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The construction details contained within this manual have been developed based on extensive research both locally and internationally. They are designed to give examples representative of good practice, rather than a complete range of possible alternatives.

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Mann House in Auckland by Ian Juriss.
Concrete is well known to many New Zealanders as a building material. Being a country of ‘doers’ has meant that not only are we familiar with concrete but also many have had personal experience with it. Footpaths, garden walls, garages and sculptures stand as testament to this hands-on experience.

In the construction industry, concrete is the most widely used material both here and overseas. Commercial structures from single to multi-storey continue to be built in concrete. Most residential construction is based on the concrete ground floor slab and our infrastructure, from underground pipes to bridges, is largely constructed of the material.

The building industry in New Zealand is well resourced to construct in concrete. Raw materials are readily available throughout the country. The techniques for constructing formwork, placing concrete, erecting precast elements and building in masonry are to a very high standard internationally. The design of concrete structures by local engineers lead the world in many areas. The existence of several quality suppliers of precast structural systems and other proprietary elements in the marketplace allow designers and builders competitive pricing, extensive system choice and excellent technical support.

For all that, New Zealanders continue to favour timber framing for the construction of their houses. It is not unusual to see a design modelled on the massive homes of the Mediterranean, built using spaced timber studs with a thin cladding of stucco or acrylic plaster on rigid board. Many designers and homeowners in this country prefer to continue to use systems and techniques with which they are familiar.

Concrete construction has been widely used for housing throughout Europe and to a lesser extent in the United States. It would be difficult to think of the work by Le Corbusier, Adolf Loos and more recently Herzog and deMuron without conjuring up images of concrete. Market research has been carried out in an effort to identify why concrete is not used more readily in the residential construction sector in New Zealand. These results indicates that there is inadequate information for those wanting to design and build concrete houses. There is also a lack of builders who are comfortable building concrete walls and suspended floors in the domestic context. The processes involved in building in concrete are different to those employed in timber framing and cladding. Builders comfortable with concrete have tended to become established in commercial construction. While the research pointed to an enthusiasm for concrete homes, designers and builders tend to stay with familiar materials and processes.

This publication seeks to bridge the knowledge gap for designers and builders of concrete homes. It does not however claim to fulfil all their information needs. It has been structured to give an overview of the principles and highlight the critical issues facing designers and builders. The construction industry has been widely consulted and research has been carried out both locally and internationally. The details have been prepared to present a broad range of construction scenarios. The designer or the builder using this manual may find the need to change relationships or sizes shown to suit their own purposes. The intention has been to present a starting point from which specific details can be developed. The details shown here have been checked for suitability for New Zealand conditions. Provided the detailing principles are adhered to, others should perform equally well.
**SCOPE**

This document has been prepared as a general guide to the design and construction of the single family house and projects of similar scale in New Zealand.

Although this manual does not specifically address fire resistance and sound transmission ratings, the adjacent table demonstrates the values that can be achieved with appropriate detailing.

It presents materials and systems that are commonly available in New Zealand. Some, such as timber joinery and concrete itself, have been in use for several generations. Others have recently come into the local market and industry experience with some of these may be limited. On the other hand, building products not available in New Zealand have not been incorporated. To do so would inaccurately present the range of materials available here.

The construction, specification and detailing issues are presented in the New Zealand context. We have specific and often unique ways of doing things. The New Zealand environmental conditions are also unique.

This book is principally concerned with design and construction issues. While it does touch upon topics such as thermal performance and structural engineering, it is not meant to serve as a guide in these areas. Structural design is still best left to the professionals except in those areas where non-specific design standards are available. Concrete masonry is one such format with NZS 4229 having been revised in 1999.

The Cement & Concrete Association of New Zealand produces a range of other publications that may be of interest to the designers and builders of concrete homes. Further information is available at www.cca.org.nz.

<table>
<thead>
<tr>
<th>Panel Thickness</th>
<th>Fire Rating</th>
<th>Sound Transmission Class (STC) rating</th>
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</thead>
<tbody>
<tr>
<td>100 mm</td>
<td>90 minutes</td>
<td>44</td>
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<tr>
<td>120 mm</td>
<td>120 minutes</td>
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<tr>
<td>150 mm</td>
<td>180 minutes</td>
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</tr>
<tr>
<td>200 mm</td>
<td>&gt;240 minutes</td>
<td>58</td>
</tr>
</tbody>
</table>

Typical fire and sound transmission ratings that can be achieved with concrete systems when appropriately detailed.
**Objectives**

Successful architectural detailing requires attention to many factors. As with most aspects of building, it is often necessary to think laterally to achieve results that are both poetic and satisfy pragmatic goals.

First off, it is important to be able to clearly identify the detailing objectives. These may come under headings such as:

- cost
- appearance and aesthetics
- buildability
- materials usage
- routine maintenance

All successful design and detailing efforts will consider these factors. The designer may make value judgments through the process, placing the importance of one aspect above another. The critical thing is to be aware of these considerations and to understand the consequences of favouring any one over the other.

**Environment**

It is also important to consider the specific environment that the details are to exist in. It is critical to acknowledge and design for:

- prevailing winds and wind patterns created by the landscape or other buildings
- rain and other weather that can be expected
- UV exposure
- dust and pollutants that may be in the air and settle on the building
- corrosive elements in the air such as salt spray
- moisture, either rising from the ground, or as general humidity

Specific environments can vary from site to site and even on different faces of the same building. While exposed concrete masonry may be appropriate on the sunny north face of a house, its use on the south side of a damp site could quickly see mould and other organic growth develop, even with regular cleaning. If inappropriate materials are used or poor detailing choices are made, the building appearance can deteriorate quickly.

**Material properties**

Concrete has a number of special and unique qualities that make it an ideal construction medium, particularly in domestic applications. These include:

- high durability
- thermal mass benefits when used appropriately
- ability to form and shape
- enclosure of space and structure in one material
- ability to form integral surface finishes and colour
- relatively inert and compatible with most other buildings materials
- excellent acoustic and fire resistant properties

Along with these qualities are some inherent limitations that the designer should bear in mind:
• once cast it is difficult to change
• not sufficiently waterproof on its own
• sharp corners or edges can be vulnerable to mechanical damage

Once the decision to use a concrete structure in residential projects is made, the designer and the builder must find ways of optimising the positive attributes while minimising the negative aspects of concrete. The best way of ensuring this is through adequate and considered planning. This Guide is one resource to help with this planning.

Maintenance

Planning for routine maintenance of the building, and in particular of the details, must be borne in mind. All materials and details perform better when they are maintained. Such maintenance may include washing, replacement of seals and sealants and re-application of waterproofing coatings.

Decisions made by the builder or designer may place high demands on the homeowner to maintain certain details. Often the homeowner is not consulted or considered at the time, a point that is particularly true of homes built speculatively.

Homeowners, where appropriate, should be consulted with over maintenance issues. In all cases, they should be made aware of routine maintenance requirements. The lifetime success of the project will benefit.
MOISTURE CONTROL

Concrete, although used in the construction of water tanks, is not generally considered to be sufficiently waterproof for housing without supplementary waterproofing systems. Not only is concrete water permeable, it also contains excess water from the construction process that must be allowed to escape. This moisture can, if not dealt with, continue to plague the homeowner. As a rule of thumb concrete requires one month per 25 mm of thickness to dry (from each exposed face) assuming dry conditions. This means that under ideal conditions a 100 mm thick concrete wall will require two months drying time if both faces are left exposed for that period.

Finishes that are applied to exterior surfaces of concrete which have not dried adequately, may be affected by the tendency of water to escape to the warm side. This could lead to bubbling of the surface finish.

The external moisture clauses of the New Zealand Building Code are increasingly being complied with through the use of painted membrane systems. These systems are continuing to develop and there are a number that have proven records in New Zealand conditions. Their use has increased the options for designers but at the same time designers must ensure that sound detailing and building principles are not ignored.

If a strategy of reliance on painted membrane systems has been adopted, it is advisable to thoroughly investigate the systems under consideration. Speak to those who have applied the products and have experience of their performance. Also obtain test results and manufacturer’s guarantees of performance.

Internal moisture control is often not considered by designers but is critical to the comfort and enjoyment of the home. The best method of assuring that the concrete home performs well in this regard is to insulate well and to specify appropriate finishes in those rooms where high moisture levels can be anticipated.

The enjoyment of a well designed concrete home will be enhanced by the designer considering the environment, material properties and sound detailing principles.

THERMAL PERFORMANCE AND INSULATION

Thermal mass within the building envelope can provide significant benefits in terms of both energy efficiency and comfort.

Maximising the thermal mass benefits of concrete requires consideration of a number of issues including: site and building location and orientation, insulation placement, glazing placement and orientation, and usage patterns, to mention a few.

