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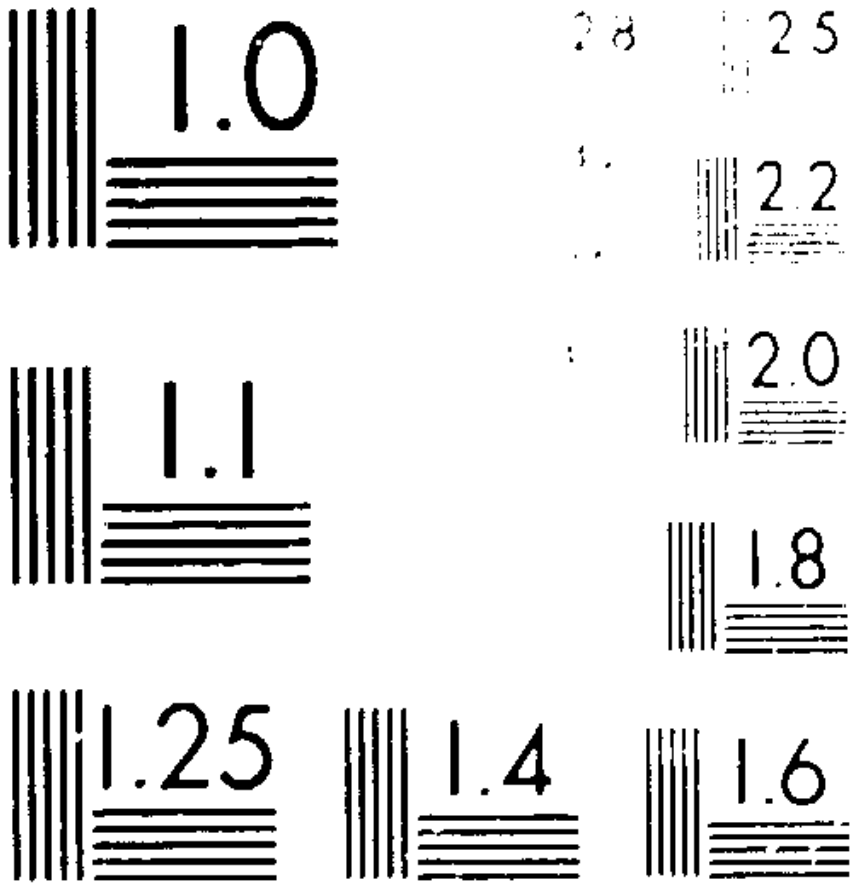
UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION
Vienna International Centre, P.O. Box 300, 1400 Vienna, Austria
Tel: (+43-1) 26026-0 · www.unido.org · unido@unido.org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PRECAST CONCRETE - RECOMMENDED PRACTICE*

by

G.C. Verge**

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** Chairman, Precast Concrete Practice Committee of Concrete Institute of Australia

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CONTENTS

PRECAST CONCRETE RECOMMENDED PRACTICE

INTRODUCTION

Precast concrete has a long and successful history of use in Australia with many large projects in building and civil engineering testifying to this usage. The precast concrete industry is well developed with specialist manufacturers in each major centre of population and experienced designers and builders accustomed to the special requirements of precast concrete. However new developments and refinements of existing procedures require periodic reviews of current practice to ensure that the fundamental objectives of specified performance with safety, economy and long term durability are achieved.

The Concrete Institute of Australia recently established a committee to review its code of practice for the design, manufacture and erection of precast concrete in the light of recent experience and current needs. This committee composed of representatives of Architects, Engineers, Government Authorities, Manufacturers and Builders has produced a draft document to incorporate recommended practices for materials, design, workmanship, inspection and testing, connections and joints. This paper discusses the main features of the new code of practice with particular reference to those changes which have been considered necessary in the light of experience with past practices. In general the committee decided to reduce the emphasis of the previous document on specifications and structural design considerations by including additional material on manufacturing and practical issues, on concrete durability and architectural concrete cladding panels.

MATERIALS

Materials for concrete, cement, aggregrates, water and admixtures are covered by reference to appropriate Australian standards with a note of caution that high alumina cement and calcium chloride should not be used in reinforced or prestressed precast concrete. The total chloride content should be controlled within strict limits as specified to reduce the risk of corrosion. Aggregates for surface finish should be verified for durability under the expected exposure conditions preferably by proven performance. Some tests that may be required include shrinkage, alkali reactivity, weathering, absorption, atmospheric corrosion, ironstone or other staining, particle shape and fracturing potential and colour and surface finish.

