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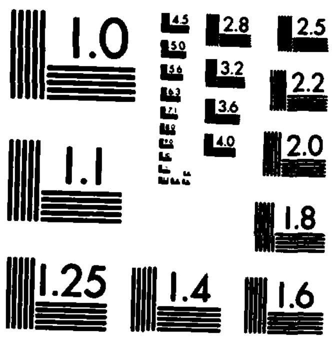


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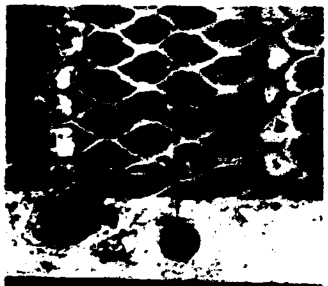

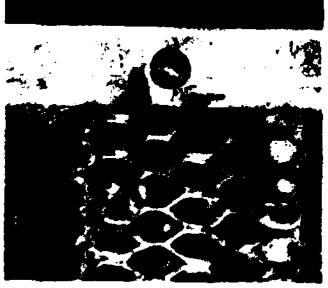

STRUCTURES LABORATORY

TECHNICAL REPORT SL-84-8

# SELECTED BIBLIOGRAPHY ON CONSTRUCTION METHODS FOR ARCHITECTURAL CONCRETE AND PORTLAND-CEMENT PLASTER


by

Robert H. Denson

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US ARMY ENGINEER WATERWAYS EXPERIMENT STATION

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| Portland-cement plaster | Forms | Exposed aggregate |
| Plaster | Cast-in-place | Finishes |
| Mixture components | Precast | Glass fibers |
| Construction techniques | Panels | Portland-cement plaster |

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

A listing of 43 references (34 of which have an accompanying abstract or review) is presented for architectural concrete and stucco materials, techniques, and applications.

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# Preface

This report was prepared for and funded by the Director of Engineering and Construction, Headquarters, US Army Corps of Engineers, Washington, DC, and was written by Mr. Robert H. Denson, Materials and Concrete Analysis Group (M&CAG), Structures Laboratory (SL), Waterways Experiment Station (WES), Vicksburg, MS. The work was accomplished under the general supervision of Messrs. Bryant Mather, Chief, SL; John M. Scanlon, Jr., Chief, Concrete Technology Division; and Richard L. Stowe, Chief, M&CAG.

Commander and Director of WES during the preparation and publication of this report was COL Tilford C. Creel, CE. Technical Director was Mr. F. R. Brown.

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## Conversion Factors, Non-SI to SI (Metric)

## Units of Measurement

Non-SI units of measurement used in this report can be converted to SI (metric) units as follows:

| Multiply | By | To Obtain |
|---|---|---|
| feet | 0.3048 | metres |
| inches | 0.0254 | metres |
| pounds (force) per square inch | 6.894757 | kilopascals |
| pounds (mass) | 0.45359237 | kilograms |
| pounds (mass) per cubic foot | 16.01846 | kilograms per cubic metre |

# SELECTED BIBLIOGRAPHY ON CONSTRUCTION METHODS FOR ARCHITECTURAL CONCRETE AND PORTLAND-CEMENT PLASTER

## Authority

1. The preparation of this document was authorized by Funding Authorization Document, Advice of Allotment (AOA) No. 2-3971, issued by Headquarters, US Army Corps of Engineers, and dated 15 July 1983.

## Introduction

2. The techniques for constructing precast and cast-in-place architectural concrete have improved in the past four years due mainly to (a) introduction of new materials for formwork, (b) use of metallic and nonmetallic fibers (although not yet widespread), and (c) use of high-range water-reducing admixtures for concrete which permit higher slumps or increased workability while achieving the desired strength. There are also new materials and technologies which have led to improved techniques for mixing and applying portland-cement plaster in new textures and finishes thereby allowing greater freedom of architectural form.

3. This document includes a partial listing of current documents which delineate the practices, both past and present, of architectural concrete and portland-cement plaster techniques. This bibliography reflects recently published information on the technological changes that have occurred which may affect the writing of new specifications or standard practices. However, it should be noted that of the 43 references listed herein, less than a third were published in the past 5 years.

## Architectural Concrete

4. Documents on the state of the art of architectural concrete include guide specifications, manuals of accepted practices, committee reports, articles and papers published in professional journals, symposia presentations, and articles on unique current-interest events published in trade journals. Some of the information may be in a chapter on architectural concrete contained in

a manual on concrete inspection. Only one document can be considered a "how-to-do-it" manual, and it is slightly dated.