This manual does not attempt to cover issues which need to be considered in maximising the benefits of thermal mass.

Designers wishing to check thermal properties of concrete homes for code compliance should refer to two New Zealand standards: NZS 4214 provides the means of calculating the thermal resistance of building elements, and NZS 4218 defines minimum requirements for the various elements of a house (ie walls, roof, floor).
Concrete Masonry

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Concrete masonry or blockwork has a long association with residential construction in New Zealand. As well as offering all the positive attributes of the other forms of concrete it is an easy format to use.

The use of concrete masonry has been well supported by the block manufacturers throughout the country. Special profiles are available to suit all the detailing conditions that can be anticipated. The range of products continues to be expanded as blocks with special surface finishes, sizes and thermal characteristics are put to the market.

In effect concrete masonry is a type of permanent formwork for concrete. The grout fill working in conjunction with the reinforcing steel provides the structural strength. New research carried out by New Zealand universities has lead to a reduction in the amount of horizontal reinforcing steel and grout fill required. 140 mm wide (15 Series) concrete masonry has also been shown to be structurally appropriate for most residential projects. These changes have been incorporated into the recently released update of NZS 4229:1999, the Standard for non-specific concrete masonry design.

Advantages of concrete masonry

- economy – particularly when the construction module is fully exploited
- does not require special or costly equipment to install
- modular units are relatively easy to handle and can be delivered to most buildings sites
- stop and start of construction is easy to incorporate structurally and architecturally
- range of profiles allowing for most detailing requirements
- interesting architectural scale and surface textures

The qualities and advantages of concrete masonry certainly make it an appealing material to consider for residential construction.

Until the nineteen -seventies New Zealand houses built of blockwork used cavity wall construction techniques. Concrete masonry is more porous than most other forms of concrete. The blocks themselves are permeable, particularly when they are manufactured using the lightweight pumice aggregate typical of the upper half of the North Island. It is however the mortar joints which are the real culprit. As the mortar dries and shrinks, cracks develop against adjoining blocks. Traditional cavity wall construction assumes moisture will be able to penetrate the outer skin, but then drop to the bottom of the cavity and out through weep holes without affecting the inner skin. The outer skin of the wall also serves to conceal the waterproofing membrane on the outer surface of the inner skin.

Time pressures and increases in the cost of construction have meant that this effective traditional method of construction has generally been replaced by the single skin masonry wall. As has been discussed earlier in this guide the change has been justified through the development of new materials which effectively seal the external surfaces while also serving as paint or plaster finishes. This is often in conjunction with rigid insulation. NZS 4229: 1999 has adopted the use of acrylic membranes as appropriate waterproofing solutions.
**DESIGN ISSUES**

**Modular setout**
While other forms of concrete construction allow freedom of shape and size, the modular nature of blockwork directs many design considerations. For reasons of economy and ease of construction, the modular height of units – typically 100 mm or 200 mm – should be adhered to. This applies to overall heights of walls as well as openings within walls. Sticking to a running module of 200 mm will provide economy, however, the length of units can be easily cut. If the module is seen, the designer may wish to specify the position of the cut units.

**Joints**
The mortar joint between blocks has a number of functions. Its primary function is to bond adjoining blocks together. This is a permanent requirement for those blocks that are not to have filled cores. The grout fill will otherwise take over as the bonding mechanism. Another function of the joint is to take up construction or manufacturing tolerances as slight variations in block sizes may occur. Finally the joint contributes significantly to the appearance of the concrete masonry wall. The industry norm of a 10 mm joint is generally considered to be a good proportion when compared to the individual masonry unit. This width can be varied by the designer to suit particular requirements. When blockwork is designed to be left exposed, the colour of the joint is a consideration. It is, however, the profile which offers the designer the greatest number of variations to suit aesthetic or weathering requirements.

Profiles of typical joints that can be specified are shown in the illustration to the left. Combining joint profiles, such as alternating flush with struck to suggest a different module, or raked horizontals and flush vertical joints can be effective.

**Bonding patterns**
The way in which the concrete blocks are laid presents another opportunity to affect the overall appearance of a wall. The traditional bonding pattern for concrete masonry is the ashlar or running bond. Another option is the stacked bond. Beyond these...
Concrete masonry is generally used in a structural capacity, for which it is ideally suited. It can also be used as an external veneer cladding in conjunction with other structural systems. The most common is timber framing but combining structural and veneer masonry with a cavity between will allow the designer to take full advantage of the external appearance, durability and thermal mass benefits.

Method of insulation

Appearance requirements and thermal mass objectives must be considered at the same time as the insulation strategies.

The most common method of insulating a concrete masonry wall is to strap and line the internal face, fitting insulation between the strapping. An alternative approach is to fix insulation externally either in the form of rigid polystyrene sheet fixed in place with an external coating or by strapping and cladding with insulation between.

Proprietary self-insulating concrete block systems are available in New Zealand. Such systems allow both faces of the concrete masonry. This is achieved through the use of a biscuit of polystyrene fixed in a cavity near the exterior surface of the block.

Concrete masonry built using the cavity method allows for effective use of insulation, thermal mass and the blockwork aesthetic. Insulation was often not included in the traditional cavity blockwork which gave these houses the reputation of being cold. While cavity construction allows insulation to be installed in the cavity, the detailing should ensure that the cavity will allow free drainage and that the type of insulation specified is capable of withstanding moisture.
Waterproofing

The considerations for choice of waterproofing system are set out in the General Section. It is most important to consider appropriate and effective waterproofing strategies for concrete masonry due to its porosity. Cracks that develop between the mortar and blocks are also areas of vulnerability that the waterproofing system must be capable of bridging.

Unpainted and unsealed blockwork is an option in some circumstances such as when using veneer construction or in garages and uninhabited basements. It is important nevertheless to bear in mind the affect water can have on the masonry. Water can bring salts to the surface in the form of efflorescence, leaving an unsightly and unpredictable white pattern on the surface.
Shrinkage control joints

Shrinkage control joints are necessary to ensure that shrinkage cracking occurs in a controlled manner and allows movement due to thermal changes. NZS 4229 specifies requirements for control joints. These should occur at approximately six metre centres and will affect the appearance of the project when the masonry is to be left exposed or painted. Applied finishes such as stucco plaster should also acknowledge the control joint to avoid consequential cracking. The designer should take charge of the control joint setout and carry out detailing as illustrated on the previous page to avoid any surprises on site.

**SPECIFICATION**

There are several New Zealand Standards that may be relevant to the written specification. These include the following:

**NZS 4229:1999**
Concrete masonry buildings not requiring specific engineering design

**NZS 4230:1990**
Code of practice for the design of masonry structures

**NZS 4210:1989**
Code of practice for masonry construction: materials and workmanship

**AS/NZS 4548**
Guide to long-life coatings for concrete and masonry

**NZS 4251:1974**
Code of practice for solid plastering

**NZS 3604:1999**
Non specific design – Light timber frame buildings

**Materials**

All materials should be procured from a dependable source.

Where appropriate, ensure that quality records are obtained and kept for easy retrieval, should they be required.

**Concrete blocks**
should be dry and remain so until they are used.

Manufacture must comply with AS/NZS 4455

Excess moisture in any of the materials can reduce structural quality and require the blocks to have to dry longer before surface finishes can be applied.

**Steel reinforcing**
should be maintained free of dirt and organic material.

**Mortar**
mixing ratio (cement/sand/lime/water) to comply with NZS 4210
To provide a compressive strength of not less than 12.5 MPa.
Grout
mixing ratio to comply with NZS 4210. To provide a compressive strength of not less that 17.5 MPa. Spread value 450 – 530 mm

Sand
chloride levels should not exceed 0.04% by dry weight of sand

Water
one of the most important yet overlooked components of high quality concrete. Water must be clean and free from excess alkali, salt, silt and organic matter.

Workmanship
Concrete masonry work should ideally be carried out by qualified tradesmen. As a minimum, tradesmen should have experience in the required areas of construction. In some instances, such as detailed structural work, it is desirable to employ a Registered Mason.

All concrete masonry work should be carried out under adequate supervision.

Grout all cells that
1. contain reinforcing
2. are required to be filled as part of the design requirements

Grouting should follow the procedures set out in NZS 4210.

Form construction joints in accordance with NZS 4210 between grout pours and between the blockwork and any hardened concrete.

The block layer must coordinate his work with the work of other trades. Coordination should take place well in advance of the work being done.

The block layer must build in all elements including fixings, bolts, ties and any service requirements as called for, and/or necessary for the completion of the job.

Once concrete masonry work is complete all block work must be cleaned.