Concrete quality should be specified by strength grade with a minimum value of 25. Durability requirements frequently limit the maximum water cement ratio and hence the minimum strength permitted.

As a guide for average conditions the maximum water cement ratio and characteristic strength are related as follows:

Max. W/C ratio	Characteristic strength F'c
0.60	30 mPa
0.55	35
0.50	40
0.45	45

The designer may specify other mix limitations or if only concrete grade is specified, require the manufacturer to provide details of the concrete mix.

DESIGN & MANUFACTURING RESPONSIBILITIES

The division of responsibility between all parties involved in the design and construction of Precast Concrete elements in a building or structure should be clearly understood and should be fully expressed in the professional engagement and contract documentation for each particular project. The parties involved would normally include the Proprietor, Contractor, Architect, Design Engineer and the Manufacturer of the Precast Concrete elements.

Responsibility to the Proprietor for the Design may rest entirely with the Designer (Architect and/or Designer Engineer) when the work is fully detailed and specified or it may be shared between the Designer and the Manufacturer (through the Contractor) when some aspects of the design are specified by reference to performance standards or where a Manufacturer's standard product is used. Any such design responsibility vested with the Manufacturer should be clearly defined in the contract documents.

It is recommended that the Designer, prior to the finalisation of the design, should seek the advice of one or more manufacturers as to the functional, structural and economic feasibility of the design.

Design responsibilities should include:

a) Co-ordination of the design of the Precast Concrete elements with the total design of the building or structure Determination of the part, if any, played by the precast concrete in the support of the structure as a whole

b) The preparation of fully expressed Contract Documents (Drawings, Specification Forms of Main Contract and Nominated Subcontract or Supply)

c) The specification of guarantees if required

d) The specification of dimensional tolerances for the precast concrete, tolerances for supporting structure and contractors' hardware, and erection tolerances for the precast concrete

e) The provision of sample material for the guidance of tenderers

f) Checking and reviewing all manufacturers' shop drawings and procedures, as required in the specifications

g) Determination of load reactions necessary for the accurate design of both reinforcement and connections, including loads imposed by live load movements of the building frame if these are to be resisted

h) Design of the supporting structure to withstand any temporary and unusual loading conditions that might be encountered as a result of the sequence of erection and/or the sequence of loading of the structure

i) Design of the supporting structure so that it will carry the weight of the precast concrete as well as any superimposed loads without excessive deflection or rotation

j) Design of an acceptable method of fixing the precast unit in to the building and also a method of lifting the units ensuring that the specified cover is available and also space for concreting.

k) Provision as part of the design for the effect of difference in material properties, stiffness, temperatures and other elements which might influence the interaction of precast concrete units with the structure.

l) Evaluation of thermal and structural movements as they might affect requirements for joints connections reinforcement and compatibility with adjacent materials

m) Design for durable exterior walls with respect to weathering, corrosive environments, heat transfer, vapor diffusion, and moist air or rain penetration

n) Analysis of the water tightness of exterior concrete wall panel systems evaluating joint treatment, including the performance of adjacent materials for compatibility in joint treatment and the proper sealing of windows and other openings

o) Proper selection of surface finishes recognizing certain limitations in materials and production in regard to uniform colour, texture and performance, especially the limitations which are inherent in natural materials

p) Proper selection of interior finishes defining the area of exposure and the interior appearance for occupancy requirements, again recognizing material and production limitations

q) Checking of the fire resistant, thermal and acoustic properties where required by statutory authorities or otherwise.

Manufacturing responsibilities should include:

a) A review of the design of the precast concrete elements for feasibility with respect to finishes, connections, handling stresses, material quality, joint treatment and tolerances for both manufacture and installation

b) The reporting of any discrepancies to the Designer (preferably prior to tender date)

c) An analysis of precast elements for handling including lifting or temporary loadings imposed on them prior to final incorporation into the finished building or structure;

d) The provision of additional reinforcement or temporary strengthening of units to ensure that no stresses are introduced which would exceed the requirements of codes or standards governing the project or have an adverse effect on their

performance of safety. (Provision for any construction loads which are in excess of stated design requirements and which may occur after installation of the units should not be the responsibility of the manufacturer);

e) The provision of samples with tenders or as requested following tendering

f) The provision of Prototypes if specified.

