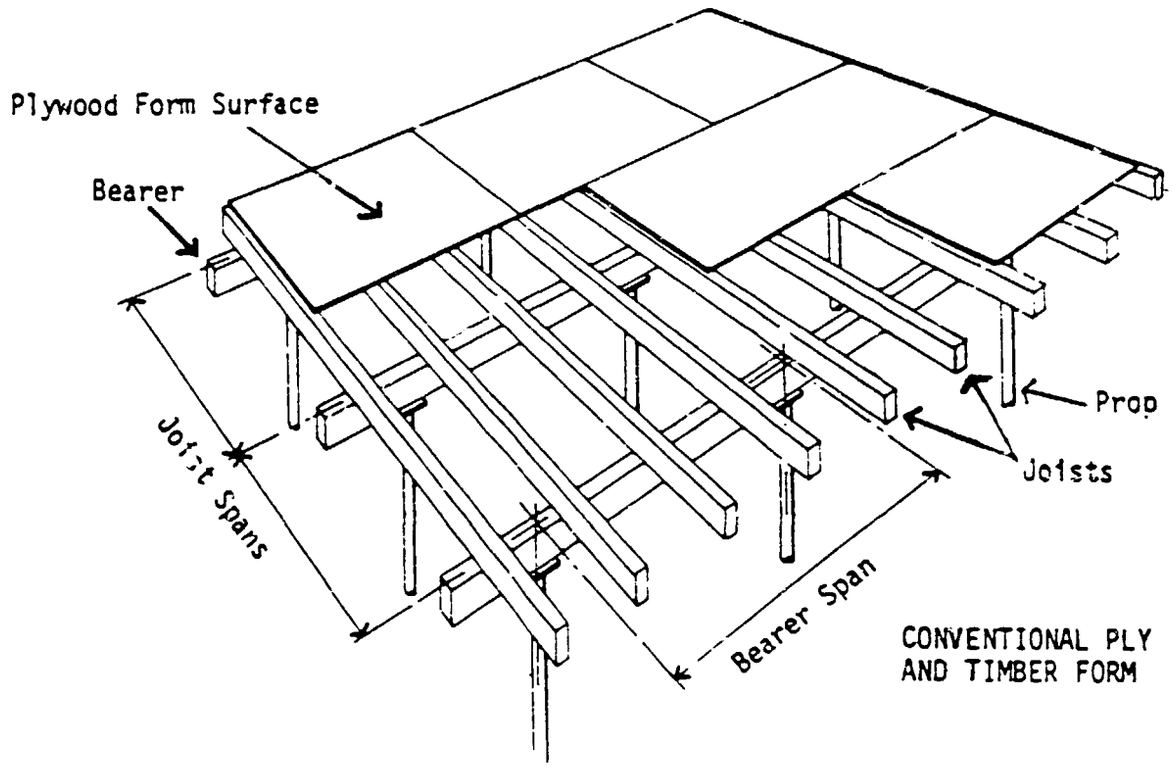
If all the requirements for quality are met, then a safe rigid form will inevitably result. Quality and safety are not incompatible with economy. The requirements of Construction Safety Regulations and the Codes do not contain any provision which prevents the contractor devising form systems that give maximum speed of erection, removal and re-use.

Many ingenious custom-made and proprietary form systems have been devised to optimise the costs of the construction process.

In this brief overview of the "state of the art" of formwork in Australia, the discussion will be confined to the more common systems for slab soffits and beams, walls and columns.

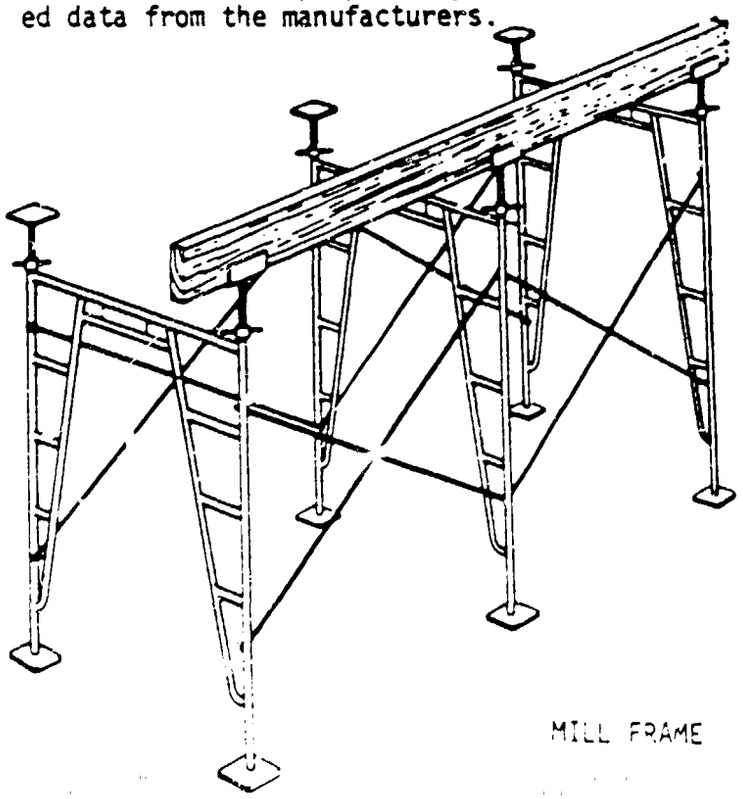
2. FORMWORK SYSTEMS

Twenty-five years ago most formwork in Australia was either made from sawn pine boarding on hardwood bearers and steel props or built from heavy all-steel modular systems. The ready availability of quality structural plywood and good grades of imported structural-quality oregon caused a swing to ply and oregon forms supported by proprietary propping or tying systems.



