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Guide for Emulating Cast-in-Place Detailing for Seismic Design of Precast Concrete Structures

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The committee would like to acknowledge Cloyd E. Warnes' contribution for providing the initial information on emulation, and FDG, Inc., of Arvada, CO, for providing graphics.

This guide provides information for detailing precast concrete structures that should meet building code requirements for all seismic design categories by emulating cast-in-place reinforced concrete design. This guide also explains how emulative precast concrete structures can address the provisions of ACI 318-08, including those of Chapter 21, if special attention is directed to detailing the joints and splices between precast components.

Keywords: ductility; elastic design; emulation; flexural strength; joint; precast concrete; precast detailing; reinforcement.

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ACI 550.1R-09 supersedes ACI 550.1R-01 and was adopted and published February 2009.

CHAPTER 1—INTRODUCTION AND SCOPE

1.1—Introduction

Emulative detailing is defined as the design of connection systems in a precast concrete structure so that its structural performance is equivalent to that of a conventionally designed, cast-in-place, monolithic concrete structure (Ericson and Warnes 1990).

Emulative detailing is distinct from jointed detailing, where precast elements are connected with special jointing details, such as welded or bolted plates, in that the bending stiffness of the connections differs from that of the members. As commonly applied, "emulation" refers to the design of the vertical or horizontal elements of the gravity and lateral-force-resisting system of a building. Emulative detailing of precast concrete structures is applicable to any structural system where monolithic structural concrete would also be appropriate, regardless of seismic design category (Precast/Prestressed Concrete Institute 1999).

Design practice in some countries with a high seismic risk, such as New Zealand and Japan, follows design codes that address precast concrete detailed by emulation of cast-in-place concrete design. Performance of joints and related details of emulative precast concrete structural concepts has been extensively tested in Japan. Because emulative precast concrete structures have been constructed there for over three decades, emulative methods for seismic design are widely accepted.

Typical details showing proportional dimensions, as well as reinforcing steel, are schematic only and are provided solely to demonstrate the interactivity of the jointing essentials. All connection details are subject to structural analysis and compliance with code requirements. Splicing reinforcing bars by welding or lapping is not permitted by ACI 318-08 whenever the bars are subjected to stresses beyond the actual yield points of the reinforcing steel being used. Based on tests of mechanical splices reported by the California Department of Transportation (Noureddine et al. 1996), concern was expressed about staggering of mechanical splices of reinforcing bars. Staggering is not required by current codes.

Only essential reinforcing bars are shown in detail to provide clarity. Other reinforcing steel that would typically be incorporated into a conventional design is not shown. The specification and delineation of reinforcing bars or strand sizes and locations, layers, types, and numbers are the responsibility of the designer.

1.2—Scope

The purpose of this guide is to give the reader a working knowledge of emulation and emulative detailing to meet requirements in current codes. The term "emulation" has become a common concept for designers working with precast concrete systems, but has also been misinterpreted in relation to jointed systems. This guide shows a variety of emulative details and describes how they are used. Design is basically that of monolithic cast-in-place reinforced concrete converted to precast members, so no special design knowledge is required to use emulative details.

CHAPTER 2—NOTATION AND DEFINITIONS

2.1—Notation

A_{cv} = gross area of concrete section bounded by web thickness and depth of section in the direction of shear force considered

f_c' = specified compressive strength of concrete

M_c = factored moment amplified for the effects of member curvature used for design of compression member

M_{nb} = nominal flexural strength of beam, including slab where in tension, framing into joint

M_{nc} = nominal flexural strength of column framing into joint, calculated for factored axial force, consistent with the direction of lateral forces considered, resulting in lowest flexural strength

M_{pr} = probable flexural strength of members, with or without axial load, determined using the properties of the member at the joint faces assuming a tensile stress in the longitudinal bars of at least $1.25f_y$ and a strength reduction factor ϕ of 1.0

Ω = dynamic amplification factor

2.2—Definitions

element—an individual part of the structure such as a column, beam, wall, floor, or roof section that can be precast in other than its final location.

emulation—designing precast elements and their structural connections to perform as if the structure was a conventional cast-in-place concrete structure.

emulative detail—a connection in which the structural performance is equivalent to that of a continuous member or a monolithic connection.

jointed detail—a connection where the bending stiffness differs from that of the members and requires special design to collect, transfer, and redistribute forces from one member to another through the connection.

member—an individual part of the structural system, synonymous with element, such as a column, beam, floor, roof, or wall.

structure—a building or bridge built with individual elements or members.

system—a collection of elements or members that form a structure.

CHAPTER 3—GENERAL DESIGN PROCEDURES

A large body of technical information is available for the design of cast-in-place reinforced concrete structures, and extensive research and development is ongoing for all types of cast-in-place concrete technology. Numerous textbooks have been written about the behavior and design of cast-in-place reinforced concrete. Design procedures and examples for cast-in-place reinforced concrete are available (Cole/Yee/Schubert and Associates 1993). Building codes are regularly revised to reflect new research and technology developments, and the results are incorporated into teaching and working practice (International Code Council 2006; ACI 318-08). This knowledge for designing reinforced cast-in-place concrete structures is readily applicable to the design of emulative precast concrete.