5. The subjects of these documents reflect a rather wide spectrum of interest. There are those which address specifications, mixture proportions, and forms and placement techniques for cast-in-place architectural concrete, while others address these same subjects for the precast method. Forming and formwork are examined in several references as to specifications, form materials (steel, plastic, and wood), form liners, and agents for preventing bond at the form-concrete interface.

6. One grouping of documents addresses such items as placement of reinforcing steel and installation connectors for precast panels. One document examines a technique for posttensioning of precast panels.

7. A rather large group of the documents presents techniques and ideas for surface finishes and appearances. Items examined include color, texture, patterns, designs, exposed aggregate materials and techniques, external vibration for better finishes, mechanical and chemical finish applications and techniques, and preplaced bedded aggregate. One document describes a technique for applying an architectural finish on structural concrete.

8. A few documents examine and suggest the use of high-range water-reducing admixtures and glass-fiber-reinforced concrete, while one presents guidelines for achieving high-quality architectural concrete.

9. One article addresses tilt-up panels, while another describes the use of precast architectural panels as a facade on a noise-reduction fence for a major roadway.

10. Some documents examine cost factors and the impact of the amount of detail in preconstruction planning on the total production process.

11. Finally, one document addresses the behavior of architectural concrete subjected to fire.

## Portland-Cement Plaster

12. Documentation on portland-cement plaster materials and techniques is very limited. One of these (PCA 1980), however, is quite comprehensive on all aspects of techniques, materials, bases, and normal and special applications. It is a recently written "how-to-do-it" manual. The other documents in the

bibliography address such things as unique use of plasters on insulation, repair of protective coatings, and the resistance of a plaster coating to penetrations.

## Conclusions

13. The references cited in this bibliography were reviewed in either original form or abstract form. It is recognized that searches of other data bases, using appropriate keyword callout combinations, would likely reveal more references. These can be explored at later dates if additional information is desired.

14. It is apparent that a single reference updating the state of the art is needed for architectural concrete and portland-cement plastering. This bibliography may serve as a reference for those who will subsequently perform this effort.

## Bibliography

15. The following is the bibliography along with annotation which describes the major topic of each reference.

<u>Architectural Concrete</u>

ACI Committee 311. 1981. "Architectural Concrete," <u>ACI Manual of Concrete Inspection</u>, ACI Publication SP-2, Seventh Edition, Chapter 14, American Concrete Institute, Detroit, MI, pp 291-315.

The chapter deals generally with inspection of architectural concrete work. The subjects addressed are mixture components, mixtures and mixture proportions, batching, mixing, and transporting, placing and consolidation, finishing, curing, and repairs.

ACI Committee 303. 1974. "Guide to Cast-in-Place Architectural Concrete Practice," <u>Manual of Concrete Practice</u>, ACI 303R-74, Part 3, American Concrete Institute, Detroit, MI.

This report recommends practices for the production of cast-in-place architectural concrete, emphasizing materials, forms, placement, curing, treatment, and inspection, with 34 references.

ACI Committee 533. 1970. "Fabrication, Handling, and Erection of Precast Concrete Wall Panels," ACI 533.3R-70, American Concrete Institute, Detroit, MI, 31 pp.

Concrete Institute of Australia. 1981. Papers from the 10th Biennial Conference *of the Concrete Institute of Australia, Adelaide.*

This conference proceedings contains 24 papers. The topics covered include: Structural design of concrete constructions; concrete in civil engineering; concrete as a material; concrete in architecture and in construction. Technical and professional papers from this conference are indexed with the conference code No. 00966 in the Ei Engineering Meetings (TM) data base produced by Engineering Information, Inc.

<u>Concrete Construction</u>. 19[illegible]. "Mix Design Hints for Architectural Concrete," Vol 14, No. 8, pp 309-12.

Methods of mixing of durable concrete for decorative finishes, and various mix design considerations, production of acceptable workability, and discoloration problems are discussed.

<u>Concrete Construction</u>. 1972. "Setting Steel for Architectural Concrete," Vol 17, No. 11, Nov, pp 539-540.

Tabulated data are presented and explained for bar designation and reinforcing steel diameters. Minimum and maximum diameters are the diameters to the base of the deformations and the outside of the deformations, respectively.

Concrete Construction. 1972. "Selecting Forming Materials for Architectural Concrete," Vol 17, No. 11, Nov, pp 540-541.

