ACI 533R-11

Guide for Precast Concrete Wall Panels

Reported by ACI Committee 533

American Concrete Institute®

First Printing
March 2012

American Concrete Institute®
Advancing concrete knowledge

Guide for Precast Concrete Wall Panels

The technical committees responsible for ACI committee reports and standards strive to avoid ambiguities, omissions, and errors in these documents. In spite of these efforts, the users of ACI documents occasionally find information or requirements that may be subject to more than one interpretation or may be incomplete or incorrect. Users who have suggestions for the improvement of ACI documents are requested to contact ACI via the errata website at www.concrete.org/committees/errata.asp. Proper use of this document includes periodically checking for errata for the most up-to-date revisions.

ACI committee documents are intended for the use of individuals who are competent to evaluate the significance and limitations of its content and recommendations and who will accept responsibility for the application of the material it contains. Individuals who use this publication in any way assume all risk and accept total responsibility for the application and use of this information.

All information in this publication is provided "as is" without warranty of any kind, either express or implied, including but not limited to, the implied warranties of merchantability, fitness for a particular purpose or non-infringement.

ACI and its members disclaim liability for damages of any kind, including any special, indirect, incidental, or consequential damages, including without limitation, lost revenues or lost profits, which may result from the use of this publication.

It is the responsibility of the user of this document to establish health and safety practices appropriate to the specific circumstances involved with its use. ACI does not make any representations with regard to health and safety issues and the use of this document. The user must determine the applicability of all regulatory limitations before applying the document and must comply with all applicable laws and regulations, including but not limited to, United States Occupational Safety and Health Administration (OSHA) health and safety standards.

Participation by governmental representatives in the work of the American Concrete Institute and in the development of Institute standards does not constitute governmental endorsement of ACI or the standards that it develops.

Order information: ACI documents are available in print, by download, on CD-ROM, through electronic subscription, or reprint and may be obtained by contacting ACI.

Most ACI standards and committee reports are gathered together in the annually revised ACI Manual of Concrete Practice (MCP).

American Concrete Institute
38800 Country Club Drive
Farmington Hills, MI 48331
U.S.A.
Phone: 248-848-3700
Fax: 248-848-3701

www.concrete.org

ISBN 978-0-87031-756-9

ACI 533R-11

Guide for Precast Concrete Wall Panels

Reported by ACI Committee 533

Brian D. Miller, Chair

David Wan, Secretary

George F. Baty
Harry A. Chambers
Aaron W. Fink
Sidney Freedman
Harry A. Gleich
Allan R. Kenney
Benjamin Lavon
Donald F. Meinheit
Larbi M. Sennour
Venkatesh Seshappa
Ava Shypula

Thomas J. Grisinger, Consulting Member
Weilan Song, Consulting Member

This guide presents recommendations for precast concrete wall panels. It should be used with ACI 318-08, "Building Code Requirements for Structural Reinforced Concrete," which is legally binding when adopted by the local authority. This guide discusses the basic principles of design, tolerances, materials, fabrication, installation, quality requirements, and testing.

Keywords: admixtures; aggregates; architectural concrete; coatings; cracking (fracturing); curing; deflection; design; drying shrinkage; fabrication; formwork; inspection; installation joints (junction); precast concrete panels; repairs; sandwich panels; sealants; structural design; surface defects; tolerances; volume change.

CONTENTS

ACI 533R-11 supersedes ACI 533R-93 and was adopted and published March 2012.

CHAPTER 1—GENERAL CONSIDERATIONS

1.1—Introduction

The widespread popularity of concrete as a building material can be attributed to the availability, favorable properties, and geographic distribution of its naturally-occurring mineral constituents. Concrete is easily formed and molded, comparatively economical, and durable in its finished state. Architectural precast panel use has increased because of the nature of concrete as a material and the fact that prefabricated components add to construction efficiency. By exposing decorative aggregates, using veneer facing materials, and by varying sizes, shapes, and textures of panels, the engineer/architect can respond creatively to client needs.