A selection of concrete masonry profiles that are available. Consult with manufacturers to determine the full range.
CONSTRUCTION

Planning the job

One of the most important activities when building in concrete masonry is planning the project. The economy of concrete masonry block work can only be maximised with proper planning.

Consider the module. Try to minimise the number of cut units and to maximise the sizes of any units to be cut. Doing so will also serve to keep costs to a minimum. Check with the designer who may have specified the placement of any cut units.

Plan the sequence of activities carefully. This is especially important with respect to services that will occur in masonry walls.

Setting out

Reinforcing steel must be set out at foundation levels to fall within the planned location of cells.

Normally the concrete masonry requires a vertical steel setout of 800 mm centre to centre spacing. Note that foundation stirrups typically occur at 600 mm centres meaning that only one in every four stirrups can be extended as vertical steel.

Setting out of foundations to suit the specific requirements of the design is also critical. These include

• allowing for any specified overhangs of concrete block or veneer
• allowing for set downs or insets at door openings.

Builders should take extra care when setting out services that will be concealed in masonry walls. This requires full coordination between trades such as plumbers or electricians and the reinforcing steel trade.

Weather conditions

Wet weather can cause build up of water in the blocks, as they are relatively porous. Excess water can reduce the strength of grout. This is particularly of concern where water is retained at the bottom of, or between lifts of, grouted cells.

Rain onto fresh mortar can erode its surface, affecting the appearance and possibly the structural strength of the mortar joints.

Cold conditions will not allow the mortar or grout to set properly. Concrete masonry and grout should not be placed in temperatures less than 4°C.

Hot weather conditions are generally not a problem for concrete masonry in New Zealand. However, prolonged dry conditions may warrant attention when laying or grouting the masonry. Overly dry blocks will draw moisture out of the grout or mortar too quickly thereby affecting the bond with the blocks. It is therefore recommended that the blocks be wet lightly on those surfaces which will be against the mortar or grout.

Provided the blocks are not too dry the curing of the mortar and grout does not require special care. If strong hot winds or direct sunlight in the middle of the summer are anticipated it would be prudent to ensure the mortar and block surfaces are kept moist for the first three to four days after being placed.

Protection

Builders should take care to protect finished concrete masonry from damage which could arise through the building process. This is particularly important with blockwork and veneer that has been designed to be left exposed.

While in most cases it will be impractical to erect full protection for the masonry it should be possible to anticipate work that will create risks to the completed walls. Plywood sheets serve as an excellent form of protection.
Internally insulated wall section

This wall section presents:
- single wythe 15 series concrete masonry
- building paper on the inside face of the masonry acting as a second line of defence against moisture penetration
- strapping and lining on the interior
- insulation between strapping
- concrete masonry foundation wall acting as permanent formwork for concrete slab on grade.

These details separate the thermal mass of the concrete masonry from the interior space. It also allows the concrete masonry to be expressed as an architectural finish externally.
Externally insulated wall section

This wall section presents
- single wythe 15 series concrete masonry
- exterior insulation and waterproofing system
- concrete roof system
- concrete intermediate floor system
- reinforced concrete slab with thickened edge perimeter foundation.

This construction allows full advantage to be taken of the thermal mass in the house. The texture/finish of concrete masonry can be expressed internally.
Concrete masonry veneer

Concrete masonry veneer has been widely used in New Zealand house construction.

The principle of a ventilated cavity can give a greater source of security to the homeowner and designer alike.

As with all masonry, it is important to consider the modular height in setting out openings and heights of walls. This example shows the veneer stopping short of the soffit lining as a way of expressing the nature of the masonry on a veneer. This also stops the lining from meeting the masonry off the height module.

Note the requirements in NZS 4229 and NZS 3604 for the base material and protection for masonry ties in certain exposures.
**Externally insulated wall**

This system is designed to allow a traditional external appearance. Almost any external cladding can be chosen. Timber weatherboards are illustrated here.

The internal finish should be applied directly to concrete masonry to allow the full advantage of thermal mass.

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**Foundation crawl space**

This construction detail is ideally suited to a sloping site.

The use of concrete masonry as a foundation footing can be both economical and time saving, particularly on sloping sites or those with limited access.
Timber window details

Timber joinery is still the preference for many homeowners. Modern timber windows are well made and draft free. It is important to build these windows units in to ensure weathertightness.

The details illustrated here indicate an appropriate method for doing so.
Aluminium window details

Aluminium is the most common material for exterior door and window frames in residential construction.

These details demonstrate the use of aluminium window frames in 20 series blockwork using rebated blocks. The rebated block allows a positive step for the frame to fit against.

When using an exterior membrane system be sure to extend it under the window frames prior to their installation. DPC should lap onto membrane and over building paper.

Note the requirement by some window manufacturers to fit an angle (note A) in high wind areas to relieve the pressures on the sealant joint.

It is quite common to remove the projecting profile from the sill block to achieve a more flush appearance. Note that this may cause staining under windows as dirt that has settled on the sill gets washed down by rain.
The external rigid insulation system allows the concrete masonry to be left exposed, or receive a thin finish as illustrated here. There may be thermal benefits to the home owner in adopting this strategy.

The timber frame is supported on timber packing which is continuous and plastered over. The plaster system should be reinforced across this piece.

Sealant is applied between the timber frame and the insulation system as a weather seal.
Aluminium door details

These details show the aluminium door frame set in 15 series blockwork not using the rebated profile. This presents greater flexibility for the designer to position frame in depth of block. It may be preferable to use rebated block profiles in openings as this gives maximum weathering protection.

Details show that the thermal mass is fully available to the interior space as the insulation is placed externally.

The detail shows that the upstand leg from the sill frame across the threshold has been removed. This prevents it being damaged by being walked over.
Veneer window details

The position of window frames in a veneered wall is critical to ensure adequate closure of the gap while ensuring adequate fixing for the frame. Most aluminium window frames for residential use are delivered to the site with reveals fixed in the factory. Fixing through the reveal, as shown, will allow the frame to bridge the cavity.

Timber window frames, on the other hand, may require framing support in the cavity, as shown. Units fabricated in the factory, before timber and aluminium may be able to span across the sill without fixings.
Roof details

The use of sand/cement plaster allows a smooth uniform texture finish using a material similar in nature to concrete masonry.

Care must be taken to:
- ensure adequate bond of sand/cement plaster to concrete masonry
- follow control joints in masonry through sand/cement plaster

A suitable paint finish will provide weatherproofing.

The use of an internal gutter suits many of the contemporary expressions of architectural design. Dimensions of such a gutter should be to suit the expected rainwater flow, but in no case should it be less than 600 mm for ease of cleaning.

Provide secondary overflow capacity to ensure rainwater does not back up inside house.
**Suspended floor details**

A hybrid form of construction with concrete masonry ground floor structure and a lightweight structure above. The durability aspects and appearance of concrete masonry is continued with 10 series veneer over the timber framing.

Suspended deck details are critical to get right particularly if they sit above interior spaces.

When the concrete block module is seen from outside, it is critical to ensure the full module carries through floor level and that the detailing reflects this.

**Services details**

As with most forms of concrete construction, it is critical to plan for appropriate services reticulation when detailing in concrete masonry.

When using masonry veneer construction it is tempting to reticulate services in the cavity but this is specifically prohibited in NZS 4229.

When using partial fill concrete masonry, dropping services from ceiling level in an empty cell can make the job much easier, particularly as a retrofit. It is advisable to cast sleeves into the bond beam to allow these services to be reticulated easily. Casting in additional sleeves to anticipate future alterations is also recommended.
Insulating concrete formwork (ICF) is a proprietary formwork system for concrete that is left in place to become part of the building. ICF systems have been available in New Zealand for the last 10 years and during that time have been increasingly used for both commercial and residential construction. ICF construction has been used for some 30 years in Europe, where concrete residential construction is quite common.

Block systems are widely available in New Zealand. Plank and panel systems are available internationally but not currently in New Zealand. The forms are typically made of expanded polystyrene, a closed cell polymer. The reinforced concrete core provides all the structural capacity of the wall.

The main advantages of these systems are:
- excellent insulation properties
- low levels of air infiltration
- blocks are easy to lay and fill
- relatively easy to run services concealed in polystyrene layer. This is true of both new construction and refitting work.
- long life expectancy

A contemporary house built using insulated concrete formwork.
DESIGN ISSUES

Although the principle of ICF construction is similar to that of concrete masonry, there are some important differences for the designer to consider.

Module

The modular height of systems available in New Zealand is typically 300 mm. As with concrete masonry, it will be more economical to work to the modular height for openings and wall heights. Most systems mechanically lock together along top and bottom edges.

ICF systems are available in widths of 200, 250 and 300 mm. Unit widths correspond to different concrete thicknesses. The wider blocks offer increased structural capacity, little if any insulating increase and potentially reduce the interior floor space. The greater thickness will give greater reveal depth at openings which is often sought after by designers.