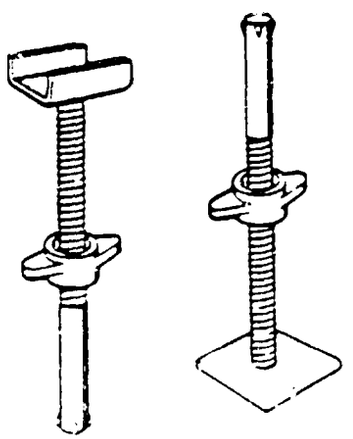
CONVENTIONAL PLY AND TIMBER FORM

This type of formwork for soffits, walls and columns still comprises the bulk of the forming done in Australia. Design of the timber components for the forms is made in accordance with the relevant SAA Codes AS1720 Timber Engineering Code, AS2269 - 1979 Structural Plywood with selection of proprietary prop components and hardware from authenticated data from the manufacturers.



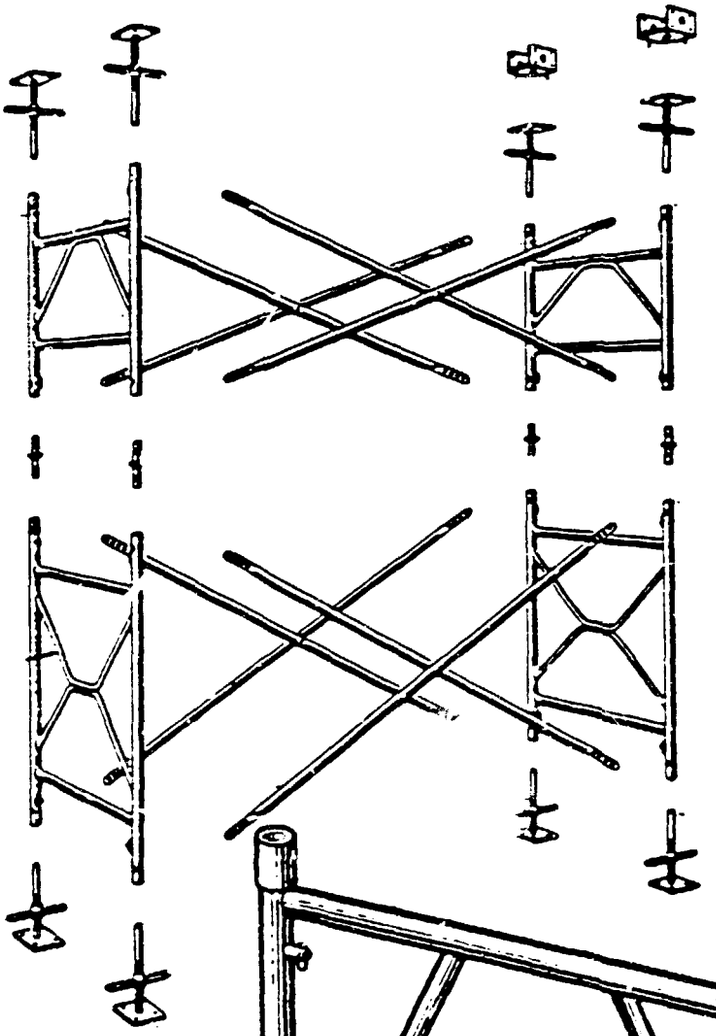
MILL FRAME

ADJUSTABLE U-HEAD

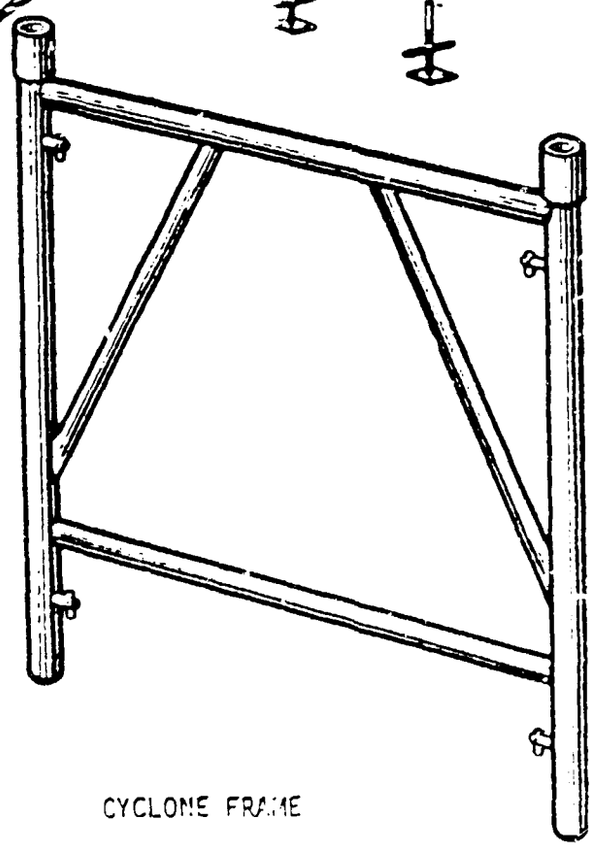


HEAVY DUTY ADJUSTABLE BASE PLATE

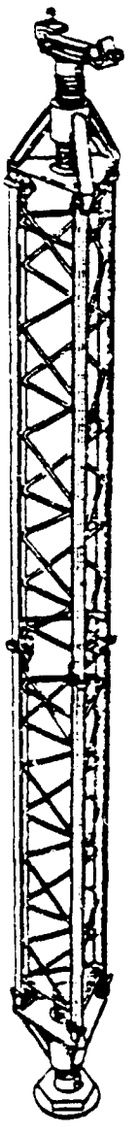
The proprietary propping systems available include telescopic adjustable steel props and modular steel framing systems such as Millframe, Kwikstage, Cuplock and Anglok. The Australian systems of form supports closely, and in some cases exactly, follow the construction practices