1.2—Scope

This document provides guidelines for specifying, planning, designing, fabrication, and erecting precast concrete wall panels. Although the focus is on precast wall panels produced in established precasting plants, site precasting is an option that has been used successfully. Tilt-up concrete, as discussed in ACI 551.1R-05, is a variation of site precasting. ACI 533R should aid in establishing and maintaining quality site fabrication as well as plant fabrication of precast wall panels.

This guide covers non-load-bearing or load-bearing panels, fabricated of normal or lightweight concrete. Panels may be one of the following types:

- Solid
- Insulated (sandwich)
- Ribbed
- Hollow-core
- Sculptured

In addition to reinforced panels, lightly prestressed (effective prestress, after all losses, between 150 and 225 psi [1.0 and 1.7 MPa]) and prestressed panels are covered. Structural design considerations addressed in Chapter 3 include the use of panels as shear wall components.

Emphasis is placed on wall panels with an integral exposed aggregate concrete surface finish. Smooth wall panels and panels with a textured or shaped architectural surface finish are included. Panels having natural stone veneer or ceramic veneer finishes are not covered in detail.

1.3—Responsibility

1.3.1 *General*—Contractual agreements should assign responsibilities to avoid disagreements on basic definitions and decisions originating from the specifying agency. A special report of an ad hoc committee for the responsibility for design of precast concrete structures was published by the Precast/Prestressed Concrete Institute (PCI 1988) and recommends assignment of authority and responsibility for design and construction of precast concrete structures.

This guide covers the design of panels by an engineer/architect. ACI Committee 533 presents supplemental design guidelines that are special to precast concrete wall panels and should be used with ACI 318-08. ACI 318-08 provides minimum design requirements and is legally binding when adopted by the local authority.

Overlapping responsibilities for the structural design of wall panels may introduce conflicts between the engineer/architect and general contractor regarding contract document review, design for handling, installation stresses, in-place loads, and adequacy of connections. It is essential that work assignments and responsibilities be clearly defined in the contractual arrangements.

1.3.2 *Structural design*—The engineer/architect can benefit from preconstruction contact with panel producers. Handling and installation procedures vary widely, and guidelines for these operations should correspond with local practices but be consistent with Chapter 3 of this guide. Most precasters maintain an engineering staff to prepare contract documents and the engineer/architect should interact with this group to obtain constructive advice and suggestions concerning local practice, fabrication details, and fabrication capabilities. When possible, this discussion should take place during the initial design phases of a construction project. Once a job is released for bidding and the structural concepts have been established, changes may be difficult to implement.

1.3.3 *Reinforcement for handling and installation*—Generally, the engineer/architect relies on the manufacturer for developing handling techniques and providing any additional reinforcement required for withstanding handling or installation stresses. The engineer/architect may wish to review calculations for handling stresses.

Contract documents may require the manufacturer to accept responsibility for design of panels to resist the loads shown and to resist other loads that occur during stripping, handling, shipping, and installation. In this case, it is common for contract documents to require that design calculations and installation drawings provided by the panel manufacturer be signed by a professional engineer who is either retained or employed by the manufacturer. When the load information in the contract documents is insufficient, the manufacturer should ask for additional information from the engineer of record.

1.3.4 *Adequacy of connections*—Contract drawings prepared by the engineer/architect should show the connections required and the load support points in sufficient detail to permit construction. During the preparation of shop drawings, manufacturers should be given the opportunity to redesign the connections if redesign will achieve economical details that facilitate manufacture or installation. If connections are designed by the engineer/architect, the manufacturer should review the connections for structural adequacy and economy. If connections are redesigned or other problems are noted, these should be brought to the attention of the engineer/architect for review. Any deviation from or discrepancy in the approved installation drawings should be communicated to the general contractor by the installation contractor before installation. The general contractor should make all necessary arrangements for corrections to be made by the parties involved before installation.