Primary considerations presented in selecting forms and form liners deal with the plywood, steel, and fiberglass-reinforced plastic forms and form liners from the point of whether they are absorbent or nonabsorbent, or whether absorbency will be uniform.

Concrete Construction. 1974. "Forming Architectural Concrete," Vol 19, No. 7, Jul, pp 337 and 338.

It is stressed that the final assessment of a structure that calls for architectural concrete is based on the appearance of its surface, and the demands this can impose on a contractor's skills may be quite different from those required for building structural concrete. This article discusses the main demands and facets that must be considered. Use of form liners, ties, and patterns is dealt with.

Concrete International. 1984. "Architectural Concrete," Vol 6, No. 1.

This issue is completely dedicated to architectural concrete and includes articles on colored and textured architectural concrete, problems and surface blemishes, and architectural concrete considerations for cast-in-place concrete. It also discusses the American Concrete Institute Architectural Concrete Guide.

Gensert, R. M. 1972. "Cost Factors for Cast-in-Place Architectural Concrete," Journal of the American Concrete Institute, Vol 69, No. 1, pp 36-45.

Cost of architectural cast-in-place concrete is evaluated with charts and curves presented giving percentage increases over costs of conventional structural concrete for a variety of factors, such as cements, aggregates, effect of overall surface geometry, surface indentations and projections, reveals, and soffits. Beam and column cross sections and profiles are based on relative costs, with linear members serving as the basic measure. Coloring by using pigments is based on cost per cubic yard of concrete, while coloring by coatings is based on square foot of surface coated.

Gustaferro, A. H. 1974. "Fire Resistance of Architectural Precast Concrete," Journal of the Prestressed Concrete Institute, Vol 19, No. 5, pp 18-37.

The report summarizes available information on the behavior of architectural precast concrete subjected to fire conditions. Based on fire tests, the report presents design data for calculating the thickness of many types of walls that will provide fire endurances of 1, 2, 3, and 4 hours. In particular, tables and design charts are included for determining the thickness of one- and two-course panels, ribbed panels, sandwich panels, and window panels. Several numerical examples are provided. The report also contains a section dealing with the fire resistance of precast concrete columns and column covers. Thirteen references are presented.

Haney, J. T. 1973. "How to Obtain Better Architectural Finishes with External Vibration," Modern Concrete, Vol 36, No. 10, pp 37 and 38.

How to eliminate fatigue cracking of welds and structural members on table or forms, how to keep noise levels lower, definition of frequency levels, methods of vibrating wood forms with liners or coatings, vibration of steel forms, concrete mold vibrations, and benefits of external vibrations are discussed.

Hatch, R. K. 1971. "Tilt-up Concrete Panels: A New Look," Concrete Construction, Vol 16, No. 10, pp 421-444.

It is shown how new architectural design techniques have given tilt-up concrete panels a new look. The new techniques include sculptured panels, dimpled surfaces, wide borders that make panels appear smaller, and panel connections with inconspicuous joints or narrow, painted recesses instead of bulky columns. Other improvements provide a variety of surface treatments. Also discussed are the design of tilt-up structures, construction procedures for tilt-up buildings, exposed finishes for tilt-up panels, tilt-up stone walls, and chemical curing and bondbreaking compounds for the tilt-up.

Hester, W. T. 1980. "HRWR Admixtures in Architectural Prestressed and Precast Concrete Applications," Journal of the Prestressed Concrete Institute, Vol 25, No. 1, pp 96-111.

Potential benefits and limitations associated with the use of high-range water-reducing admixtures in the production of architectural quality concretes are presented. Alternative factors which contribute to uniform texture and coloration of formed and exposed concrete finishes are discussed. Suggested guidelines for using these admixtures in architectural concretes are presented. Nine references are presented.

Hoyer, H. R. and Pearson, C. 1971. "Fiberglass Forming of Concrete," Construction Specifier, Vol 24, No. 4, pp 19-28.

Various aspects of developments in concrete technology and, particularly, in the area of new forming systems and placing methods are explored. It is shown how the new technology offered with fiberglass molds permits structural concrete to be used as a design element. Discussion is included of architectural aesthetics that are possible and cost savings with the novel developments in concrete technology by using fiberglass molds.

Hurd, M. K. 1979. "Shape of Things to Come--A Guide to Specifying Formwork for Concrete," Construction Specifier, Vol 32, No. 10, pp 40-49.