of the United Kingdom. The use of telescopic props requires the careful use of tube braces in two directions adequately coupled to the props. The other available propping systems have in-built bracing methods that usually more than adequately comply with the requirements of the formwork Codes.



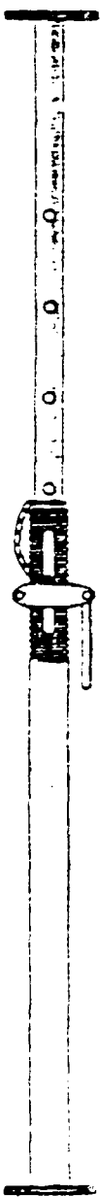
RMD FRAME



CYCLONE FRAME

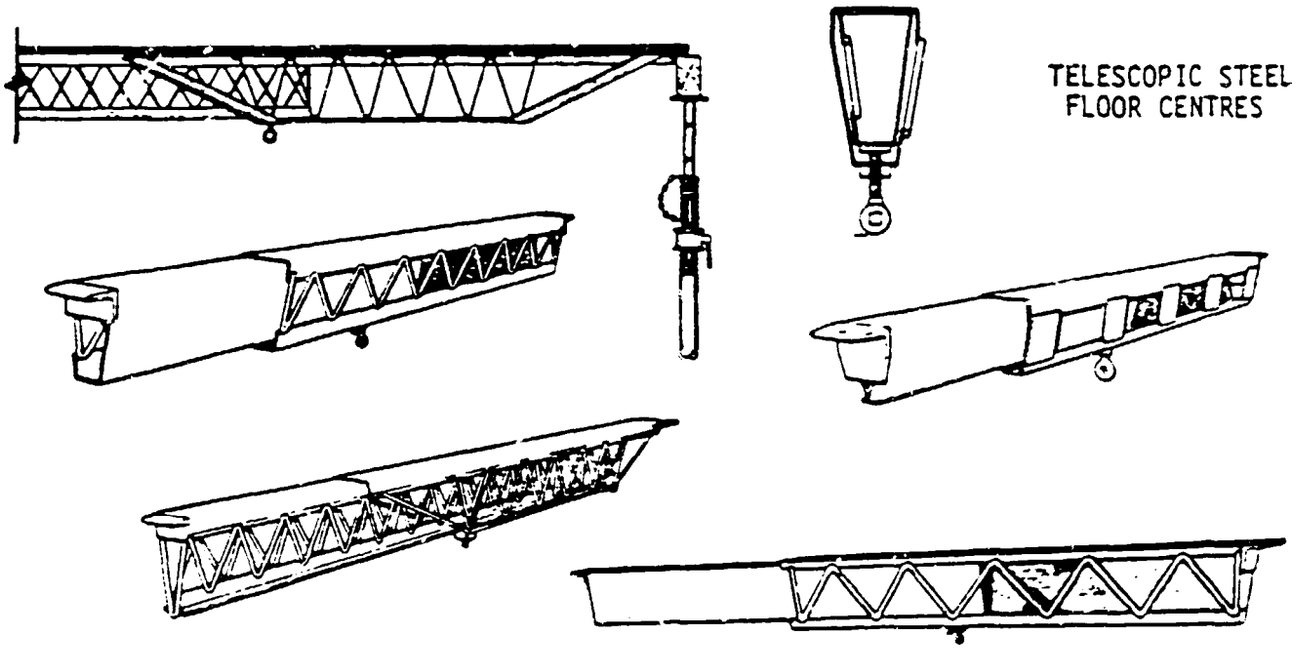


TRISHORE



CONVENTIONAL STEEL PROP

In recent years there has been a noticeable tendency back to the use of telescopic metal floor beams which had their origins over twenty years ago in the now dis-used all metal floor systems. These adjustable metal floor beams, or "centres" as they are called, are used in conjunction with timber bearers, proprietary framing systems and a plywood form surface. For large flat soffit forms they have the advantage of long economic spans and small expenditure on timber.

