OCCASION

This publication has been made available to the public on the occasion of the 50th anniversary of the United Nations Industrial Development Organisation.

DISCLAIMER

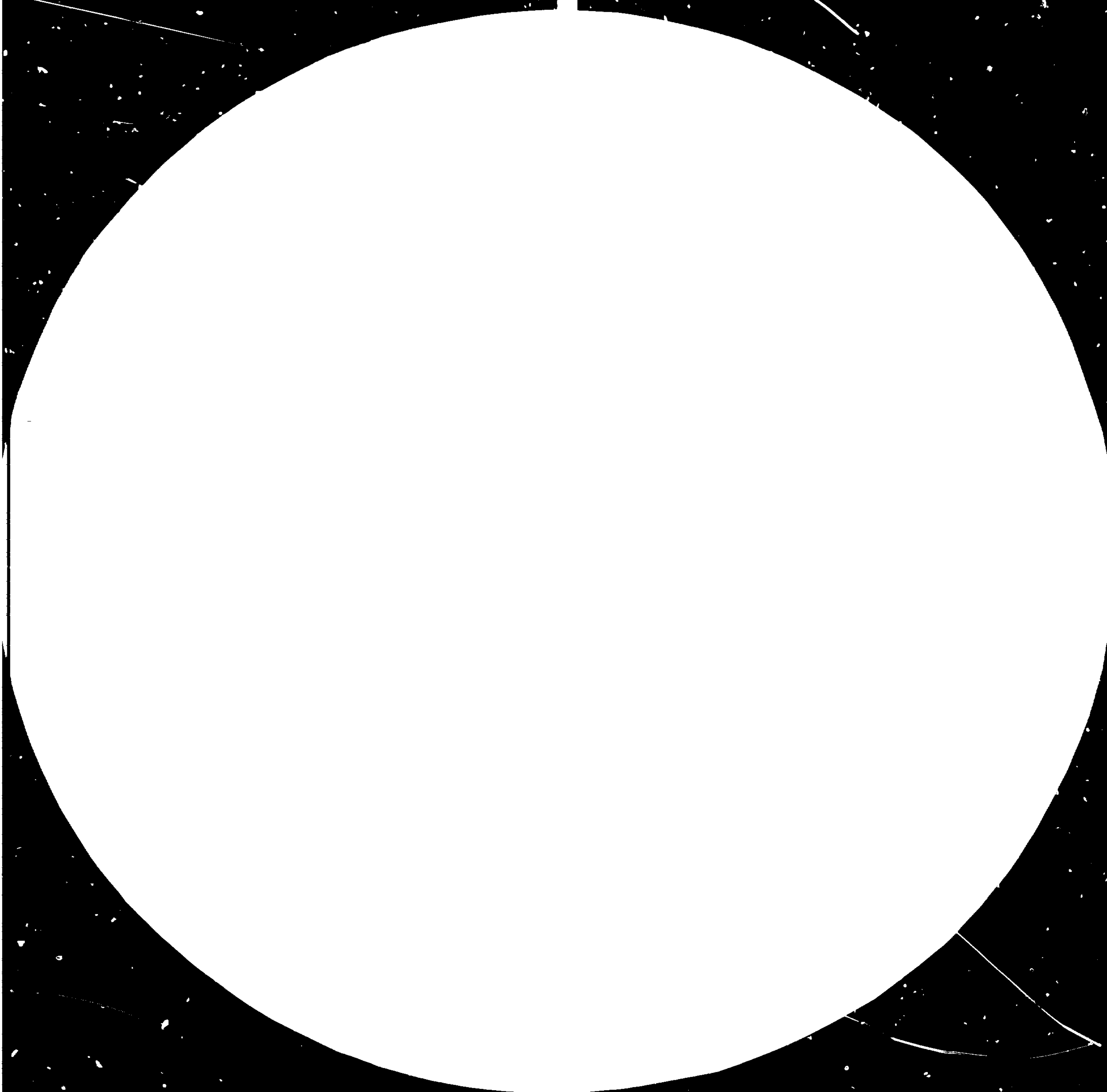
FAIR USE POLICY

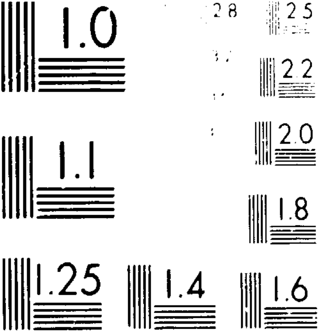
CONTACT

Please contact publications@unido.org for further information concerning UNIDO publications.