ICF blocks are relatively long, in the order of 1000 to 1500 mm with many bridges between the faces. This allows the blocks to be easily cut to length without compromising the structural qualities. With block sizes like these, it is easy to see how these systems can be laid so quickly.

Proprietary systems

This part of the guide has been prepared with information obtained from the suppliers of ICF blocks in New Zealand. As much as possible, it has been the intention of the writers to present this information in a generic manner, thereby not favouring any one supplier.

As soon as a particular system is adopted it is advisable that the designer confirm all details with the particular supplier.

Applied finishes

ICF systems comply with NZBC durability requirements, provided the blocks are appropriately finished or clad for protection from the effects of UV radiation and weather. Most ICF suppliers require that claddings or finishes are approved for use with their system. Modified acrylic plaster and paint systems, timber strapping with weatherboards, concrete masonry and stone veneers are examples of external claddings that ICF suppliers have recommended for use.

Modified acrylic plasters, plasterboard or fibre cement sheet are typically used as internal linings. ICF suppliers will give guidance to the methods of fixing linings using adhesives and screws.
Detailing – fixings

One of the most important detailing considerations with ICF systems is that of fixings. This includes fixings for both structural and architectural elements. The formwork units, as they are made of polystyrene, offer limited fixing capacity. To make allowances for timber skirtings to be secured, the fixing of windows into openings and joinery fittings to be positioned, it is necessary to cast in timber fixing blocks. These are typically 150 mm long and are secured into the concrete core by pairs of nails that protrude off the back face. This apparently low technology detail is very effective, provided the necessary planning has allowed them to be in the right places.

Structural elements such as concrete flooring systems can be accommodated and are installed after the concrete has been cast to the soffit level. The seating depth can vary between 50 and 75 mm. The method for fixing timber floor framing to ICF walls is to secure a stringer on fixings cast into the concrete core.

SPECIFICATION

It should be the objective of the specification writer to structure the documents in such a way as to encourage competitive pricing. Fortunately there are several suppliers of the forms in most parts of New Zealand.

Once a system has been selected it is advisable to confirm all details and other design issues with the selected manufacturer. This includes wall thicknesses, building in details, steel reinforcing requirements and construction requirements.

It is desirable to structure the ICF sub-contract on the basis of engineering design and supply. It may also be possible to include the erection of the system in that subcontract.

A Producer Statement: Design, or some other evidence of structural capacity should be required by the specification. This will assist the Territorial Authority in approving its use. Manufacturer’s literature and guarantees should also be required by the specification.

Standards referred to:

NZS 3101: 1995
The design of concrete structures

NZS 3104: 1991
Specification for concrete production – high grade and special grade

NZS 3109: 1997
Concrete construction

NZS 3402: 1989
Steel bars for the reinforcement of concrete

Materials

There is at present no New Zealand Standard for the manufacture of ICF units. Accordingly the designer should reserve the right to approve the supplier.
ICF Blocks should be made of fire retardant materials. In situations where fire resistance ratings are required. These must be specified as not all ICF blocks provide adequate fire resistance.

Concrete infill to achieve a minimum compressive strength of 20 MPa. Maximum aggregate size to be 14 mm. Concrete slump should comply with the ICF manufacturer’s requirements. A 100 mm slump is typical. Expansive additives must not be used in any circumstances as these can blow out the forms.

Steel reinforcing to comply with NZS 3402.

Workmanship Erection and filling of the system should be carried out either by the ICF supplier or by a firm approved by them.

The installation should be carried out by persons with experience in this type of work. All necessary and appropriate equipment and construction techniques to be employed.

The blocks are fitted together and propped in place before filling with concrete. Temporary wire ties may be necessary to prevent the blocks floating on the concrete fill. These should be installed every four courses.

Allow to build in all fixings and services as detailed and required by various trades. Typically, such fixings are supplied by the relevant trade or by the builder, to ensure they are correct.

The ICF trade must coordinate with all other trades.

Allow to locate and form construction joints in accordance with NZS 3109.

Before placing concrete, ensure all cells are clean and reinforcing is secured in place. Consolidate concrete with a max 25 mm diameter poker vibrator or by rodding. Vibration should ensure that all cells are filled with well compacted concrete. Extent and height of lifts to be in accordance with ICF manufacturer’s recommendations.

Significant construction tolerances for ICF are to be expected given the nature of the material. It is prudent to limit tolerances and to ensure subcontractors are aware of them so they can make appropriate allowances. Recommended limits are as follows:

Deviation from plan location 20 mm
Deviation from vertical within a storey 10 mm per 3 m
Relative displacement between load bearing walls in adjacent stories intended to be in vertical alignment 5 mm

Deviation from line to plan
Any length up to 10 metres 5 mm
Any length over 10 metres 10 mm

Deviation from horizontal
Any length up to 10 metres 5 mm
Any length over 10 metres 10 mm
CONSTRUCTION

Planning the job

Due to the speed with which ICF systems can be erected, it is important to plan well ahead.

Follow the manufacturer’s recommendations for the height of each lift.

ICF blocks are easy to cut, allowing opportunities to deviate from the block module.

It is important to consider, from a construction viewpoint, that the ICF walls have no structural capacity until the concrete core is cast. Therefore it is important to provide adequate propping and support for these elements until the concrete has achieved the appropriate structural strength.

Setting out

As with other systems covered in this guide, it is important to set out reinforcing to suit the ICF block width. This must be confirmed prior to casting of foundations.

The ICF forms can be used for internal and external walls.
Weather conditions

Due to its insulating qualities, in theory concrete can be placed in colder conditions than it can into other types of formwork. However, this is rarely a factor in New Zealand conditions.

The forms themselves can be placed in most weather conditions, although the unfilled forms are susceptible to displacement in high winds. Concrete can be placed in the forms when it is raining provided measures are taken to remove water in the bottom of the forms, which if left will mix with the concrete thereby reducing its strength.

Curing and drying

ICF systems enhance concrete curing by slowing water evaporation. This effect can increase concrete strengths. Obtain, and comply with the ICF and coating manufacturer’s recommendations for drying times prior to the application of surface finishes.

Protection

ICF is vulnerable to mechanical damage particularly before claddings are applied. Protection, such as plywood sheeting, should be considered in areas of high risk during construction.

At exposed corners and edges PVC protection is recommended as part of the cladding system.

Prolonged exposure to sunlight can cause surface deterioration of the polystyrene. If the surface becomes scaly after a period of exposure, this scaliness must be removed prior to the application of surface finishes. The minor deterioration that may occur will have no effect on the structure of the wall. Some reduction of the insulation properties may occur, depending on the depth of deterioration.

It is important to prop ICF units appropriately until concrete has set.

Stone and other veneers can be used to give the house a traditional appearance.
Wall section

These details indicate how the ICF construction system can be combined with various concrete floor systems. The roof details indicate a concrete floor slab system with topping formed to falls. With all parapet conditions it is important to make allowance for overflow in case primary drain becomes blocked. Insulation is shown on top of roof slab to allow thermal mass to help moderate indoor temperatures and to prevent condensation that may develop in certain conditions.

Suspended floor detail indicates precast beam and infill system. A suspended ceiling can be included to conceal services and the soffit of the flooring system. With appropriate planning and good workmanship, it is possible to leave these surfaces exposed, thereby saving the cost of the ceiling, enjoying greater floor/ceiling heights and the thermal mass benefits of the concrete.

ICF can be used as permanent formwork for foundations.

---

**CONCRETE ROOF**

- Reinforcing mesh
- Construction joint
- ICF block system
- Reinforcing

---

**CONCRETE FLOOR**

- PVC starter strip, forming a drip edge
- Paved G.L.
- Unpaved G.L.
- Reinforced concrete footing

---

**WALL / SLAB**

- Fix Butyl into chase cut into wall. Fix 90° PVC angle cap to Butyl edge and seal in place. Plaster down onto PVC angle
- Butyl on Plywood base
- Insulation over DPM
- Concrete topping to falls
- Prop in place until conc. is cured
- Concrete slab conc. is cured
- Metal frame suspended ceiling

---

**Reinforcing corners of plaster systems**

---

**External plaster finish**

---

**Concrete slab conc. is cured**

---

**Metal frame suspended ceiling**

---

**Internal finish**

---

**Reinforced conc. topping**

---

**Reinforced conc. slab**

---

**ICF block system**

---

**Compacted granular hardfill**

---

**DPC**

---

**Sand blinding**

---

**Unpaved G.L.**

---

**Paved G.L.**

---

**Rough broomed surface to ensure good key**

---

**Timber formwork**

---

**Conc. beam & timber infill floor system**

---

**Cut hole in block at each conc. beam**

---

**ICF block system**

---

**Internal finish**

---

**Reinforcing**

---

**Construction joint**

---

**Internal finish**

---

**Metal frame suspended ceiling**

---
Wall section

The details on this page indicate a traditional sloping roof with overhang. Planning is required to cast in appropriate fixings for structural and architectural elements, as ICF will not support or transfer any loads.