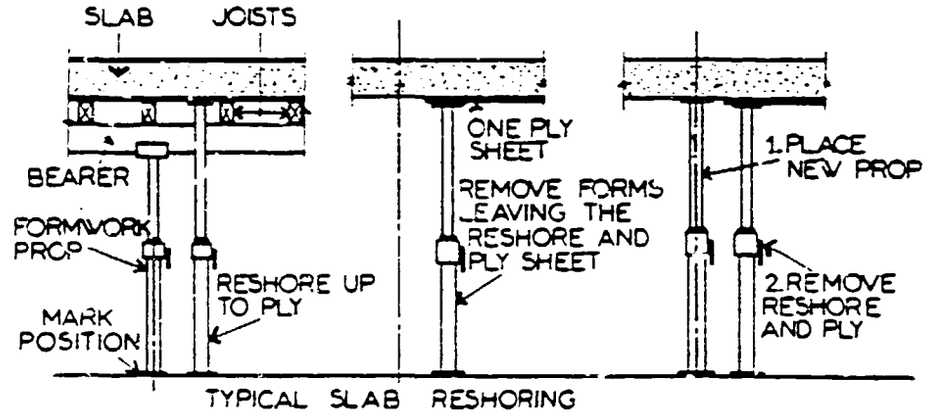


TELESCOPIC STEEL FLOOR CENTRES

Fully prefabricated, metal framed, proprietary systems with ply surfaces have been introduced in recent years. Popular examples are Rapid-Slab, Acrow U-Form, Kwikform and G.K.N. Multiform. All of these examples have the capacity to be equipped with ancilliary devices that permit the removal of soffit framing while leaving the props undisturbed and the contact with the concrete surface that they support. At the head of the prop is a mechanism: cam, wedge or screw thread, that permits the shock-free lowering of the form joists, bearers and ply down the shaft of the prop for sufficient distance to enable the soffit system to be stripped out for re-use on other forms. This soffit removal often takes place within three days of the pour of the slab.

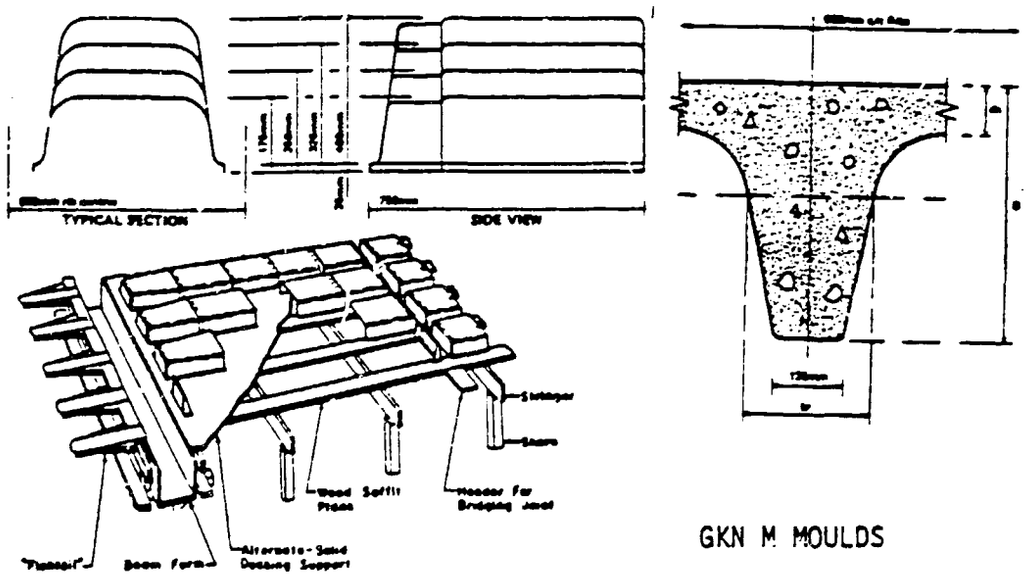
All of these fully prefabricated systems are modular in vertical and horizontal dimensions. Vertical adjustments for particular cases are adjusted by the normal screw-jack adjustment system, either at the base or within the support prop. Where the form system is between side constraints: beam sides or wall faces, custom-made infill panels must be constructed to adapt the modular dimensions to the required dimension. These are the undisturbed propping systems that are noted as the preferred systems for multi-storey work in the AS1509 Code. However, although they are the preferred system due to the safety of load distribution between floors, the undisturbed connection from floor to floor leads to high loads being accumulated on the lowest slabs of the propping systems.

Reshoring (secondary shores) methods, although less safe than undisturbed systems, are noted in the AS1509 Code as causing lower maximum loads on slabs but having higher initial loads. Most multi-storey projects in Australia use secondary shores for the propping and soffit removal system.