For more information about UNIDO, please visit us at www.unido.org

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




1.0
2.8
2.5
2.2
2.0
1.1
1.8
1.25
1.4
1.6

Distr.
LIMITED

ID/WG.347/15
28 September 1981

ENGLISH

United Nations Industrial Development Organization

Workshop on Cement and Concrete Products
Brisbane, Australia, 18 - 29 May 1981

CONCRETE IN BUILDINGS - * A REVIEW OF CURRENT AUSTRALIAN PRACTICES

by
C.F. Morrish**

* The views expressed in this paper are those of the authors and do not necessarily reflect the views of the secretariat of UNIDO. This document has been reproduced without formal editing.

** Chief, Information Division, Cement and Concrete Association

V.81-30204

CONTENTS

INTRODUCTION

A glance at the skyline of any Australian city will indicate the extent to which concrete is the pre-eminent building material in downtown commercial areas. Concrete framing, of one type or another, is used in the vast majority of all recent office buildings. Precast concrete claddings, employing a wide variety of surface finishes, are the pre-eminent facing material.

All buildings are constructed in accordance with the Australian Strength Standard, AS 1480 - Concrete Structures Code. This is an Ultimate Design Code which bas been based largely on the Codes of the American Concrete Institute (ACI) and the British Code, with the exception of those sections dealing with shear and torsion. These have been developed from local data and experience. Where prestressed elements are included in any structure, they are required to comply with AS 1481 - Prestressed Concrete Code. Currently, both these codes are being revised. Because of the extent of use of prestressing and partial prestressing in building construction, the two Codes will be amalgamated into a single code for structural concrete. This will have a limit state format.

In Australia these Codes are enforced by the building regulations administered by municipal authorities. Queensland, New South Wales, South Australia and Western Australia operate under a common set of regulations known as the Australian Model Uniform Building Code. Victoria and Tasmania are in process of modifying their current regulations so that uniformity is achieved nation-wide. Both the current codes and regulations have been developed in the context of highly sophisticated readymix and precast concrete supply industries.

Structure in building is also controlled by the recently published Earthquake Code, but the only major city in which this has direct applicability is Adelaide. The building techniques we will examine are those applicable in non-seismic areas of Australia. One of the principal design factors in this country is wind loading. Design wind speeds are taken as 45 m/s for most coastal cities, 50 m/s in Brisbane and 61 m/s in cyclonic regions across the northern half of the Continent.

Generally the codes and regulations have worked well. The only point of qualification which might be emphasised is a need for slightly greater stringency in those clauses relating to the durability of concrete structure. As a majority of our buildings are erected within a few kilometres of the coastline and are subject to severe on-shore winds, we are generally dealing with a near marine environment. Because of the sophistication of our concrete industry, it has become relatively simple to satisfy compressive strength requirements with cement contents which are low by world standards. As engineers tend to specify concrete by compressive strength, this has, in some cases, resulted in concretes being employed having too high a water:cement ratio and too low a cementitious content to prevent corrosion of steel, where minimal cover to steel is specified. Consequently the Cement and Concrete Association recommends that compressive strength requirements should be qualified by the nomination of minimum cement contents and maximum allowable water:cement ratios for four categories of exposure (1).

FLOOR SYSTEMS

Concrete has not always enjoyed its present pre-eminent position as a framing material. A major change took place following the construction of the first flat plate building in Sydney, (Caltex House), in the late 1950s. Engineers, builders and architects were quick to appreciate the enormous cost benefits of the reduced floor to floor height possible with flat plate and flat slab floors and the simplicity and mobility of formwork systems required for such floor structures. The use of flat slab floors has become the preferred approach for a majority of multi storey commercial, institutional and residential building structures.

Insitu post-tensioning of flat slabs is a well developed and popular technique to secure increased column spacing, thus granting greater freedom of internal layout and subdivision. These techniques will be the subject of a separate paper.