The suspended timber floor must be securely anchored to the wall to transfer vertical and lateral loads. This should also coincide with a horizontal bond beam. As the intermediate floor acts as a diaphragm in this case, only one horizontal bar is required in the bond beam. The timber frame floor/ceiling assembly allows electrical services to be easily reticulated, but acoustic performance is somewhat compromised in comparison with a concrete system.

The concrete slab on grade forms a perfect base for the insulated concrete formwork system. It is important to coordinate reinforcing steel starter bars and fixings for skirtings and the like.
Aluminium window details

The key to fitting doors and windows into openings in ICF partitions is to plan for, and cast in, appropriate fixings. These fixings must be H3 treated or higher, as they are generally in full contact with concrete. These fixings are intermittent, about 150 mm long at 450 mm centre spacings. The nails on back help anchor the timber to the concrete.

These details also make use of aluminium flashings and sealant to ensure a weathertight opening. The flashings must be compatible with the exterior finishing systems and fixed in a manner that will not cause the acrylic plaster system to break down.
Timber window details

These details, like those on the facing page, rely on the fixing capacity of cast in timber blocks.

The interior finishes here are shown to return in to the window frame as a reveal. This is effective in creating a “massive” look to the walls.

External corners of ICF are vulnerable and must be protected with PVC cornes integrated with the plaster system.

ICF block system
Modified acrylic plaster. Return at reveal
Corner protection
Sealant
Corner strip
Form drip edge
Sealant & backing rod
PVC flashing

Timber window frame
Sealant
Corner protection
Intermittent timber blocks. Fix galv. nails skew nailed to timber & cast in concrete infill.
Internal finish. Return to reveal

Continuous H3 timber, shaped to fall
External finish. Carry under flashing.
Timber plate
ICF block system

Fit timber sill over flashing & timber packing
Sill flashing
External finish. Carry under flashing.
**Aluminium door details**

It is good practice to step back the concrete slab edge at door openings to avoid an awkward and vulnerable sill outside the door. This requires particular coordination between the concrete placer, ICF contractor and metal door and window supplier.

It is also advisable to allow for a threshold that is robust and easy to pass over, this may require the aluminium frame profiles to be modified.
**Timber door details**

The timber frame is set in the centre of the massive ICF wall. This massiveness is accentuated by returning the interior and exterior wall finishes into the reveal.

Careful coordination of the rebate for the door sill will allow a near seamless transition from inside to out.

All timber must be separated from concrete by DPC.
Hybrid construction detail

It may be desirable to combine structural systems as this detail indicates.

The important coordination exercise here is to ensure that the timber framing is set out to allow the exterior finishes to continue flush from the ICF to the Exterior Insulation Finishing System.

Note that the acoustic separation provided by this timber framed floor is minimal.

Refer to the manufacturer’s literature for guidance on details that can improve acoustic performance.

High thermal mass detail

To overcome the thermal mass being separated from the internal space, it is possible to remove the inner skin of ICF to reveal the concrete cores which can then be plastered smooth to a finish that is tough and durable.
Concrete masonry veneer

It is possible to combine the excellent durability and appearance of concrete masonry with the insulating qualities of ICF.

Waterproofing of the ICF outer face (in the cavity) is usually by a painted on system such as bituminous paint.

The veneer (10 series) must be secured to the structure by way of ties that are embedded in the concrete cores. This will require special attention to coordination of ties with anticipated joints.
Roof details

Providing adequate and appropriate fixings for additional structural or architectural elements is critical. All three of these details show typical fixings that must be allowed for.

Ensure adequate provision is made for overflow should the primary system block up. Internal gutters should be wide to allow ease of service and deep enough to accommodate the expected runoff.
Terrace details

Raised terraces over living space are now very popular. Detailing of terraces presents a number of challenges in:

- allowing ease of transition – inside vs. outside
- preventing water ingress at door openings
- preventing water ingress at walls, especially at construction joint between slab and upstand

A step in raised concrete floor levels requires a special coordination effort to ensure continuity of structure and support of the concrete flooring systems.
Services

ICF present the easiest way of reticulating services of any concrete structural system.

Services up to 40 mm, depending on the thickness of the polystyrene face, can be accommodated by cutting away a chase. Generally these services must be securely fixed to the concrete core by way of lamps and tappets. The chases must then be covered over by the finishing process. Plasterboard is generally able to span across the gaps but care must be taken to not place a sheet joint on the chase.

Plaster systems will require a bandage. The supplier should be contacted for details.

Services can also pass through the walls but positions and sizes must be approved by the manufacturer.
Precast Concrete

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The development of concrete precasting techniques in this country has allowed reinforced concrete to compete favourably with other forms of construction. Curiously it has not made a serious entry into the residential construction market until the past 10 years. This later period has coincided with the development of proprietary self insulating precast systems. Details of such systems are presented in this section but there is also plenty of scope for applied insulation systems.

Concrete precast methods were pioneered in the US early in the 20th century. The New Zealand industry is well developed and generally acknowledged as a world leader. There are good supplies of the raw materials and technology in most parts of the country.

Precasting, whether done in factory conditions or on site, offers the opportunity to control the quality to a high standard.

Advantages of precast concrete construction systems include the following:

- **quality control** – the quality is better able to be controlled by casting multiple units in the same mould, by casting walls flat rather than standing upright and through the ability to better control environmental conditions.

- **lower costs** for the reasons noted above.

- **finishing options** inherent in solid concrete construction

- **interesting shape and texture** possibilities

- **speed of construction** – with off site production the panels and other precast elements can be made while the site is being prepared. It is possible to set up a house in two days with an experienced crew.

The Pascal House in Auckland by Cook, Hitchcock & Sargisson.
Precast flooring systems are ideal for use in a concrete home. A number of different flooring systems are currently available in New Zealand. These proprietary systems have been developed for commercial buildings, but are also suitable for the span and loading demands that can be anticipated in residential construction. Suppliers generally offer design services which can be incorporated into the overall structural design philosophy. These flooring systems can be categorised as follows:

- flat slab
- hollow core slab
- rib and infill
- steel tray permanent formwork

The systems all offer excellent stiffness, durability, acoustic and thermal performance, they can be planned to include penetrations and openings and are cost competitive with timber flooring systems. They are also not prone to annoying squeaks that can occur with timber floor systems.

**DESIGN**

As with in-situ concrete (refer to In-situ section), there are choices to be made with respect to the following:

**Surface Texture**

There are many opportunities with precast concrete to create interesting surface textures. Finishing techniques for the formed (underside) face are described in the surface finishes section. The screeded face (topface) generally becomes the ‘second side’ or back. Texture options include:

- exposed aggregate
- acid etched
- ground and polished
- board formed

**Colour**

Concrete used in precast work can be coloured. This can be achieved with colour throughout the mix, or alternatively, it is possible to place coloured concrete on the exposed face with standard concrete behind.

**Panel or unit format**

The size and layout of individual panels is essentially limitless. However, there are some practical limitations. Typical parameters that may dictate panel size are:

- the area available for casting (when casting on site). This may be an area of a floor slab or a separate temporary casting slab.
- efficient repetitive use of special moulds
- site access
- capacity of lifting equipment or transport
- the positioning of panel joints relative to openings.
Precast Concrete

- There are also aesthetic considerations to be made. Panel size will dictate joint set out and affect scale, texture and surface articulation of the house design.

The designer must also take into account panel thickness. There are structural aspects to consider for both transport and permanent positions. The designer may be particularly interested in panel thickness when considering opening reveal depths and thermal mass benefits. Commonly panel thickness varies between 100 mm and 150 mm.

**Jointing Details**

The width and depth of joints between panels, as well as the profile of the panel edges, must be considered by the designer. Examples of weatherproofing details are shown to the left, the most commonly used detail in the face-sealed joint. Other considerations include how connections are made between panels, to the floor, and to any other structural or non-structural elements. These deliberations will most certainly include the structural designer for the project. Options include expressing plates and bolts, countersinking and plastering over welded plates or to conceal entirely by using pressure grouted tubes.