CONTRACTUAL ARRANGEMENTS

Various contractual arrangements may be made to suit the circumstances of each particular project. In general the main alternatives are set out below. At present most precast concrete work is covered by alternative (a).

a) Specific Documentation

The Designer prepares tender documents with all aspects of the design fully detailed and specified including reinforcement and dimensions.

The Manufacturer submits, with his tender, drawings incorporating the details indicated by the Designer. He may suggest modifications that in his experience would improve the economic, structural and other aspects of the design. The manufacturer should clearly identify such modifications and ensure whether or not they are included in the acceptance of his tender. After acceptance of his tender the manufacturer should submit shop drawings for review by the Designer to ensure that the design intent has been met and for the approval of the Contractor.

A Designer using this alternative and providing complete reinforcement and connection details should be receptive to reasonable modifications, both structurally and functionally. Alternative proposals from a precaster should match the required quality and remain within the parameters established for the project. To give favourable consideration to such proposals is particularly advisable if the suggested modifications are made to conform to the precaster's normal and proven procedures.

b) Specific/Performance Documentation

The Designer prepares tender documents with all aspects of the design, except for the structural aspects, fully detailed and specified. The structural aspects of the design are specified by reference to performance standards which would include all limiting combinations of loads together with their points of application. This information should be supplied in such a way that all details of the unit can be designed without reference to the behaviour of other parts of the structure. The division of responsibility for the design shall be clearly stated by the designer in the tender documents.

The manufacturer completes the design in accordance with the specified structural performance standards and submits, with his tender, drawings and design information including

structural calculations. After acceptance of his tender the manufacturer submits shop drawings for reviewing by the Designer and for the approval of the Contractor.

The manufacturer accepts responsibility for complying with the specified structural performance.

Experience has shown that divided design responsibility can create contractual problems. It is essential that the allocation of design responsibility is understood and clearly expressed in the tender documents.

This alternative is normally adopted where the Architect does not engage a Design Engineer to assist in the Design.

c) Performance Documentation

The Designer prepares tender documents incorporating outline details only and specifies all aspects of the design by reference to performance standards.

The manufacturer completes the design in accordance with the specified performance standards and submits with his tender drawings and design information including structural calculations.

The manufacturer accepts responsibility for complying with the specified performance standards. After acceptance of his tender the manufacturer submits shop drawings for reviewing by the Designer and for the approval of the Contractor.

This alternative could be used where a manufacturer's standard product is specified.

The preparation of performance specifications for precast concrete requires particular skill and experience to clearly define the end result and to ensure durability, economy and optimum quality. The use of performance specifications by Architects who do not possess such skill and experience and who are not assisted by an experienced Design Engineer is not recommended.

DETAILS OF DESIGN

The requirements for details of design include strength and serviceability criteria, crack control, slenderness limits, camber, deformations due to shrinkage, creep and temperature, minimum reinforcement, cover for various exposure conditions and the detailing of sections for ease of manufacture and handling. Details of penetrations, end blocks, corbels and haunches and similar discontinuities are required to control cracking and ensure durability.

WORKMANSHIP

Reinforcement should be clean and free from harmful material likely to impair bond or mar the concrete surface; reinforcement should be bent accurately and located carefully especially in thin members. Welding of reinforcement should preferably be carried out in a jig and not in the mould to reduce the risk of damage to the face of the mould.

Galvanizing should not be used as a means of reducing cover, rather it is one way of reducing the risk of corrosion of reinforcement. Severe cold working such as bending of reinforcement should not be permitted prior to galvanizing.

Moulds should be constructed of metal, timber concrete, plastics or other appropriate material. The construction details and materials should meet the following criteria:

a) The mould should have adequate stiffness to control dimensional accuracy and be capable of dismantling and reassembly within acceptable limits of tolerance.

b) The mould should be provided with means of adjusting and maintaining verticality, alignment and form.

c) Grout-tightness, where required, should be assured by the provision of compressible seals.

d) The mould should be capable of being modified to produce required variations to the shape and dimensions of the basic members if necessary.

e) The mould should maintain rigidity while being handled during the production and curing process.

f) The mould should posses low adhesion to concrete, and be able to be readily cleaned unless surface appearance of the concrete allows otherwise, or it is to be used as permanent formwork.

g) Inserts, embedded items and blockouts should be positively located by the mould to the required tolerances.

h) The mould should be capable of producing the type and quality of surface finish required by the Designer.

i) The mould may require the incorporation of removeable and compressible elements to relieve restraint stresses.