They had their dawn in lift slab structures which enjoyed some popularity, particularly for residential buildings, in the early 1960s. Today lift slab construction is almost wholly confined to very large span slab and roof structures for industrial and hospital buildings. Perhaps the most notable current use is in Western Australia where the Public Works Department (2) has evolved a system employing very thin slabs spanning up to 14.6 metres in both directions. A prototype tested to destruction combined inverted umbrella capitals and a prestressed flat plate in which the cables were grouped into ribs, thus creating shallow areas between ribs suitable for penetration by services. This was to permit construction to proceed in advance of finalising the design layout for services in the hospital building. Rib depth was 215 mm and slab depth 127 mm, giving an average depth of 180 mm. Following testing it was decided to increase rib depth in the actual structures to give an overall increase in average thickness of 20-25%. This still results in a remarkably thin floor system for spans in excess of 14 metres.

The bulk of Australian building construction employs insitu floor systems of one type or another. This is not to suggest that the precast industry does not market a wide range of precast flooring elements. However, they tend to be used only in special situations. A combination of good climate, an adaptable work force, and the subcontracting system through which most of our concreting is placed, has tended to give insitu concrete a slight economic advantage over most precast systems. The scattered and isolated nature of our markets serving comparatively small concentrations of population has forced a fairly small scale approach to precast concrete flooring manufacture. However, this is changing. Already in the Sydney area we have two major facilities for extruding prestressed floor planks and they are gaining increasing market share, although, at the present time a considerable proportion of their product is being used for load bearing wall panels, primarily for industrial and warehouse buildings (3).

Just as building claddings are custom fabricated, so, many precast flooring systems have been tailored to the requirements of specific buildings. An example is the AMP Centre in Sydney, which rises 186 metres above street level. The tower block has a slip formed core and 34 perimeter columns, each transmitting an average load of 2,000 tonnes. Insitu concrete beams span between the core and perimeter columns supporting 105 mm thick precast lightweight concrete planks to produce a column free interior. Each plank acts as permanent formwork for a 50 mm insitu structural topping.

SLIP FORMING

A majority of service cores for both commercial and residential buildings are slip-formed or jump-formed to speed construction and to allow lift installation to proceed as speedily as possible while the rest of the structural frame is being completed.

Slip-forming has also enjoyed some popularity as a technique for constructing the load bearing walls in multi-storey residential buildings, in advance of floor placement. Most of the earlier examples of this technique are in Western Australia, but there are examples to be seen in most of our urban centres. Perhaps the most impressive example is a 33 storey block of apartments (4) at the northern entrance to Surfers Paradise.

One quite novel approach was employed for the residential tower block at Freshwater Close in Perth. All walls were slip-formed three floors behind the service core. On completion, a flat plate concrete floor was cast at the upper floor level and the formwork was then winched down to each succeeding lower level. Another novel technique, and one which has been patented, was that adopted for a building in St. Leonards, N.S.W. (5). In this building the roof was constructed at ground level and then hoisted aloft on columns and core progressively cast in three metre heights, formwork and roof being hoisted in conjunction. All floors were then cast separately at ground level and hoisted aloft to their final position, two internal columns acting as the guides.

Slip-forming of columns and service core together, stiffened as required by temporary steel bracing, was also most successfully used in the construction of the Hilton Hotel in Sydney. In the nearby Qantas Tower in Sydney, four blade columns were jump-formed in conjunction with the service core and tied together by three major trusses. Floors were formed by 'T' shaped precast components supported at their outer extremities by cables suspended from these trusses (6).

PRECAST CLADDINGS

Precast concrete claddings, used first with an exposed aggregate finish, saw large scale use in Australia from the late 1950s, i.e. at the time that the flat plate floor first made its local appearance. This was a happy coincidence as it enabled designers to employ a straight forward framing system which could be enclosed rapidly with dry elements which ensured a high quality, attractive finish. Within 5 to 10 years in most cities, the concrete curtain wall, in all its varied forms, has become the preferred choice for the vast majority of major buildings. The general standard of finish achieved was exemplary and compared favourably with the best on offer elsewhere in the world. The Australian climate is comparatively kind to concrete, and where high quality finishes and adequate cover to steel have been nominated, these claddings have performed exceedingly well and have given few problems.

Almost without exception precast concrete wall claddings are custom built to suit individual designer requirements. Once the use of precast concrete cladding became popular it was not long before designers queried the good sense of using concrete elements for weather protection only, and a number of interesting buildings have been erected in which precast concrete claddings act as load bearing facades. Typical of the better examples are Greater Pacific House in North Sydney and the Hamersley Building in Perth (7). The latter represents one of the most elegant uses of a load bearing facade. The column mullions were cast in 3 storey lengths and taper to 50 mm at their leading edge, similarly the sun hoods, which project almost 1.5 metres, have a leading edge only 50 mm thick. The erection of the mullions was staggered from floor to floor as only every third mullion was required to support the wet concrete load from any floor. This ensured freedom of access and egress for the table forms employed.