**Edge details**

Individual panel edges, especially when exposed to view, are a design opportunity. These considerations are best made in the context of the joint design but should also look at corners, openings, top edges and junctions to other materials. Panel edges are vulnerable, especially during placement of panels. It is very difficult to successfully cast a crisp 90° corner on any concrete panel, it is therefore advisable to chamfer the corners.
Insulation and weatherproofing

Although more waterproof than other forms of concrete, such as masonry, precast concrete is still permeable to water and requires waterproofing. Waterproofing can be achieved by application of acrylic paint systems, which can be applied direct or as part of a plaster finish system. Veneer cladding systems can also provide the required waterproofing. Insulation can be placed on the exterior, interior or between skins of concrete. This latter strategy has given rise to a number of specialist panel systems which allow all the positive aspects of concrete to be realised without compromise. These systems make use of a polystyrene sheet, between an outer skin or veneer of concrete, and an inner skin which typically acts as the structure. The two faces are held together by thermally non-conductive ties which are cast into each wythe.

SPECIFICATION

Designers have a choice to make between proprietary ‘sandwich’ construction and the traditional forms of precast. If the choice is to use a proprietary system, the specification should be generic to allow a range of proprietary systems to be evaluated.

A proprietary system supplier may be required to provide Producer Statements, guarantees and construction recommendations.

It may be prudent to require the contractor or precaster to produce sample panels for evaluation of such aspects as surface finishes. Work should not be allowed to proceed without the designer’s approval of these samples.

The Standards which apply to precast concrete construction are as follows:

NZS 3101:1995
Concrete Structures Standard The design of concrete structures

NZS 3104:1991
Specification for concrete production - High grade and special grade

NZS 3109:1997
Concrete construction

NZS 3112
Methods of test for concrete

NZS 3113:1979
Specification for chemical admixtures for concrete

NZS 3114:1987
Specification for concrete surface finishes

NZS 3402:1989
Steel bars for the reinforcement of concrete

NZS 3121:1986
Specifications for water and aggregate for concrete

NZS 3421:1975
Specification for hard drawn mild steel wire for concrete reinforcement
NZS 3422:1975
Specification for welded fabric of drawn steel wire for concrete reinforcement

Materials
All materials should be procured from a dependable source.
Where appropriate, the builder must ensure that quality records are kept for all precast concrete work. These records must be easily retrievable should they be required.

Formwork
Formwork requirements are detailed in NZS 3109.

Reinforcing steel
To comply with NZS 3402, NZS 3422.

Concrete
Readymix concrete to the specified compressive strength and to the requirements of NZS 3104.

Special aggregates
For special finishes specify the aggregate type, colour, size, range and depth of exposure. All aggregate to comply with NZS 3121.

Lifting inserts
Proprietary lifting devices are preferable. It is important to match the lifting inserts with the apparatus that will be used for lifting and the processes that will be adopted for casting and lifting.

Steel connection plates
It is recommended to galvanise any mild steel fixings that will be exposed to weather.

Workmanship
Construct formwork in the configuration necessary to produce the required set out and detail of panels. Pay particular care to edge details.
The construction and casting of panels should be carried out by tradesmen experienced in precast concrete construction.

Place and cure concrete to produce the specified finishes and tolerances. Curing should be carried out for at least 7 days.
Surface finishes shall be as specified by the designer and as defined in NZS 3114.

Allow to cast in all items required for fixings or services. This requires coordination between the trades before the panels are designed and cast.
The installation should be carried out by contractors experienced in precast construction. All necessary components such as gaskets, sealants and flashings should be supplied and fitted.

Rigging and lifting must be done using the lifting points specified. Take care not to knock or drag panels along the ground.

Panels must be secured in place before any temporary supports are removed. At all times during the construction process, but especially the lifting of panels, the health and safety of all workers and the public must be ensured.

<table>
<thead>
<tr>
<th>Panel dimension (metres)</th>
<th>Up to 3</th>
<th>3 – 6</th>
<th>Over 6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Width (mm)</td>
<td>±0, -5</td>
<td>±0, -10</td>
<td>±0, -12</td>
</tr>
<tr>
<td>Height (mm)</td>
<td>±5</td>
<td>±10</td>
<td>±10</td>
</tr>
<tr>
<td>Planeness (mm)</td>
<td>±5</td>
<td>±5</td>
<td>±5</td>
</tr>
<tr>
<td>Squareness (mm)</td>
<td>±5</td>
<td>±15</td>
<td>±15</td>
</tr>
<tr>
<td>Edge straightness (mm)</td>
<td>±5</td>
<td>±7</td>
<td>±10</td>
</tr>
<tr>
<td>Thickness (mm)</td>
<td>±10</td>
<td>±10</td>
<td>±10</td>
</tr>
</tbody>
</table>

Ensure existing surfaces all comply with the tolerance requirements.
Planning the sequence of activities, especially if the panels are to be cast on site, can save substantial time and frustration. Good planning will allow the panels to be cast earlier and will allow work to carry on around the panels once they are cast.

With on-site casting planning the site is critical. The location to be used for casting must be of appropriate size and in a location that can continue to be accessed as the panels are erected. Access must be available for materials and for the crane.

The sequence of casting panels must be logical if they are to be cast one on top of the other, last on is first off. Normally panels are erected sequentially from one corner.

Setting out
If the panels are to sit on the ground floor slab, it is critical to confirm constructed dimensions of the slab, prior to constructing the panels. It is also critical to coordinate and check positions of starter bars and grout tubes.

Weather conditions
The wall panels must not be cast in rain or cold conditions below 4°C.

Particularly in hot, windy weather it is important to prevent excessive surface evaporation which can lead to plastic cracking. A common method of providing protection is to use anti-evaporative spray. Precast panels are particularly prone to this potential problem, due to their large surface area.

Once the panels are cast and ready for erection, the construction process need not be affected by the weather.

Panel erection & finishing
After factory produced panels are cast and adequately cured, they must be transported to site. Suppliers of these panels have delivery and erection systems in place which should be of benefit to the builder.

The tilt-up panel erection process begins with the separation of panels. The performance of the bond breaker during this operation is critical. The bond breaker must:

- permit clean complete separation of panels
- not discolour the panel surface
- minimise suction at time of separation
- be compatible with the curing components that may be used.

Note that release agents used to facilitate the stripping of formwork in in-situ construction are not suitable as bond breakers.

The crane is critical to the erection process. It must be rated to achieve the panel lift at the maximum anticipated working radius. The lifting capacity of a crane reduces considerably with larger working radii. The crane must be able to access the site.
and be adequately supported in each position it will be set.

The rigging, lifting point and support design for movement of panels is critical. The strategies must be discussed and agreed between the appropriate parties. The builders concern will be access for fixing operations and ease of panel handling, the engineer will be concerned that the support points are structurally appropriate and the designer will want to make sure the lifting inserts can be hidden from view after the panels are in place.

One of three strategies can be adopted:

- Top edge lifted panels will hang vertical but this is not economical for units over 3-4 metres in height.
- Face supported panels will hang slightly off vertical, however, they can easily be plumbed with adjustable props once in position. Face lift points may require plastering or alternatively they can be deliberately featured.
- The use of lifting points on the face and top edge is sometimes used but requires a crane with two separate ropes.

The crane must move the panels smoothly into position, avoiding shock loading which can induce cracking in the unit. Panels must be supported entirely by the crane until they have been secured into final position and propped. It is important to select propping positions that will not interfere with other construction activities.

**Surface finishes**

While the design and specification of surface finishes falls within the scope of the designer, it is the builder or precaster who must ensure the specified finish is achieved. The surface finish treatment must be coordinated with the lifting and casting strategy. The most common face to treat with an integral finish is the face cast down. As lifting points will be on the back face, this allows the bottom face to be completely monolithic.

The table indicates common methods for achieving surface textures.
The exposed aggregate finish warrants special consideration. Chemical retarders are often used to allow the surface to be etched. The cement matrix can then be removed with a water blaster once the panel has been lifted.

The use of chemically impregnated paper can simplify this process but also gives the designer additional scope for achieving patterns in the surface. Architects Herzog and de Muron have experimented with retarder impregnated paper to achieve stunning concrete effects.

Sandblasting is also an option but has largely fallen out of favour with the introduction of the processes described earlier.

<table>
<thead>
<tr>
<th>Types of Finish</th>
<th>Face-up (single casting)</th>
<th>Face-down (single or stack casting)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rebates, grooves and patterns</td>
<td>Hammer form into top surface (Position and depth difficult to control)</td>
<td>Fix form to base slab (Position and depth easy to maintain)</td>
</tr>
<tr>
<td>Plain, smooth surfaces</td>
<td>Finish panel with bull float and trowel (Common paving technique)</td>
<td>Finish off floor or casting pad (Reproduces all imperfections of that surface)</td>
</tr>
<tr>
<td>Exposed Aggregate</td>
<td>Water washed (Special aggregates and patterns difficult to control)</td>
<td>Sand embedment (Special aggregates and patterns easy to achieve, independent of concrete mix)</td>
</tr>
<tr>
<td>Fine Textures</td>
<td>Broomed, Combed, Imprinted, Rolled</td>
<td>Timberforms, Formliners</td>
</tr>
<tr>
<td>Coarse Textures</td>
<td></td>
<td>Timber forms, Profiled steel sheeting, Polythene over stones, Formliners</td>
</tr>
</tbody>
</table>

Cutaway of door opening in a precast sandwich type wall.