Forms should be designed for the loads specified in the formwork code. If external vibrators and or superplasticizers are to be used, the lateral pressure should be not less than the full hydrostatic pressure.

Forms should be built accurately. In general the fabrication tolerances of the form should be one half those required of the concrete product.

Handling and storage of precast units should ensure that induced stresses are within the specified limits for the appropriate age of the concrete. Any limitations for handling and storage should be shown on the drawings.

Special facilities for lifting should be provided. Any exposed steel parts should be protected against corrosion.

Units should be marked for ready identification and stacked so they are accessible as required and protected against accidental damage in the casting yard.

DIMENSIONAL TOLERANCES

Tolerances should be based on the specific requirements of structural sufficiency and dimensional accuracy, having regard to the size and type of the member. Tolerances at a nominated time should be specified by the Design Engineer and be measured with the member orientated in the same attitude and supported in the same manner as in the completed structure. The effects of differential temperature in the unit should be taken into account when tolerances are measured.

Where close tolerances are specified due regard should also be given to the tolerances specified or achievable in the supporting structure. This is essential as the achievement of fine tolerances in practice depends on a number of factors, all of which must be taken into account. Any such reduction in tolerance should be made with considerable discretion and restricted to the particular dimensions where accuracy is important, as it will necessitate a very high standard of construction of the mould and the closest supervision and inspection at all stages of manufacture, with consequent increased cost.

Whilst dimensional variances are inevitable, precast concrete units can be manufactured within comparatively fine tolerances. The tolerances specified in the accompanying table are normal requirements and larger tolerances should be specified by the designer where practicable.

For irregular, curved or unusual-shaped units the necessary dimension and tolerances should be clearly defined in the specification or shown on the drawings.

The cumulative effect of tolerances of precast components on the joint thicknesses should be taken into account in the design of the joints.

DIMENSIONAL TOLERANCES IN PRECAST UNITS

Flat Panels:

a)	Overall length, width and thickness -	
	less than 3 m	+0mm - 6mm
	not less than 3 m but less than 6 m:	+0mm - 9mm
	not less than 6m	+0mm -12mm
b)	Thickness of any part	$\pm$3mm
c)	Openings, length and width	$\pm$3mm

SURFACE FINISHES

The type of surface finish required will depend on the nature of the unit, its final location and whether or not it is to receive an applied finish. The appropriate finish, which may vary from face to face, should be carefully chosen and clearly specified. Surface finishes depend on properly fabricated moulds, and the

Designer should clearly understand the capabilities of and the restrictions or limitations of mould production.

It would be optimistic to imagine that every unit cast during the course of a contract will be perfect. Defects and blemishes will occur, and the main operations in making good are filling holes, removing stains and repairing mechanical damage. The range of defects and blemishes that usually occur are included in A.S. 1510 - control of concrete surfaces.

The three grades for colour uniformity of off form concrete are:

Type C - where limited colour uniformity is acceptable.

Type B - where colour variation is a reflection of form lining absorbency only and may be due to deliberate selection of form linings having different surface characteristics.

Type A - where particular care is required to give a uniform colour throughout.

For concrete of specific colour uniformity, the formwork should be either Class 1 or Class 2.

Class 1 - formwork for high quality finish and fine tolerances

Class 2 - formwork for medium quality finish and close tolerances

The normal quality of precast off form concrete is Type B, Class 2. Type A should only be used in rare circumstances for National Monumental structures.

Colour variations on the exposed concrete may be due to variations in colour of the constituents, e.g. sand or cement, variations in mix proportions, moisture movement, e.g. loss of water from the mix or mortar Contamination, e.g. by the form face or release agents, non-uniform curing, e.g. different rates of formwork stripping and curing, staining e.g. efflorescence, rust staining.

Exposed aggregate finishes can be obtained by the face-up or face-down techniques, the choice of method being governed largely by the shape and detail required. Aggregates may be exposed by

a) washing off with water when casting face up
b) application of retarder to the mould face for face-down casting, followed by removal of the cement matrix.
c) grit or sand blasting
d) tooling, which may include some fracturing of the aggregate. Cover may need to be increased.
e) Hammered Rib which exposes the aggregate in a ribbed surface
f) grinding to produce a smooth surface
g) acid etching which should be used with caution because of the possible penetration of chlorides and increased risk of corrosion.

Applied finishes such as tiles or natural stone may be achieved while the concrete is plastic or after it has hardened. Care is required to ensure proper bond between the base concrete and the finish during manufacture and in subsequent service especially where the properties of the base and the applied surface are significantly different.