An alternative approach is to use the claddings as permanent formwork for insitu concrete columns and spandrels. This is the most popular approach today as it minimises the required crane lift whilst exploiting the structural capacity of the cladding. The first building to employ this technique was Australia Square in Sydney (8), Australia's first ultra-high-rise building. Rising 51 storeys this building utilises precast column and spandrel casings as permanent formwork acting integrally with insitu concrete backup. The spandrels were also designed to act as safety barriers during floor construction. In this building precast soffit liners were also utilised as permanent formwork for the 'Nervi' type ribbed floors at the sixth and seventh level in the main tower block.

This technique is now widely used and in a variety of ways. Another example is the Goodsell Building, Sydney (9). Here the reconstructed polished black dolerite facings butt together to form permanent formwork for the columns.

The system used in Australia Square has been further developed by the originating companies - Lend Lease Ltd and its building subsidiary Civil & Civic Ltd, in a system known as 'Progressive Strength', which has won application in a wide variety of building types. As this will be the subject of a special paper on Special Construction Techniques, it will not be examined in detail here. The system basically employs precast concrete casings designed to act as permanent formwork for columns and spandrels and to accept the wet concrete load from one typical floor. These are used in conjunction with trussed reinforcement for each typical floor. The trusses have a flange plate attached to the bottom chord capable of accepting a variety of sacrificial or recoverable forms, which when taken together, are capable of supporting the wet concrete load.

An adapted form of this system was used by Civil & Civic to achieve very high rates of construction for Australia's tallest office building, the 224 metre high, 68 storey MLC Tower Building in Sydney (10). One special problem in this building was the risk of troublesome deflections developing in the long spandrels, which were precast in 2 or 3 segments. This was overcome by erecting these spandrels on a group of 3 trusses set one floor above the other and post tensioned to provide a positive hog which would be exactly eliminated - bringing the spandrel elements into proper alignment - on acceptance of the full load.

The architect responsible for both the MLC Tower and Australia Square, Australia's Harry Seidler, has been responsible for some of Australia's most elegant buildings. In a number of these he has explored the potential of a sculptured precast spandrel beam as a combined architectural/structural device. Perhaps the most successful example is in the Barton Trade Offices in Canberra (11). These offices consist of 7 rectangular buildings linked by cylindrical service towers, the whole set around 2 internal courtyards. The structure of each rectangular building consists of precast column elements each a half storey in height (1.7 metres), precast, post tensioned 'I' beam spandrels spanning about 24 metres, and a flooring system consisting of shaped precast, post tensioned 'T' beams, about 1.5 metres wide, spanning some 16 metres. The 'T' beams are anchored to the central web of the spandrels by post-tensioned lateral tendons, the anchorages being fully exposed as part of the architectural design. The 'T' beams are shaped to provide a flat slab at the point of support. This system provides column free space, which in the longer sides of each courtyard, measures 90 metres by 16 metres.

Another elegant building, designed by Noel Bell - Ridley Smith, and similarly exploiting the potential of the spandrel beam, is St Andrews House (12), behind St Andrew's Cathedral in Sydney. This building houses a mix of school and office activities in which column free space was imperative. The spandrel 'I' beams are each cast integrally with half the permanent formwork for cylindrical corner columns.

Another outstanding and related example is the Campbell Park Defence Offices in Canberra (13). Precast 'U' beam spandrels, with a simple off-form finish, span some 17 metres and carry a precast tripple 'T' floor system supported on the lower flange. The insitu concrete supporting elements and service cores are notable for a superbly executed hammered nib finish which helps to humanize an otherwise rather brutal scale.

INSITU SURFACE FINISHES

The extensive use of finely controlled insitu concrete finishes is one of the more notable aspects of commercial and institutional building in this country. There are many fine examples ranging from the American Express Building (14) in downtown Sydney, to the recently completed High Court Building (15) in Canberra.