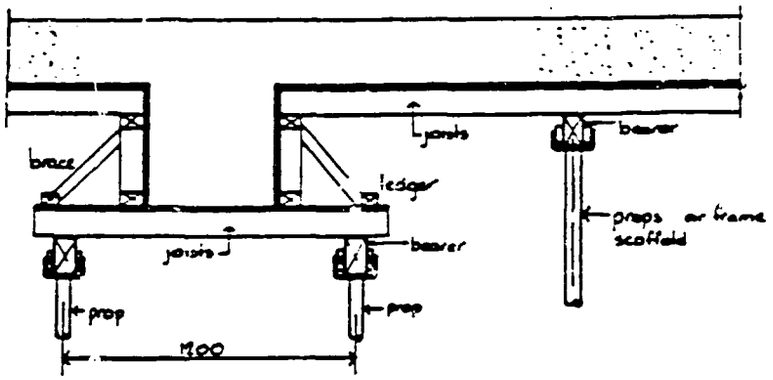
TYPICAL SLAB RESHORING

The weight and strength advantages of multiple tee beam systems for large floor spans have long been appreciated by design engineers. The cost of forming these in timber is prohibitive and can only be justified in important public buildings. Plaster hollow beam blocks, fibreglass, metal and plastic sheeted rigid foam systems have been developed to cater for the custom-made cases, whilst proprietary modular systems such as G.K.N. Multiform 'T' and 'M' moulds are available but have dimensional constraints that must be incorporated in the building at design stage.



GKN M MOULDS

Beam forms, in Australian construction, are almost invariably custom-made. Standard practice is to form a working base of bearers, joists and ply on a proprietary frame system: Millframe, Kwikstage or the like, and then to form up plywood beam sides with top and bottom plates with studs between, all nailed to the ply beam form face. The edge of the soffit ply is then seated on this. Care is taken to minimise the amount of soffit slab loading that is carried on the beam system. Too high a load from the slab will cause uneconomic sizes in the beam forms.

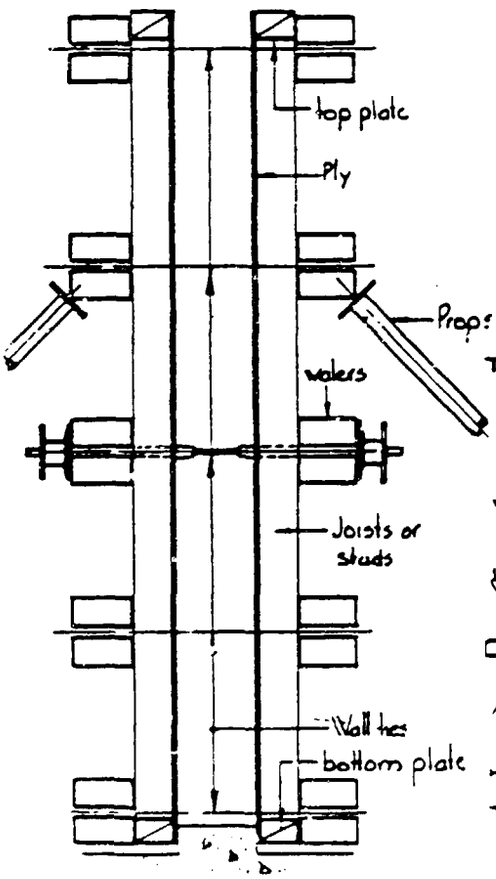


TYPICAL BEAM FORMWORK

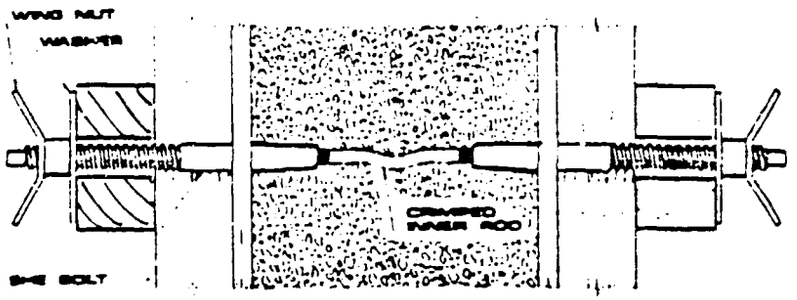
Beam forms are costly and there is a tendency towards wide shallow beams to reduce form costs. Although these lead to more concrete and reinforcement in the beams, the simplicity of the shallow forms and the saving in time of construction usually more than compensates for the costs of the extra material.

Wall forms, in a manner similar to soffit forms, are also constructed of both custom-made and proprietary modular formwork.

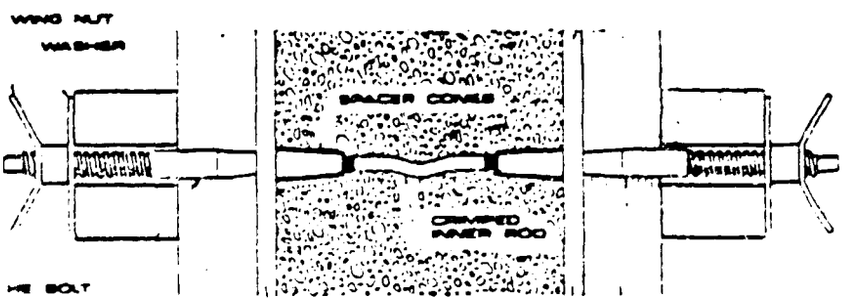
Where skilled labour and materials are available and when the design requirements are for a quality surface, ply and timber forms are used. Tie systems are invariably proprietary products. Similar to the United Kingdom, three general types are in use with timber and ply forms. These are through-ties, he-bolts and she-bolts.