CONNECTIONS & JOINTS

Connections are required to transmit calculated forces by means of haunches, insitu concrete, welding or bolting steel sections, dowelling, bonding or the like. The details chosen should allow for the expected tolerances in the precast elements and the supporting member. The detailing of the reinforcement and any embedded hardware should be checked carefully with large scale sections of these elements drawn to allow for actual bends and the tolerances of manufacture and erection.

Joints should be planned to reduce problems with thin sections, difficult stripping details such as square edges and recesses and details which require close tolerances for effective sealing or appearance. The waterproofing of joints may be effected by either sealing with field moulded sealants or using the open drained system.

Field moulded sealants should be used only with small panels of about 3 m dimension where the joint is subject to relatively small movements. The shape of section, minimum dimensions and edge details depend upon the design movement and the sealant type. Generally a minimum width of 10 mm and a backing rod to control the sealant depth and prevent bond at the bottom of the joint, are required.

Open drained joints are preferred to sealed jionts because they do not depend upon the bond of field moulded elastomeric materials for weatherproofing. Rain water is drained to the face of the building at each floor level with a baffle in vertical joints to deflect direct rain and stepped flashing at the horizontal joints. The back of the joint is sealed to provide a wind barrier - this requires access during erection and thus usually dictates the location of the joint with respect to the building structure.

REPAIRS

Concrete is a brittle material and when subject to handling and transport stresses, it is inevitable that some cracking and spalling will occur. Provided that such damage occurs to only a small proportion of the quantity produced repairs, if considered necessary, should be permitted. Unnecessary repair work, particularly of a purely cosmetic nature, should be avoided. It is very difficult to completely disguise a repair and repair work is a skilled,costly process.

Cracks may occur prior to the hardening of concrete (plastic cracks) or subsequently when the concrete has some tensile strength. Plastic cracks are usually repaired by veeing out and filling with a filled epoxy resin. Cleavage cracks may be repaired by epoxy injection. Unless exposure conditions warrant, cracks less than 0.2 m width should not be repaired.

Recurrent cracking will have a particular cause which should be identified and the manufacturing process or design detail modified to eliminate this cracking.

Broken concrete may be replaced by using the original concrete mix if the base is relatively green, that is less than 28 days old and by proper moist curing to achieve bonding and continuity.

Alternatively a bonding agent preferably of the resin watercure variety may be used to improve bond or a resin modified concrete may be used for broken areas of structural concrete.

WEATHERING

The weathering and deterioration of a building facade depends upon the environment around the building, the design and detailing of the exposed concrete, the durability of the concrete and the colour and surface texture of the concrete. Air pollutants deposited on the surface cause dirtying and chemical attack of the concrete principally from dust and the oxides of carbon, sulphur and nitrogen.

Detailing of the facade should provide for natural cleaning by the flow of rainwater washing exposed surfaces and by preventing water flow from sheltered positions where dirt accumulates to exposed surfaces where this dirt is deposited. Drip grooves, rain checks and separate drains should be provided to eliminate streaking due to dirty water staining the underside of sills, corners of windows and beam-column junctions.

Surface durability requires dense concrete of water cement ratio 0.45 - 0.55 and cement content 360-400 Kg/m^3. Porous concrete, poor workmanship and inadequate attention to the staining from adjacent materials such as metal inserts, copper pipes and the like are common causes of surface deterioration. Smooth concrete can experience surface cracking or crazing resulting in a staining pattern. A light texturing by sand blasting can avoid this problem.

The choice of colour should be related to the location of the building. A white facade located in an industrial or inner city area subject to heavy pollution will become grey within a short time. A dark colour would be a better choice in this case unless particular care and a regular maintenance program is adopted. Rough textured concrete weathers more uniformly than a smooth surface because of the natural dispersion of the textured surface, however the rough texture tends to collect dirt more quickly than a smooth surface. Patterned or profiled surfaces have been used successfully to achieve a satisfactory weathering performance with the modelling of the surface enhanced by the controlled weathering pattern.

CONCLUSION

Precast concrete is an important building material for structural and architectural purposes. Its continued successful use depends upon adherence to some fundamental principles of material technology, design and detailing, and workmanship in the factory and on site. The Concrete Institute's code of recommended practice is expected to make a significant contribution to the continuing education of those people in the industry responsible for the design and construction of precast concrete structures.