

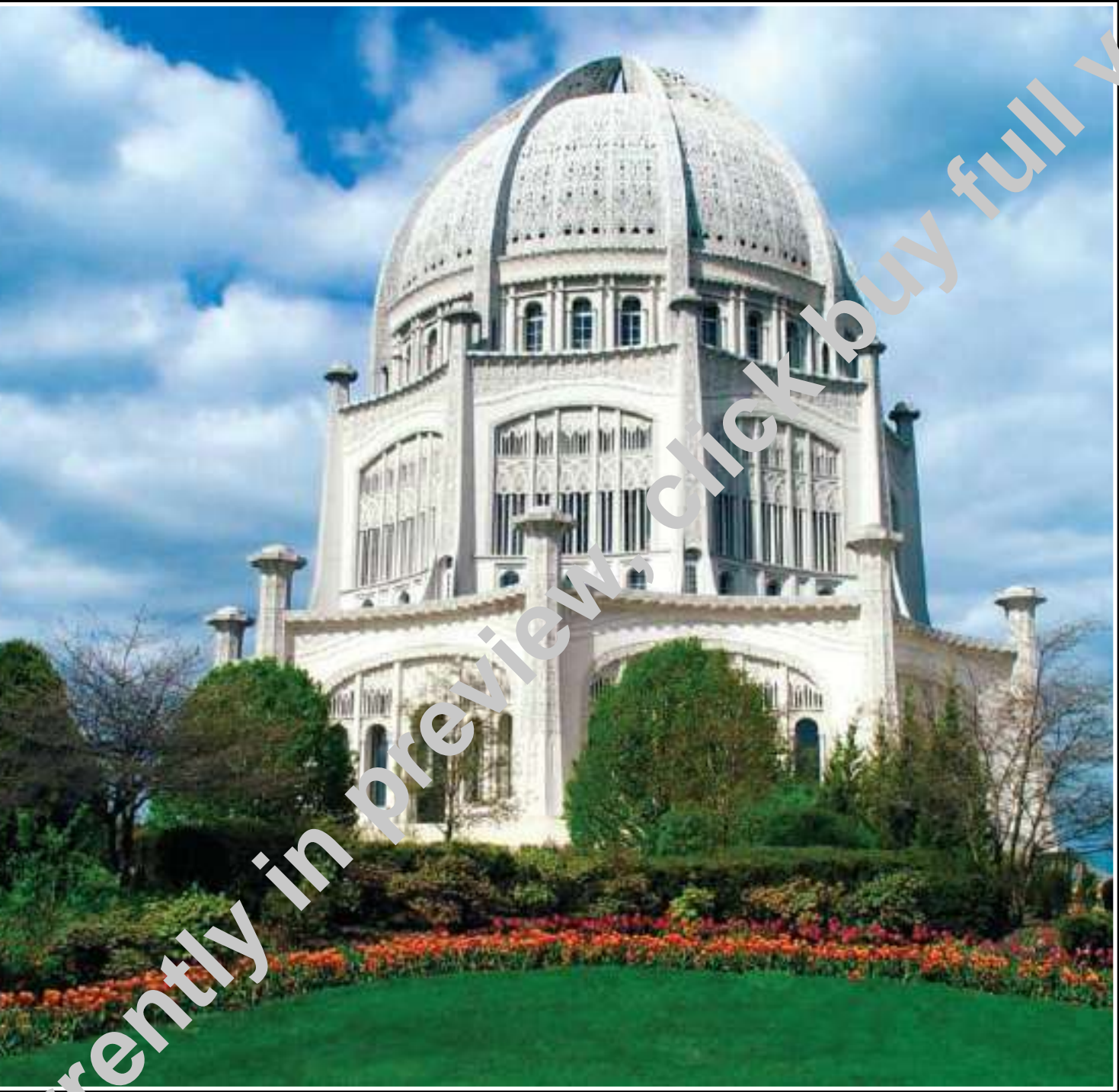
ARCHITECTURAL
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*Baha'i House of Worship
Wilmette, Illinois;
Architect: Louis Bourgeois.*

ARCHITECTURAL PRECAST CONCRETE

THIRD EDITION

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While every effort has been made to prepare this publication as best practice standard for the industry, it is possible that there may be some conflicts between the material herein and local practices.