TYPICAL WALL FORM

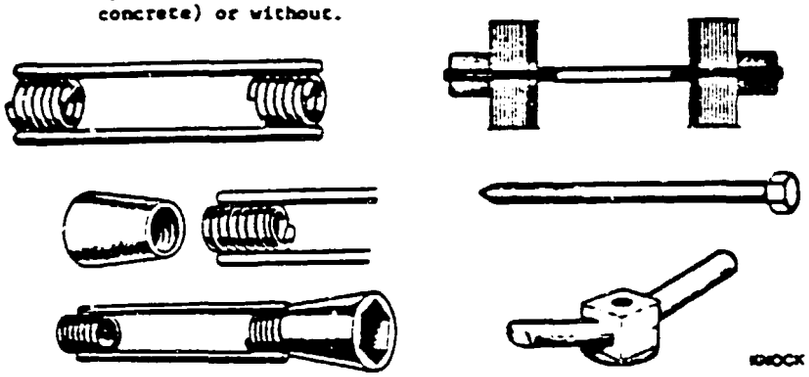


TYPICAL APPLICATION USING SHE BOLTS

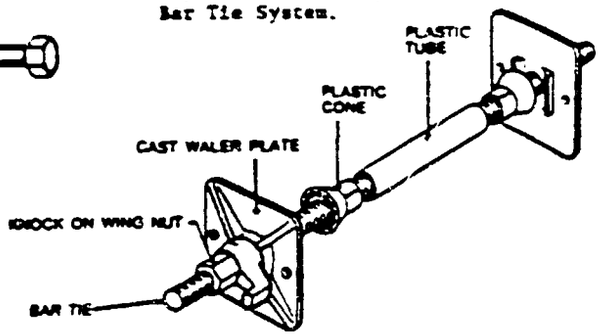


TYPICAL APPLICATION USING HE BOLTS & CONES

Cyclone Coil ties. These can be used with cones (for off-form concrete) or without.



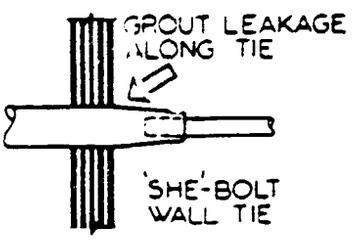
Rapid Metal Developments.
Bar Tie System.

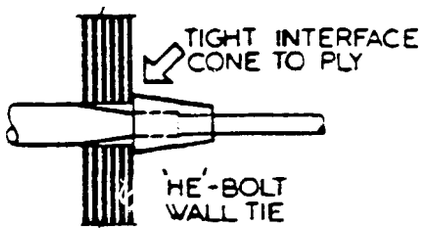


Through-ties range from light capacity snap ties to high tensile bar-ties of capacity up to 113 KN. The bar-ties have the advantage of complete recovery of all metal components after stripping the wall form, with only a cheap plastic spacer tube remaining in the wall.

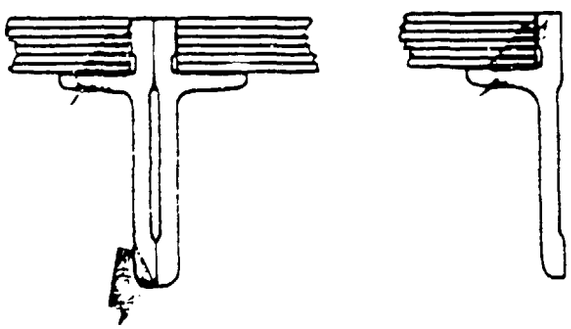
He-bolts, similar to through-ties, have the capacity to hold the form faces apart and also give tightness to the form face at the cone form interface. They are however more difficult to install as the cone/tie/cone sub-assembly must be in place before the closing form face is hoisted.

She-bolts do not have this problem as they can be installed after the erection of both form faces. They have the problem however of a tendency to grout and water leakage at the tie holes which leads to hydration staining and loss of fines.