1.3.5 *Handling and installation responsibilities*—Responsibility for panel installation and cleaning, joint treatment, and supply of hardware for handling, attachment, and bracing should be clearly defined in contract documents. The specifier should not prescribe specific subcontractors in the document specifications. General contractors are generally more knowledgeable of the skills and experience of subcontractors who can perform the services and can more easily evaluate the alternatives.

1.3.5.1 *Cleaning*—Specifications should require clean panels after installation and cleaning need not be the object of a separate operation. The precast manufacturer, carrier, or both, are responsible for delivering clean panels (refer to Section 7.6). After panel installation, protecting panels from soiling and staining during subsequent operations should be the responsibility of the general contractor.

1.3.5.2 *Furnishing attachment and handling hardware*—Clip angles, inserts, bolts, and miscellaneous metal items are required for construction with precast panels. These items may be attached to the building frame, embedded in the precast panel for erector or for other trades, or provided loose at the job site for connection purposes.

Responsibility for supplying items to be attached to or placed in the structure to receive precast concrete units depends on structure type and local practice. Contractual agreements should indicate who is responsible for the supply and installation of hardware. When the supporting frame is structural steel, installation hardware is normally supplied and installed by the precast erector or steel fabricator. When the building frame consists of cast-in-place concrete, hardware is normally supplied by the precast manufacturer and placed by the concrete contractor. Detailed hardware layout is prepared by the precast manufacturer for approval by the engineer/architect. Occasionally certain special inserts or sleeves are required for other trades. In these instances, the trade involved is responsible for having such parts approved and delivered to the panel manufacturer in time for embedment in the wall panels. These should be accompanied by the engineer/architect's approved placement drawings and instructions for installation.

1.3.5.3 *Execution of connections*—The general contractor is responsible for accurately constructing bearing surfaces and anchorages for precast elements. When a panel cannot be erected within tolerances specified in the contract documents, the matter should be called to the engineer/architect's attention for consideration and correction.

Changes, other than adjustments within the prescribed tolerances, can only be made after approval. Any adjustments affecting structural performance should be approved by the engineer of record. No panel should be left in an unsafe support condition.

1.3.6 *Shop drawing approval*—Installation and shape drawings prepared by the precast manufacturer (refer to Section 6.1) should be forwarded to the general contractor for approval regarding constructibility and then forwarded to the engineer/architect who checks for conformance with the design requirements and contract documents. Drawings reviewed by the engineer/architect should be returned to the manufacturer with a statement similar to one of the following:

- Reviewed for conformance with the contract documents. No resubmissions necessary.
- Reviewed, as noted, for conformance with the contract documents. No resubmissions necessary.
- Revise and resubmit.
- Rejected.

1.4—Aesthetic considerations

Fabrication techniques and procedures covered in this guide allow flexibility during fabrication to achieve uniform aesthetic results and concrete quality. Performance specifications for the appearance of precast wall panels explaining aesthetic requirements or establishing understandable criteria for acceptance are difficult to achieve. It is recommended that reference samples be used in determining product characteristics and quality, rather than writing restrictions that are difficult to achieve and may prohibit the manufacturer from using a process that offers the best possibility of producing the desired panel.

1.4.1 *Design reference samples*—Full-size sample panels are preferred, but construction specifications may require that the color and texture match small samples. Such samples

should be at least 12 x 12 in. (305 x 305 mm), although larger samples may be desirable. If both panel faces are to be exposed, samples should show the finished interior surface as well as the exterior face of the precast.

The manufacturer should submit samples to the general contractor for approval by the engineer/architect, while retaining duplicate samples. If the sample is not approved, resubmissions should be made until approval is obtained. Sample approval should be in writing with reference to the correct sample code number, or the approval may be written on the sample itself.