Stripping, restoring, strength tests, shells, and architectural concrete in formwork specification and use are discussed. The term formwork is used in this article to indicate the total system of support for freshly placed concrete, including the mold or sheathing which contacts the concrete, as well as all supporting members, hardware, and necessary bracing. Following this terminology, falsework, centering, ties and other hardware, props, shores, braces, and sills all are part of the "formwork." Nine references are presented.

Jones, J. and Lutz, T. P. 1977. "Glass Fiber Reinforced Concrete Products--Properties and Applications," Journal of the Prestressed Concrete Institute, Vol 22, No. 3, pp 80-103.

The paper presents a state-of-the-art report on the production techniques, properties, applications (with design and erection suggestions), and economics of alkali-resistant, glass-fiber-reinforced concrete products manufactured by the spray-up process. The advantages, limitations, and cost of the material, especially in regard to producing architectural precast panels, are fully discussed. Twelve references are presented.

Kim, J. B. 1980. "Certain Connection Problems with Architectural Precast Concrete Exterior Panels," International Journal of Building Science Applications, Vol 4, No. 2, pp 159-167.

It is well known that properly located, designed, fabricated, and installed connections are most important for structural safety of architectural precast concrete panel walls. This paper discusses certain connection problems encountered in the field and discusses a philosophy of responsibilities among the prime consultants-architects and/or structural engineer, the contractor, and the precast concrete manufacturer. Twelve references are presented.

Lokken, E. C. 1976. "Concrete Walls for Highway Noise Reduction," Journal of the Transportation Engineering Division, ASCE, Vol 102, No. 4, pp 637-649.

Sound walls are being increasingly used to reduce the impact of traffic noise on residential and business installations adjacent to major urban traffic routes. Noise wall projects using cast-in-place concrete, precast concrete panels, concrete masonry units, and plaster or air-placed concrete are described. Precast concrete projects include both conventional and cellular concrete, and panels with their longest dimension placed both horizontally and vertically in the wall. Masonry walls include mortared-in-place block of several types and a pilot project using prefabricated block panels in a wall more than 13 ft high. Some unusual wall designs from California are illustrated, including a combination noise wall-safety barrier-planter design and a wall using red stucco and roof tile in Spanish motif to enhance the view of the wall from the property-owners' side. A variety of experimental installations using air-placed concrete and plaster are also included. Nine references are presented.

McMillan, C. M. 1975. "African Eagle Life Centre--A High-Rise Precast Load-Bearing Facade," Proceedings, Pan-Pacific Building Conference, Honolulu, HI, 26-29 Jan 1975, pp 258-266.

The paper describes the interesting features of the facade of a 30-story building in Johannesburg, South Africa. To satisfy the various architectural and functional requirements, a precast concrete facade was chosen. The precast units are shaped in plan, and on the exterior surface the natural granite aggregate is exposed by washing. The units carry the full load of the building and consequently the analysis of the stresses and development of the joint details posed an interesting design problem.

National Technical Information Service. 1982. "Architectural Construction Materials: Concretes and Cements, 1980-October, 1982 (Citations from th NTIS Data Base)," Springfield, VA, 203 pp.

Concrete/cement construction materials for architectural applications are investigated in these research reports. Structural design and performance are reviewed. Studies for bridges, pavements, arifields, and cold weather construction are excluded. (This updated bibliography contains 195 citations, 114 of which were not in the previous edition.)

Naus, D. J., Freeman, R., Muir, W., and Williamson, G. R. 1975. "An Inspection of Techniques for Achieving Exposed Aggregate Surfaces for Site-Cast Concrete," CERL TR M-61, US Army Corps of Engineers, Construction Engineering Research Laboratory, Champaign, IL.

This report presents and identifies techniques for acceptable exposed aggregate finishes for site-cast concrete. It discusses mixture proportions, chemical and mechanical finishing, cost advantages, and repair techniques.

"Seaside Beauty's Hidden Strength," New Civil Engineer, 22 Sep 1983.

This article is a generalized presentation on a unique use of architecturally finished structural concrete for renovation of an existing seawall.

Portland Cement Association. 1956. "Color and Texture in Architectural Concrete by Aggregate Transfer," Publication No. A019A, Skokie, IL, 16 pp.

Portland Cement Association. 1952. "Forms for Architectural Concrete," Publication No. PA033.03A, Skokie, IL, 64 pp.