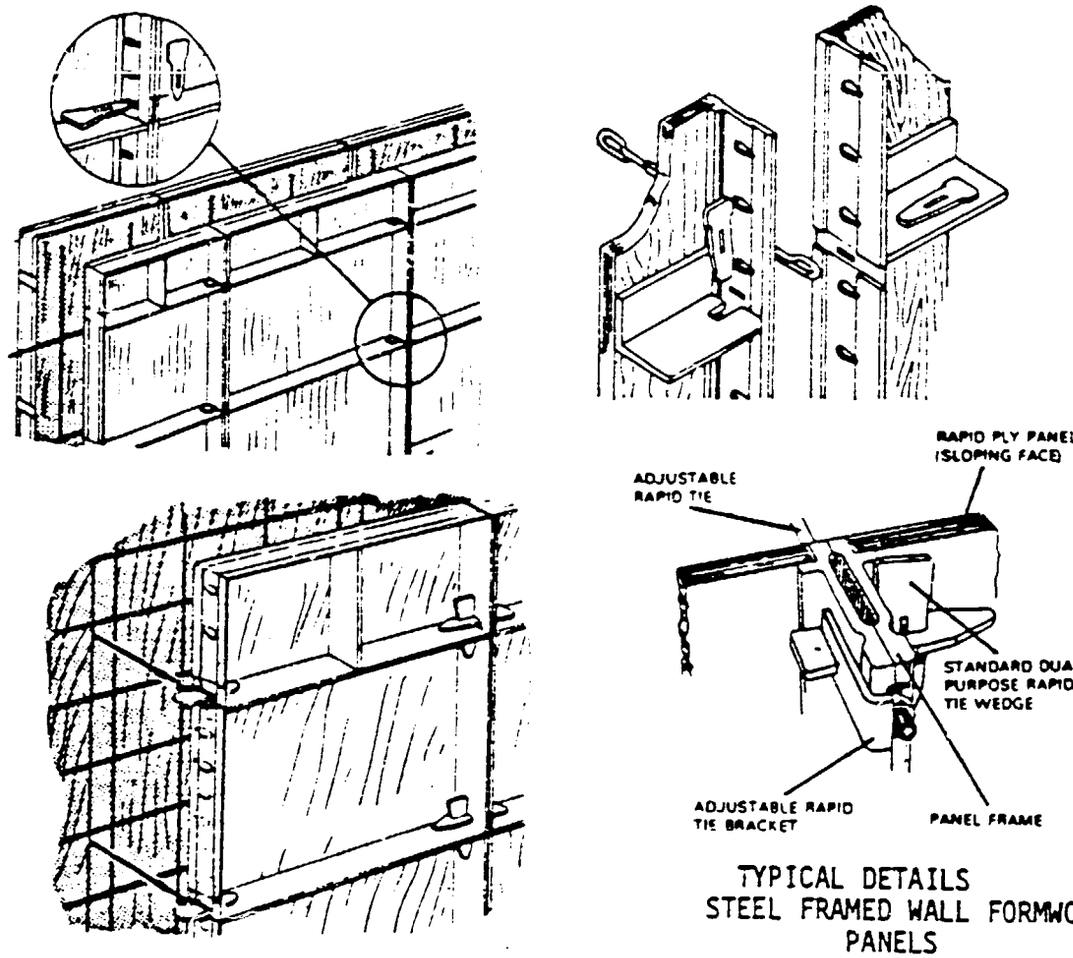




Modular systems such as R.M.D., Rapid-Ply, Acrow U-Form and G.K.N. Multi-form are also available. These consist of modular sized, plywood faced, metal edge framed panels that clip together to form large surfaces with metal snap-ties installed at the conjunction of all panels. These systems can be readily erected by unskilled labour with the minimum of supervision.