1.4.2 *Range samples*—At least three full-scale (but not necessarily full-size) sample panels should be specified. These sample panels should contain typical cast-in inserts, reinforcing steel, and plates as required for the project. These panels should establish the range of acceptability with respect to color and texture variations, surface defects, and overall appearance. It should be clearly stated in the contract documents how long the full-scale samples should be kept at the point of manufacture (precasting plant) or at the job site for comparison. Approved full-scale panels should be allowed to be used in the completed structure. If full-scale samples are required before, or at the beginning of, fabrication, lead time is necessary and the construction schedule should be adjusted accordingly. When full-scale sample panels are not specified, the first fabrication panels should be submitted for inspection and approval by the engineer/architect.

CHAPTER 2—NOTATION AND DEFINITIONS

2.1—Notation

b = width of cross section
f_c' = concrete compressive strength specified at age considered during design
h_{eff} = effective thickness of member
I_g = moment of inertia of gross concrete section neglecting reinforcement
k = effective length factor
ℓ = length of span
r = radius of gyration of cross section
ℓ_u = unsupported length of panel

2.2—Definitions

ACI provides a comprehensive list of definitions through an online resource, "ACI Concrete Terminology," (http://terminology.concrete.org). Definitions provided herein complement that resource.

bowing—the deviation of the edge or surface of a planer wall member, in the out-of-plane direction, from a line passing through any two corners of the member

camber—a deflection that is intentionally built into a structural element or form to improve appearance or to nullify the deflection of the element under the effects of loads, shrinkage, and creep.

surface out-of-planeness (roughness)—a local smoothness variation rather than a bowing variation. The tolerance for this variation is usually expressed in fractions of an inch (millimeter) or in inches per 10 ft (millimeters per 3 m). Although other criteria are available, the tolerance is typically checked with a 10 ft (3 m) straightedge or equivalent and definition of roughness.

tolerance—a permitted variation from the basic dimension or quantity as in the length, width, or depth of a member.

unequal bowing—may be observable when panels are viewed together on the completed structure. When two panels bow in the same direction, the magnitude of unequal bowing is determined by subtracting one bowing value from another. When panels bow in opposite directions, the convex bowing is taken as positive (+) and concave bowing is taken as negative (–) by a standard sign convention, the unequal bowing is the algebraic difference.

warping—deviation of a planer surface due to displacement of one corner in relation to any two adjacent corners. Warping tolerances are stated in terms of the magnitude of the corner variation. This value is usually given in terms of the allowable variation per 1 ft (300 mm) of distance from the nearest adjacent corner with a not-to-exceed maximum value of comer warping.

CHAPTER 3—WALL PANEL DESIGN

3.1—Introduction

This guide presents design recommendations for prestressed and conventionally reinforced concrete wall panels. Load-bearing and non-load-bearing panels are covered. Precast wall panels can be differentiated on the basis of structural function as well as panel configuration. The classes and types of panels covered in this guide are defined in the following.

3.1.1 *Panel classes*

3.1.1.1 *Non-load-bearing panel (cladding)*—A precast wall panel that transfers negligible load from other elements of the structure. This panel is generally designed as a closure panel and should resist all applicable service and factored loads from wind forces, earthquake-induced forces, thermally-induced forces, forces from time-dependent deformations, self-weight, and those forces resulting from handling, storage, transportation, and installation.

3.1.1.2 *Load-bearing panel*—A precast wall panel designed to carry loads from one structural element to other structural elements. Load-bearing panels should interact with other panels and the supporting structural frame to resist all applicable design loads in addition to those listed for non-load-bearing panels. Load-bearing panels also include panels designed to function as shear walls.

3.1.2 *Panel types*

3.1.2.1 *Solid panel*—A panel of constant thickness; an allowance for surface texture should be made in determining effective thickness.

3.1.2.2 *Hollow-core panel*—Precast panel that has voids within the thickness in one direction for the full length of the panel.

3.1.2.3 *Sandwich panel*—Precast panel consisting of two layers of concrete separated by a nonstructural insulating core.

3.1.2.4 *Ribbed panel*—Precast panel consisting of a slab reinforced by a system of ribs in one or two directions.