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The Design Manual for the Architect represents years of intensive work and study within and outside the Precast/Prestressed Concrete Institute (PCI). The following Committee has accomplished the task of reflecting and refining these many viewpoints:

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Architectural precast concrete is a child of the 20th century and modern technology, but it can trace its lineage back to ancient history. As such, it is a building material almost without precedent. Concrete in its cruder forms was used by the Romans in the construction of their aqueducts. Europe refined the time-tested formula in the 19th century, developing reinforced concrete that combined the compressive properties of concrete and the tensile strength of steel. Continuing technological growth and industrialization created a genuine need for new techniques and materials that could be used in prefabricated construction. Architectural precast concrete was developed to fulfill this need.

The first documented modern use of precast concrete was in the cathedral Notre Dame du Raincy in Raincy, France, by Auguste Perret in 1922. It was used as screen walls and infill in an otherwise in-situ concrete solution. In 1932 work began on producing the white concrete exposed aggregate ornamental elements for the Baha'i House of Worship (frontispiece and Fig. 1.2.1). The Depression years followed soon after, and then World War II. Following the end of the world conflict, when labor and material costs began to increase, the use of architectural precast concrete began to flourish. The development and introduction of improved transportation equipment and large tower cranes on major projects provided a ready means of hauling and lifting large precast concrete panels into place. By the mid-1960s, architectural precast concrete as cladding and loadbearing elements had gained widespread acceptance by architects and owners.

Improvements in fabricating processes allow architectural precast concrete to be produced in almost any color, form, or texture, making it an eminently practical and aesthetically pleasing building material. The term architectural precast concrete encompasses all precast concrete units employed as elements of architectural design whether defined to stand alone as an architectural statement or to complement other building materials. Concrete's moldability offers the freedom to sculpt the structure's facade in imaginative ways. It is difficult to imagine an architectural style that cannot be expressed with this material. Precast concrete is not only compatible with all structural systems, it can be designed to harmonize with, and complement, all other materials.

Throughout the formative years, the architect, the engineer, and the builder, as well as the precaster, lacked any definitive reference volume that defined and illustrated this interesting material. This lacking was both world- and language-wide.

The Precast/Prestressed Concrete Institute (PCI), a non-profit corporation founded in 1954 to advance the design, manufacture, and use of precast and prestressed concrete,

had long recognized the need for a manual to provide guidelines and recommendations pertinent to the design, detailing, and specification of architectural precast concrete. In 1973, PCI published the first edition of *Architectural Precast Concrete* and for the first time there was a comprehensive design manual on the subject of architectural precast concrete. Compiled, edited, and published by PCI, this manual presented a single authoritative reference for the architectural decision-maker.

New developments in materials, manufacturing, and erection procedures have expanded the role of architectural precast concrete in the construction industry since the first manual was written. In keeping with its policy of being a leader in the concrete industry, PCI is publishing this third edition of *Architectural Precast Concrete* in order to make state-of-the-art technology available to the architects and engineers who design and build with this versatile material.

The third edition of the manual is a major revision incorporating much of this new technology. The sections dealing with color, texture, and finishes; weathering; tolerances; connections; and thermal properties have been extensively revised. Information on sustainability and design for blast has been added. Detailed guide specifications have been modified to meet today's construction needs. In addition, the photographs used to illustrate pertinent points throughout the manual have been selected to represent the potential design opportunities for architectural precast concrete.

Numerous manufacturing and erection techniques are included in the text to provide a better understanding of design concepts and elements requiring design decisions. Design, contract drawings, and specifications are all vitally important, and should be combined with an assessment of the capability and experience of the precasters who bid on the project.