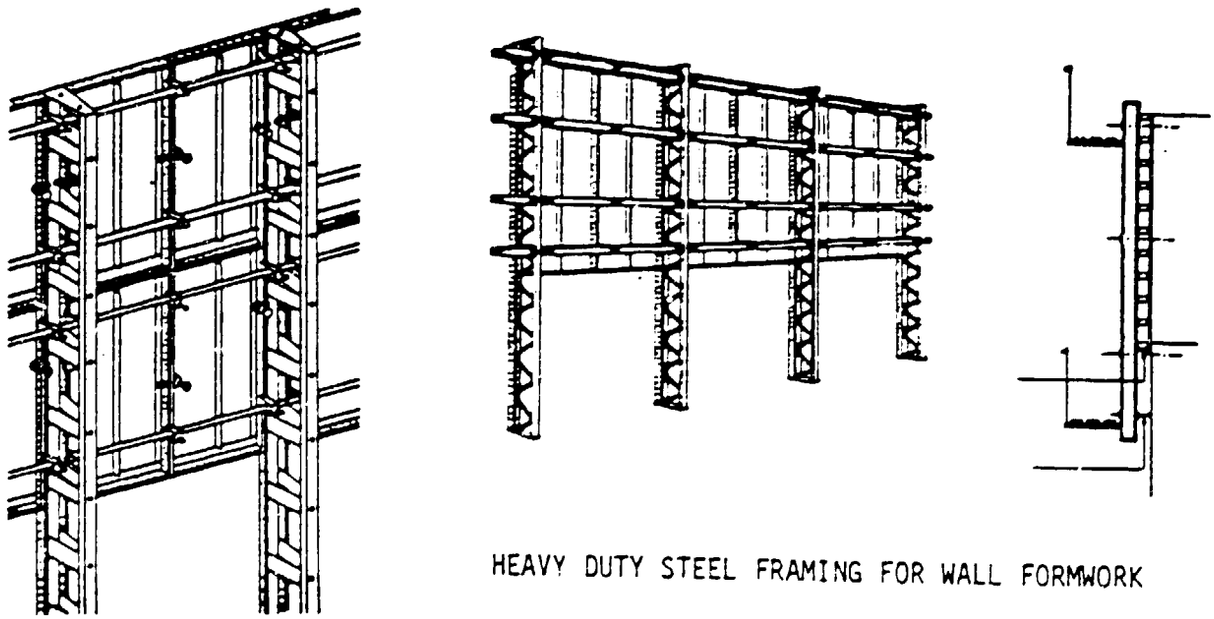


CROSS-SECTION OF STEEL FRAMED WALL FORMWORK PANELS



TYPICAL DETAILS
STEEL FRAMED WALL FORMWORK PANELS

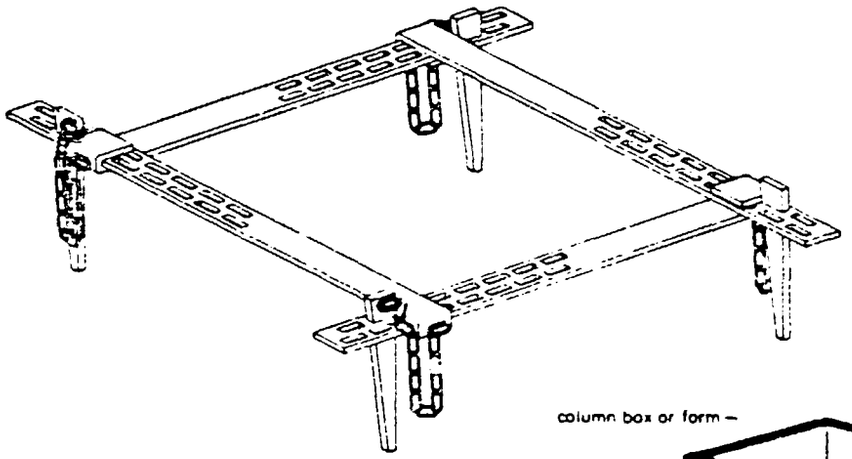
While large gang forms have been made in timber, and these have been quite successful, there has been a recent move towards constructing these large forms with ply faces backed by either partly or wholly steel frame systems in order to achieve maximum spacings between wall ties and maximum size of form.



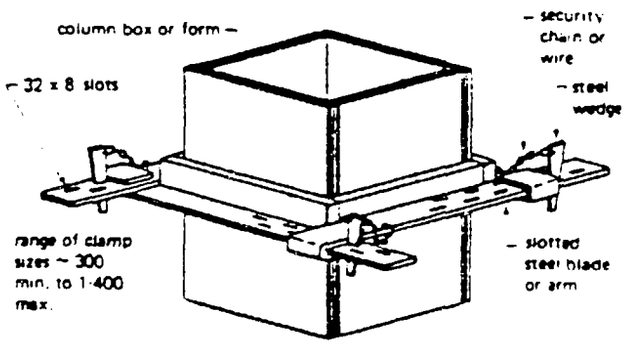
HEAVY DUTY STEEL FRAMING FOR WALL FORMWORK

These form systems usually have horizontal steel members supporting the ply and spanning between vertical steel soldiers. Standard proprietary steel soldiers of either cold formed beam sections or trusses are available from a number of suppliers. e.g. Acrow, R.M.D. and S.G.B. Brooker. High capacity ties like 20 mm bar-ties, are used either singly or in pairs to take full advantage of the long span characteristics of these steel soldiers. With most projects having adequate crane capacity over the whole site, the hoisting, stripping and re-location for re-use of these heavy large forms does not pose any constructional problem.

Column forms are subject to the same loading patterns as walls,and bracing and tying systems therefore bear some similarity. The majority of column forms are custom-made ply and timber forms held together against fluid concrete pressures by proprietary column clamps. These same clamps are used on ply faced metal edged modular panels for columns. For circular columns,cardboard or metal spiral wrapped tubes are available. These give a very economical solution to the previously difficult problem of forming. the efficient circular column shape. Special consideration must, however, be given to holding the easily distorted tube vertical and ensuring that bracing props and collars do not push the tube out of round.



COLUMN CLAMP



Typical column clamp

3. TRENDS IN AUSTRALIAN FORM CONSTRUCTION

The construction industry in Australia has available to it a wide range of materials and components for both custom-made forms and forms assembled from proprietary modular components.

Most large construction projects have the formwork done by specialist subcontractors who are able, because of the continuity of work they get with many projects, to carry large stocks of ply form timbers and hard-ware. With maximum and fast re-use of materials they are able to offer

a more economic costing than the main contractor could achieve with his own workforce. Such contractors, because of their equipment stocks and their capacity to give continuing employment to a skilled workforce, show a strong preference for the custom-made form systems of ply and timber.

On smaller projects or projects in remote areas where specialist formwork skills are not so readily available, there is a greater tendency to use proprietary modular systems. As all of the components for these are available for hire, with purchase needed only in the case of consumables such as wall ties, this offers a low capital expenditure, low skill solution to the formwork problem.

However, it must not be thought that the use of modular systems is confined to the smaller project and custom-made forms to the larger specialist organisation.

The selection of form system is more complex than this. At the simplest, it depends on the function of the building, the finish required, availability of materials, work force skills, the number of form re-uses and the dimensional constraints of the project.

It is suggested that if more projects were designed to suit the constraints of the modular systems, then these would be more frequently selected as the solution to the formwork process.

With the growing need for a larger construction work force, the lack of skilled labour is becoming ever more apparent and one partial solution to this for formwork appears to be the increasing use of modular form systems.

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