Portland Cement Association. "Architectural Concrete," Special Concrete, Mortars, and Products, Section II, Chapter 5, John Wiley, New York.

This chapter gives a fairly general discussion on exposed aggregate, precast concrete curtain walls, and form liners.

"Recommended Practice for Glass Fiber Reinforced Concrete Panels," Journal of the Prestressed Concrete Institute, Vol 26, No. 1, Jan-Feb 1981, pp 25-93.

This committee report provides information on the planning, preparation of specifications, design, execution, and supervision of the manufacture and installation of glass-fiber-reinforced concrete panels. Primary emphasis is on thin-wall architectural panels made of glass-fiber-reinforced concrete by the spray-up process under controlled factory conditions. Thirty references are presented.

Shilstone, J. M. 1973. "How to Obtain Predictable Architectural Concrete," Concrete Construction, Vol 18, No. 8, pp 363-413.

The table provided reflects the degree of influence which various details in the construction process have on architectural concrete finishes. A rating of 4 indicates that the degree of influence is low. Ratings 2 and 3 are relatively intermediate levels of influence. This table is intended as a general guide.

Shilstone, J. M. 1973. "Achieving High-Quality Architectural Concrete by Understanding Details of the Construction Process," Architectural Record, Vol 153, No. 5, pp 161-164.

Guidelines are presented for selection of architectural concrete and methods of construction. Tabulated data are presented listing the factors that affect quality and giving numerical ratings as they pertain to different types of architectural concrete surfaces.

Tanner, J. 1977. "Architectural Panel Design and Production Using Post-Tensioning," Journal of the Prestressed Concrete Institute, Vol 22, No. 3, pp 48-63.

This paper presents an economical design method, including practical manufacturing techniques, for producing architectural precast concrete panels for both crack and deflection control using low-friction unbonded tendons. Design examples illustrate the proposed method, and a cost comparison of post-tensioned versus mild steel reinforced panel production is given.

US Army Corps of Engineers. 1983. "Cast-in-Place Architectural Concrete," Guide Specification CEGS-03330, Washington, DC.

__________. 1983. "Precast Architectural Concrete," Guide Specification CEGS-03450, Washington, DC.

Waddell, J. J. "Special Concreting Techniques," Concrete Inspection Manual, Chapter 22, International Conference of Building Officials.

Subjects discussed are sample panels, color, paint, exposed aggregate, texture, surfaces, and finishes.

## Portland-Cement Plaster

ACI Committee 524. 1963. "Guide to Portland Cement Plastering," ACI Journal Proceedings, Vol 60, No. 7, pp 817-834.

Elmarsson, B. 1980. "Plastering on Top of Additional Insulation," Document of the Swedish Council on Building Research, No. 23, 96 pp.

Technical problems involved in the application of plaster to additional thermal insulation are summarized and described. The problems discussed are related to the behavior of the brittle layer of plaster in combination with the relatively flexible base provided by insulation. Seven references are presented.

Munger, C. G. 1977. "Repairing Protective Coatings--Procedures for Nonmetallic Substrates," Plant Engineer, Vol 31, No. 2, pp 127 and 128.

Substantial cost savings are possible when protective coatings are repaired and maintained rather than allowed to deteriorate to a point where a complete new coating system is required. However, unless the job is done right, th repair may deteriorate in a relatively short time and have to be redone. This article, the third of four on protective coating repair, discusses procedures to be used in effectively repairing coatings applied to nonmetallic surfaces. The materials discussed include wood, concrete, plaster, and stucco.

Portland Cement Association. 1980. Portland Cement Plaster (Stucco) Manual, Skokie, IL.

This manual is a guide to acceptable practices for designing, mixing, and placing portland-cement plaster.

Taylor, P. R. 1973. "Correlation Between Ceramic-Shell-Mould Stucco Programme and Penetration Defects," British Foundryman, Vol 66, Pt 11, pp 327-336.

Results showed distinct evidence of the relationship between degree of penetration defects and primary stucco grading distribution. General experience suggested that the grading distribution of the stucco applied to the second slurry coating could also exert a significant effect, at least where a relatively coarse stucco followed a relatively fine stucco. Using zircon sand on the first two coatings produced better penetration resistance than zircon sand applied to the first coat only and followed by a coarser stucco on the second coat.

US Army Corps of Engineers. 1978. "Stucco." Guide Specification CEGS-09101, Washington, DC.

__________. 1983. "Veneer Plaster," Guide Specification CEGS-09215, Washington, DC.

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