The guidelines and recommendations presented show current practices in the industry. These practices should not, however, act in any way as barriers to either architectural creativity or to potential innovations on the part of the precaster.

The practices described in this manual may be used as a basis by both architect and precaster in the development of exciting new concepts using advances in technology. This initiative will undoubtedly lead to deviations from some of the stated recommendations in the text.

The editor of the manual worked closely with the PCI Architectural Precast Concrete Committee and with the professional members of the Institute. Technical accuracy has been reviewed by architects, engineers, precast concrete producers, material and equipment suppliers, and af-

filiated industry organizations. This unique combination of various disciplines and viewpoints provides an interaction that ensures knowledge of all aspects in design, engineering, production, and erection of architectural precast concrete. Since conditions affecting the use of this material are beyond the control of the Institute, the suggestions and recommendations presented are provided without guarantee or responsibility on the part of PCI. It is assumed that each project and architect is unique, and requires different solutions for different problems. For this reason, all examples shown must be considered as suggestions rather than definitive solutions.

Architectural precast concrete combines maximum freedom of architectural expression with the economy of mass production of repetitive precast concrete elements. For this concept to function most effectively, it is strongly recommended that the architect seek counsel from local PCI and Canadian Prestressed Concrete Institute (CPCI) architectural precast concrete producers in the early design stages and throughout further development of the contract documents (see PCI website www.pci.org for local producers and resources). Many consulting engineering firms specializing in the development and design of precast concrete are also available to the project architect.

With precaster/consultant assistance, proper aesthetic, functional, structural, mechanical features and objectives may be rendered with economical detailing. Their assistance may more accurately reflect local material characteristics, manufacturing and erection efficiencies, cost factors, quality control standards, and local trade practices. A continuing dialogue between designer and precaster will ensure optimum product quality at a minimum installed construction cost.

This manual is arranged in a sequence that corresponds to the steps that an architectural/engineering firm might employ when evaluating, selecting, and incorporating materials into a construction project. Other publications of interest to the design team include *PCI Design Handbook – Precast and Prestressed Concrete* (MNL-120); *PCI Manual for Quality Control for Plants and Production of Architectural Precast Concrete Products* (MNL-117); *PCI Erector's Manual – Standards and Guidelines for the Erection of Precast Concrete Products* (MNL-127); and *PCI Erection Safety for Precast and Prestressed Concrete* (MNL-132).

Chapter 1 provides a general background concerning the **State-of-the-Art** of architectural precast concrete and covers the applications and benefits of architectural precast concrete along with definitions.

Chapter 2 considers **Design Concepts Related to Usage and Economics** for the initial evaluation and selection of architectural precast concrete for a project. The

architect would primarily use this information during conceptual wall analysis. Repetition and the master mold concept portions of Chapter 2 would be of most interest to the architect's staff concerned with production and detailing.

Chapter 3 contains **Surface Aesthetics** design considerations and is concerned with the critical decisions the designer must make among the many available options as to color, shape, and texture. This chapter covers everything from initial samples and concrete mixture design to acceptability of appearance and weathering. Weathering should be reviewed during conceptual wall analysis.

Chapter 4 presents **Design**. This chapter covers design responsibilities, impact of structural framing considerations, contract documents, reinforcement, connections, tolerances, and joints. The job captain, draftsman, and detailer members of the architect's staff must carefully consider these factors. They should also be familiar with the design considerations included in Chapters 2 and 3 if a sound, economical finished product is to result.

Chapter 5 reviews **Other Architectural Design Considerations** and covers interfacing with other materials including windows, energy conservation and condensation control, sustainability, acoustical properties, blast considerations, fire resistance, and roofing. Each requires careful consideration in developing the design criteria and working details for the architectural precast concrete systems and assemblies adjacent to the precast concrete.

Chapter 6 Guide Specifications is intended as an aid to specification writers. The information contained in this chapter should be evaluated in close coordination with the project designer and detailer to avoid creating unnecessary pitfalls in the project by providing the best possible contract documents. Specifications should be neither open to interpretation nor unnecessarily restrictive.