A three level project planned using off site precast concrete panels.
External insulation on tilt panel

The details illustrated here are of the exterior envelope consisting of a concrete slab on grade, site precast wall panels and timber framed intermediate floor and roof.

External weatherproofing and insulation is provided by one of many rigid polystyrene systems with acrylic plaster/paint. In this case the panels, designed to be seen from the inside should be cast with this face down. Lifting inserts will be covered by rigid insulation.

If skirting is required, allowance should be made to cast-in fixing blocks. Vertical panel joints will be seen internally and should be detailed accordingly.

The panel to slab connection is made after the panels are erected. This is very efficient structurally and economically but requires special consideration if the floor slab is to be exposed.
Sandwich panel construction

These details indicate the use of polystyrene insulation between concrete panels in wall section. Also shown is a horizontal joint detail, which must be carefully considered in the elevation design.

Concrete flooring system can be designed to lock into supporting walls, as shown, or supported on a surface mounted steel angle, as shown on the following page.

Grouted duct connections allow shorter panels than the detail shown previously, and for the floor slab to be cast in one operation. This makes it easier to achieve a uniform finish, which can be an advantage if it is intended to leave the slab exposed.
Sandwich panel construction

This wall section indicates precast panels (site or factory) which extend from floor slab to parapet in one section. This eliminates the need for a horizontal joint between panels which is often not architecturally desirable.

Veneer panel is shown to thicken near the top, at the expense of the structural panel thickness. This allows veneer to cantilever as parapet. Insulation thickness is maintained.
Jointing details

The architectural expression of joints between panels requires consideration. Design decisions include; how the edges are shaped, the width of joints, integration with other details, and proportions that result from their set out.

The structural fixings can be expressed as steel plates or hidden from view.

Flexible silicon based sealants are typically used to weatherproof the joints. It is important that these sealants are checked and maintained periodically.
**Miscellaneous details**

It is important to limit heat conduction through cold bridges by insulating adequately. This detail shows rigid insulation fixed to the back face of the concrete parapet to limit this transfer. Plywood is fixed over this as a substrate for the butyl rubber roofing membrane. An aluminium extrusion is used to secure the end of the butyl and provide a crisp edge to the parapet.

The open web steel framing members allow a spacious ceiling, reminiscent of warehouse structures. This can add architectural interest and allow long spans, but sound transmission can be a problem.
Steel joinery details

Steel door and window sections are regaining popularity with designers in many circumstances. Steel frames are narrower than aluminium or timber therefore presenting a finer line in the elevation design.

These details indicate the window frame screw fixed to steel fixing blocks which have been welded to steel plates cast into the opening reveal.

Inside, the window reveal is left as natural concrete, placing high requirements on the standard of finish in this area.
Timber window details

Timber joinery can be an attractive design option in an exposed concrete wall. The colour, texture and substance of exposed timber is a positive choice in this detail. It is critical to plan for adequate fixings for the frame, and to separate the timber frame from the concrete by DPC.
Aluminium window details

A step in the concrete reveal is formed and maintained by the casting in of a PVC angle. The window frame is fitted against the angle with a space allowed for sealant.

The exterior face of the concrete is shown to be sealed. The sealer should be applied to the concrete around the window opening before installation of the frames. A second line of defence is the building paper.

Timber reveals give a more traditional appearance inside. The insulation in this example separates the thermal mass from the internal space.
Aluminium door details

These details demonstrate the use of intermittent cast-in fixing blocks around the entire opening, a practice quite common in ICF detailing. Blocks are about 150 mm long and placed at approximately 450 mm centres. The step for the door frame, allows a more positive weathering detail. It is achieved by stopping the external installation short of the concrete edge.

Internally the concrete can be left exposed and the edges are shown to be arrised. Sealant here is used architecturally to conceal the packing space between the concrete and the timber reveal.

This detail requires close tolerances which can be achieved with precast concrete.
Timber door details

These timber door frames are shown to mask the exposed edge of polystyrene sheeting.

Fixing for the frame is by plug and screw into the concrete. Architrave profile has been scribe cut to follow concrete.
**Services installation**

Electrical and other cable services can be easily accommodated by all precast concrete systems with adequate planning.

These details indicated conduits cast into the concrete panels from ceiling to skirting level.

In this example, the actual service point is located in a deep skirting.
In-situ concrete is the traditional form of concrete construction. Until the early part of the 20th century it was the main method used. While in-situ concrete above ground level is used less in New Zealand with the advent of precast systems, it still widely used in many other countries.

Systems are being developed and used in both Europe and the U.S. to allow cast in place concrete to be cost and time efficient. In developing parts of the world, in-situ concrete, which relies on higher labour input than other forms of concrete construction, is still dominant.

In New Zealand it is often not cost effective to design traditional load bearing cast-in-situ concrete structures in the face of competition from precast and modular systems. There are however some situations where in-situ is the ideal structural material, such as building sites that have difficult access.

Cast in-situ concrete has become a material that designers exploit for its structural qualities above all else. The chance to cast monolithic building elements – walls, columns, beams, suspended floors and roofs which are beautifully detailed – appeals to many designers both in New Zealand and offshore. The work of Le Corbusier, Louis Kahn, Carlo Scarpa and more recently Tadao Ando in Japan is familiar to many. The perception of their work is very closely linked to their ability to exploit the qualities of in-situ concrete. Briefly, they are:

• limitless flexibility of size and shape with no modular restrictions. Current developments in the U.S. are toward entire buildings being poured monolithically.
• a wide variety of surface textures and colours can be achieved.
• it can be cast as a “sandwich” incorporating an integral polystyrene sheet insulation.
• a robust material which does not require much maintenance
• it is a universally available material.
Most of the design issues begin and end with the formwork possibilities. The major cost of any cast concrete is that of the formwork. The relative cost of this element is reduced significantly when the formwork is able to be re-used. However repetitive uses on the same project suggests the need for construction joints. Construction joints occur between different placements of concrete.

The detail and set out of these joints should be practical and coordinated with the overall design of the project. These joints can be unsightly if not properly planned and constructed. The colour of the concrete can vary slightly from one batch to the next. In large wall or soffit areas it may be desirable to introduce many joints in a pattern, some as construction, others as ‘dummy’ joints to mask the impact. In addition to construction joints, it may be necessary to provide control joints to allow for shrinkage and thermal movements in walls. These joints should be shown on the drawings. As a general rule, for domestic construction, control joints should be placed at 6 metre centres. Work closely with the builder to understand his strategies for use of formwork on the particular job; and with the structural engineer, who can advise specific requirements for shrinkage control joints.

The desire for a particular surface finish or “look” may have drawn the designer to cast in-situ concrete. There are many textures and combinations thereof that have been explored to date. No doubt there are an equal number that have not. Some possibilities are:

- board formed surfaces, achieved by constructing the formwork of roughsawn timber planks. The boards can be arranged in a pattern which will be mirrored in the final product.
- exposed aggregate – this is more difficult with in-situ concrete than with precast, but it can be done by washing the surface with acid. The use of a retarding agent combined with waterblasting is an effective method of achieving an exposed aggregate finish.
- fairface surface finish with a pattern of holes created by the removal of formwork ties. This finish has been made popular recently by Japanese architects and is achieved through careful consideration of the formwork and casting processes.
- coloured concrete. Oxides and pigments can be used to tint the concrete to a wide variety of colours.

In-situ concrete is only as good as the formwork, which must cope with dynamic loading during the placement and consolidation phases of work. Shuttering can bulge, settle and lean, all of which have the potential to induce small variations in the structure. In addition, the concrete will shrink as it dries. Detailing must therefore consider these and allow adequate tolerances.
Edge details should take into account the difficulty of filling all corners of the formwork with concrete. Concrete may not find its way into corners, leaving them vulnerable to being damaged during removal of the formwork. It is recommended practice to soften these edges with a chamfer or bullnose or, at minimum, a bead of sealant in the corner of the form smoothed out with a finger.

As discussed earlier, load bearing walls are not the only form in-situ concrete may take. The designer can consider a column and beam structure with infill or hung curtain wall or claddings. Such systems can also be used in combination with walls.

Such a concrete structure would have the advantages of allowing large internal and perimeter spans which will give opportunities for expansive open walls spaces and access to sun and views.

The use of cast in-situ floor and roof planes can give the benefits of concrete systems such as acoustic and thermal performance. The concrete can be left exposed from below due to its monolithic form.