The popularity of these finishes is largely attributable to the availability of locally manufactured off-white elements, having a very low iron content (so that problems of hydration staining are minimal given good concrete practice), and the existence of the Australian Standard, AS 1510 for Formwork for the Control of Concrete Surface Finishes. The latter has provided designers and builders with specific guidelines on how to control the critical role which formwork plays in the achievement of these finishes always provided that properly designed concretes are employed. The Code specifies 3 types of colour control and 5 types of surface texture control for finishes obtained directly from the form, or subject to subsequent tooling. It provides suggested standard details for the assembly of formwork and makes the use of structural backing to formwork linings compulsory where good colour and textural control are required. It also insists that at least 3 full scale test panels be constructed in advance of the major work so that the actual formwork, parting agents and concretes nominated, can be tested in conjunction, to ensure that the designed finishes can be achieved. Typical of the results achieved is the Library and Humanities Building at Griffith University (16) in this city, designed by Robin Gibson the architect responsible for the Cultural Centre which you will be able to see rising on the banks of the Brisbane River.

Perhaps some of the most spectacular finishes have been those in which heavily textured finishes, such as hammered nib, have been incorporated. One novel technique, which has been developed locally, is the jacking of hemp rope out of the concrete surface, following the striking of formwork. This gives a well controlled, heavily textured finish, providing a delightful play of light and shadow (17). Its most successful use has been in the T & G Building rising above Park Street in Sydney.

The building which does, perhaps more than any other, express how well both high quality insitu and precast concrete surface finishes can be used alongside each other, is the Perth Concert Hall (18). In this building the concrete was entirely supplied by the readymix concrete manufacturer to both the precaster and to the builder on site. A superlative pale buff finish has been achieved, both externally and internally.

It is buildings such as this, and of course the Sydney Opera House, which have giv en the local architect and engineer tremendous confidence in concrete as a building material, suited to both modest institutional buildings or major commercial structures.

FINALLY

Regrettably, but inevitably, in any review paper of this length, it is possible only to touch upon the more obvious aspects when covering a major subject such as Concrete in Buildings. There are countless other aspects worthy of discussion. Nevertheless the main influences on the extensive use of concrete in building in this country can be summarised as :

a) a favourable climate which results in few lost days for on-site working

b) the growth of a well developed, dependable and sophisticated readymix concrete supply industry in all urban and most country centres

c) a precast concrete industry geared to custom-built fabrication of high quality claddings and dedicated to the achievement of high quality finishes with good colour control

d) the availability of locally manufactured off-white cements which ease some of the problems of achieving high quality insitu finishes

e) a well equipped building industry

f) well educated designers, particularly in the field of structural engineering

REFERENCES

(1) DURABILITY OF CONCRETE STRUCTURES
C&CA Technical Note No. 37
October 1980

(2) LONG SPAN FLOORS
Constructional Review, March 1975
pp 28 - 31

(3) PROJECT SILVERWATER
Constructional Review, February 1980
pp 24 - 29

(4) HOUSING - THE GOLDEN GATE
Constructional Review, May 1978
pp 46 - 49

(5) CLIMBING FLOOR AND LIFT FLOOR TECHNIQUE
Constructional Review, August/September 1973
pp 16

(6) QANTAS CENTRE - STAGE I
Constructional Review, August 1970
pp 32 - 34

(7) HAMERSLEY BUILDING
Constructional Review, August 1971
pp 46 - 51

(8) AUSTRALIA SQUARE SYDNEY
Constructional Review, September 1966
pp 10 - 17

(9) GOODSELL OFFICES SYDNEY
Constructional Review, February 1971
pp 18 - 25

(10) MLC TOWER
Constructional Review, August 1979
pp 54 - 60

(11) GROUP TRADE OFFICES
Constructional Review, May 1975
pp 12 - 16

(12) ST ANDREWS HOUSE
Constructional Review, November 1975
pp 54 - 56

(13) CAMPBELL PARK OFFICES
Constructional Review, November 1972
pp 4 - 16

(14) KING GEORGE TOWER
Constructional Review, August 1976
pp 12 - 19

REFERENCES (Cont'd)

(15) HIGH COURT OF AUSTRALIA
Constructional Review, August 1979
pp 20 - 25
Constructional Review, August 1980
pp 12 - 19

(16) GRIFFITH UNIVERSITY
Constructional Review, November 1975
pp 11 - 25

(17) ROPE FINISH
C&CA Publication No. NC101

(18) CONCERT HALL
Constructional Review, May 1973
pp 3 - 9