An **Index** is provided at the end of the manual for easy reference.

A design manual by its very concept can only illustrate what has been accomplished, not what can be. Any attempt to categorize and define architectural precast concrete with its myriad expressions and possibilities is not fully possible. Precast concrete is a versatile material that offers the designer the opportunity to be innovative and obtain desired design objectives that cannot be accomplished with other materials. This manual will help architects define their own potential and will provide a basis for reaching it, not by giving design alternatives, but by pointing out state-of-the-art options in using architectural precast concrete. The significance of precast concrete as a building material lies not in its ability to do new things, but in its inherent quality of being flexible enough to make a design concept become a reality.



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Photography.*

1.1 MANUAL CONTENT AND CONCEPTS

In order for the reader to derive maximum benefit from this manual, the concepts that guided its preparation are briefly outlined in this section.

Concrete is material that has been used for centuries but its present qualities and usages characterize it as modern and versatile. The color and texture possibilities along with the infinite variety of forms and shapes possible with architectural precast concrete, as a result of its plasticity, allows the designer to customize elements and overcome the monotony of many proprietary systems, the confining regularity of masonry units, and the design limitations of materials subject to the shortcomings of dies, brakes, and rollers. With precast concrete, the designer is in complete control of the ultimate form of the façade and is free of any compromise that might be traceable to a manufacturing process. Also, precast concrete has excellent inherent thermal, acoustical, fire resistive and blast resistant characteristics.

Research and quality control of concrete components has led to a better understanding of the unique potentials for precast concrete. Improvements in proportioning, mixing, placing, finishing, and curing techniques have advanced concrete qualities. These improvements have allowed design strength to be substantially increased in the last few decades. Durability, appearance, and other important aspects, such as transportation and erection, have kept pace with these developments.

By continuing to provide the designer with design freedom, the precast concrete industry has experienced steady growth since the 1960s, particularly in the ever-widening range of precast concrete applications. The widespread availability of architectural precast concrete, the nearly universal geographic distribution of the necessary raw materials, and the high construction efficiency of prefabricated components all add to the appeal of architectural precast concrete construction. Precast concrete design engineers and precasters have a high level of craftsmanship and ingenuity along with a thorough knowledge of the material and its potential in converting the designer's vision into a finished structure. Related to this knowledge must be an understanding by the designer of the important design

considerations dictated by:

1. Material characteristics;
2. Wall analysis — interrelationship with other materials;
3. Weathering effects;
4. Colors, finishes, and textures; and
5. Manufacturing and erection efficiencies including cost factors, quality-control standards, and local trade practices.

These design considerations are described in considerable detail throughout this manual. It is important that the designer carefully evaluate the applicable design considerations when choosing the shape, color, and texture that will be emphasized on a project. Design considerations based upon manufacturing and erection factors are complex and varied. Because of the limitless expressions of precast concrete, such design considerations can rarely be stated in unqualified terms. It is important for the designer to know which considerations are valid and to assess their influence on a specific application. The design considerations for architectural precast concrete are not any more numerous or difficult than the ones associated with other materials. Optimum utilization of precast concrete will result from a thorough understanding of the applicable design considerations. Consider, for example, the interplay between the configuration of a precast concrete unit and its structural capacity, and between its shape and available finishes. Add to this the available options in reinforcement, including the possibility of prestressing the unit to offset tensile stresses caused by handling or service conditions, and the importance of understanding these design considerations becomes clear.

The architect, with or without prior experience with precast concrete, will benefit from a detailed study of the entire manual in order to obtain an understanding of interrelated design considerations. Subsequent to such a study, the manual will be a valuable reference for the future design of architectural precast concrete.

Structural precast concrete products comprise an important segment of the precast concrete market. These units are normally produced in standard shapes such as double or single tees, and channel, solid, or hollow slabs with many different finishes that are often