**SPECIFICATION**

The written specification for in-situ can follow the form of specifications for commercial work with a greater emphasis placed on workmanship issues.

**Standards**

*NZS 3104*
Concrete production – high grade and special grade

*NZS 3109*
Concrete construction

*NZS 3114*
Concrete surface finishes

*NZS 3402*
Steel bars for the reinforcement of concrete

*NZS 3422*
Welded fabric of drawn steel wire for concrete reinforcement

*NZS 3604*
Light timber frame buildings not requiring specific design

*NZS 3101*
Concrete structures standard

*NZS 3610*
Formwork for concrete
Insulation and waterproofing

As with all concrete wall systems, in-situ concrete must be waterproofed and insulated to meet NZBC requirements. Most often waterproofing is achieved by the use of acrylic paint and/or plaster systems.

Insulation may be placed on either interior or exterior faces or may be cast within the wall.

Materials

**Reinforcing Bars**

Bars are to be to the requirements of NZS 3402

**Spacers and Chairs**

Precast concrete or purpose made moulded PVC to approval. Concrete spacer blocks to only be used where the concrete surface is not exposed in the finished work.

**Ready Mixed Concrete**

High or Special grade to NZS3104. Maximum aggregate size 19 mm. Concrete strength as specified by the engineer.
Workmanship

Require that all formwork and reinforcing be inspected and approved prior to the concrete being placed.

Allow to build in all bolts and fixings as required by other trades and as shown in the drawings. This is an important consideration particularly for the main contractor who is responsible for facilitating the coordination between trades.

Minimum concrete cover shall comply with table 5.5 of NZS3101 but shall in no circumstances be less than 40 mm.

Where concrete is cast against ground the minimum cover shall be 75 mm, or 50 mm if using a damp proof membrane between the ground and the concrete.

Pumping and placement of concrete is to be in accordance with NZS 3109.

Concrete shall not be allowed to free fall more than 2 metres in any one-placement operation. This is an important consideration where the construction details call for the height of the wall to be cast in one operation.

Curing of concrete to occur for the first seven days after placement. This is generally done by keeping exposed surfaces moist during that time. If any curing compounds are to be used they must first be approved by the designer and checked that they will not adversely affect the application of finishes.

Construction

Formwork

Planning the efficient and effective use of formwork is critical to the success of in-situ concrete. The nature of the formwork will depend on the designer’s objectives. It is important to consult with the designer regularly throughout the process to ensure the formwork is appropriate. Equally, the designer must consider, at an early stage, the way in which the formwork will be made. Poor communication between the designer and builder can result in diminished quality or cost escalation.

The formwork must be constructed to accommodate the plastic of concrete which has a mass of approximately 2400 kg/m³. The general requirements are set out in NZS 3109.

Setting out

While it is critical to get things right with in-situ concrete, it is not a construction method of high technology. It is important to coordinate all services, rebates, penetrations and surface finish requirements before concrete is placed in the forms.
Weather conditions

Concrete should not be cast in wet or cold conditions. NZS 3109 provides guidance on precautions that should be taken for hot or cold weather concreting. Interestingly, in places like Canada and Scandinavia, concrete is placed in cold conditions throughout the winter. This often requires extensive heating of formwork which is not justifiable in our relatively mild climate.

Moisture

Only a small proportion of the water in concrete is required for adequate hydration of the cement to occur. The excess water must not be allowed to escape too quickly as it is required for the curing process. This is especially important in the first 7 days.

Conversely, after casting is completed it is desirable for water to escape quickly to allow timely application of finishes. Concrete dries at a rate of about 25 mm per exposed surface per month, depending on the time of year. This implies that a 100 mm concrete wall will take around 2 months before moisture sensitive finishes can be applied. Construction programmes must allow for adequate natural drying to occur. Forced drying, through heating, is not recommended due to the unevenness in drying. Often it is just the surface which is dry. Contractors are advised to check moisture levels with appropriate measuring equipment and to coordinate with the manufacturers of applied finishes.

An early house built in Wellington combining in-situ walls with precast concrete roof elements.
Sandwich construction details

These details of the external envelope indicate how proprietary polymer ties and polystyrene insulation board can be used in an in-situ application. This form of construction is best known in its precast context.

The formwork must be set up to allow the insulation to remain in place while the concrete is placed in both faces. This is best done by balancing the pour to both faces up the height of the wall.

At suspended floor level the wall is cast full height eliminating the need for a construction joint. In this case the chosen concrete floor system is supported on a steel angle bolted to the finished wall.

At ground floor level the in-situ wall is connected to the slab and foundation by starter bars.

The outside veneer face has weep holes formed to allow any water that enters above to trickle down the face of the insulation and escape without affecting the internal space.
In-situ floor and roof plane detail

One of the great advantages of in-situ concrete is the ability to create soffits that can be left exposed for reasons of aesthetics, cost and thermal mass.

These details indicate at upper level how such a roof can be supported on cast in-situ or precast concrete columns. This will allow expansive areas of glass to be used.

At the lower level the in-situ wall is left exposed externally and insulated inside. Corbels and wall thickenings transfer the structural loads from above.

The external walls are cast before the ground floor slab, enabling a controlled environment which may suit some finishes.
External wall details

In-situ concrete allows the designer to incorporate profiles and features which may not be possible with other forms of construction.

An integral gutter, or any other profile, is able to provide architectural relief while serving a practical purpose.

At suspended floor level there may be a need to incorporate construction joints as part of the overall wall pattern. It is important to specify the appropriate joint profile and make allowances for barriers to water ingress.

At foundation level, openings may be necessary for a variety of reasons, in this case to ventilate the crawl space.
Roof parapet details

This roof is used as a trafficable deck with top laid insulation. The concrete soffit is left exposed internally, supported on columns rather than walls.

The veneer wall in this example is internal, stopping short of the roof structure to avoid being loaded structurally.

Construction joint

This plan view of the vertical joint in a sandwich type wall suggests the edges are formed in sympathy with other joint details. Weathersealing is by sealant over backing rod, a minimum 10 mm gap is necessary.
Aluminium door details

These walls are insulated and lined internally, giving a more traditional appearance.

At the head, a rebate is cast in by a removable insert in the formwork. This delicate operation allows the head flashing to be seated securely.

At sill level, the concrete slab edge should be set back to allow the threshold to overhang.
Timber door details

These externally insulated walls have a pronounced chamfer on the internal reveal edge. The frame, positioned in the centre of the finished wall, is fixed to cast in fixing blocks at head and jambs.

Note the architrave, which is scribe cut to the reveal.

Weatherseal at the jambs is sealant, which will require periodic maintenance.
**Aluminium window details**

This set of details indicate the use of domestic joinery profiles in a concrete wall which is strapped and lined internally. The insulation is placed between the strapping. The window frame is shown fitting flush to the outside. While sealants provide adequate weathering at the jambs, at the head a flashing is shown fitted into a formed rebate.

Note that it is advisable to have the window supplier measure the opening after the formwork has been stripped.

This detail has not incorporated timber fixing blocks for the frame. Therefore, it will be necessary to install the frame by screw fixing into plastic plugs fitted into drilled holes in the concrete. It is important to wait until the concrete has gained adequate strength before drilling.
Timber window details

The timber window frame is fitted into a wall with external rigid insulation and applied acrylic plaster as the weatherproofing. Flashing details are incorporated using the proprietary flashings that can be ordered with most External Insulating Finishing Systems.

Note the use of fixing blocks cast into the opening allows the frame to be installed in a manner using standard nail fixings.

The frame is set to the depth of the wall and is held away from the concrete visually by a 5 – 10 mm negative joint. The joint lacks the crispness that may be possible with lightweight linings, but it is important to respect the nature of the concrete materials and allow the chamfer as shown here.
Steel windows are regaining popularity in the residential construction market. Fixing of the window frames to the structure is by way of lugs welded onto the frame before delivery to the site. These lugs are screw fixed to intermittent timber fixing blocks, the positions of which must be coordinated with lug positions.

Frames are fitted against a PVC angle held in the formwork by the fixing blocks. The angle will stabilise the concrete edge and provide suitable backing for sealant.
Services

It is possible to cast-in allowance for services in concrete walls. It is important to coordinate this provision with the structural engineer and the relevant subtrades.

Electrical services generally drop from the ceiling in the space to be served which demands a long conduit drop. An alternative would be to extend the service from the level below.

Be sure to allow sweeps in the conduit both at the top and bottom to allow the cables to be drawn easier.

It may be prudent to allow spare capacity or spare dropper points for future alterations.
References

Websites


Books


Concrete masonry in housing seminar. (1974). Wellington: Concrete Publications Ltd.


**Articles**


