Guest Column

dedicated to the dissemination of information from other organizations

ACI Resources for Concrete Buildings of Moderate Size and Height

By Mike Mota, Ph.D., P.E., F. ASCE

The goal of this article is to highlight several technical resources developed by American Concrete Institute (ACI) Committee 314 "Simplified Design of Concrete Buildings". This committee was formed in 2004 with a specific mission to, "develop and report information on the simplified design and economical construction of concrete buildings of limited height."

The resources discussed in this article include a) Newly released ACI 314.R11 *Guide to a Simplified Design for Reinforced Concrete Buildings*, and b) Case studies for three projects (16-story hotel in Illinois, and two multi-story post-tensioned parking garages located in California and Maryland).

ACI 314.R11

This is intended to provide the more salient features of the newly published ACI document ACI 314.R11 *Guide to a Simplified Design for Reinforced Concrete Buildings* (referenced as the *Guide*) available through the ACI website. In short, this document presents simplified methods and design techniques that facilitate and expedite the design of low-rise reinforced concrete buildings of moderate size and height.

The *Guide* meets the minimum requirements of ACI 318-11; however, it is not a "deem to comply" document. The chapters have been organized to follow the typical design process, with procedures introduced to follow the typical course of a building design.

As presented, the information is derived from the following documents: *Building Code Requirements for Structural Concrete* (ACI 318-11) and *Commentary* (ACI 318R-11); *Minimum Design Loads for Buildings and Other Structures* (ASCE 7-10) by the American Society of Civil Engineers; and *International Building Code* (IBC 2009) by the International Code Council.

Although many of the tables, charts, and values are based on the referenced documents, the information has been modified or reorganized to be more conservative, to match design process flow, or better support the holistic and simplified design approach.

It should be clear to the reader that the manuscript is a guide and not a standard; therefore, it cannot be adopted by the Building Code. The information is presented in such a manner that a structure designed using this document will, in principle, comply with the minimum requirements of the Codes and Standards on which the *Guide to a Simplified Design for Reinforced Concrete Buildings* was based.

The *Guide* is a self-contained document and ***must*** be applied in its entirety. Because the simplified provisions are interdependent, it would be unsafe to employ only a portion of the document and disregard the rest. As the *Guide* is intended to be used as a design aid, it is the licensed design professional's responsibility to ensure the requirements of the applicable Building Code are satisfied.

Background

The *Guide* was preceeded in 2002 by the first International Publication from ACI, known as IPS-1 (International Publication Series-1), *Essential Requirements for Reinforced Concrete Buildings*. IPS-1 was the result of an agreement between ACI and two Colombian Institutions: the Instituto Colombiano de Normas Técnicas y Certificación (Colombian Institute for Technical Standards and Certification) and the Asociación Colombiana de Ingeniería Sísmica (Colombian Association for Earthquake Engineering).

The motivation of ACI 314.R11 and the parent document IPS-1 was a result of frequent discussions with design professionals that reinforced concrete codes might be unnecessarily complicated for most types of applications, such as small

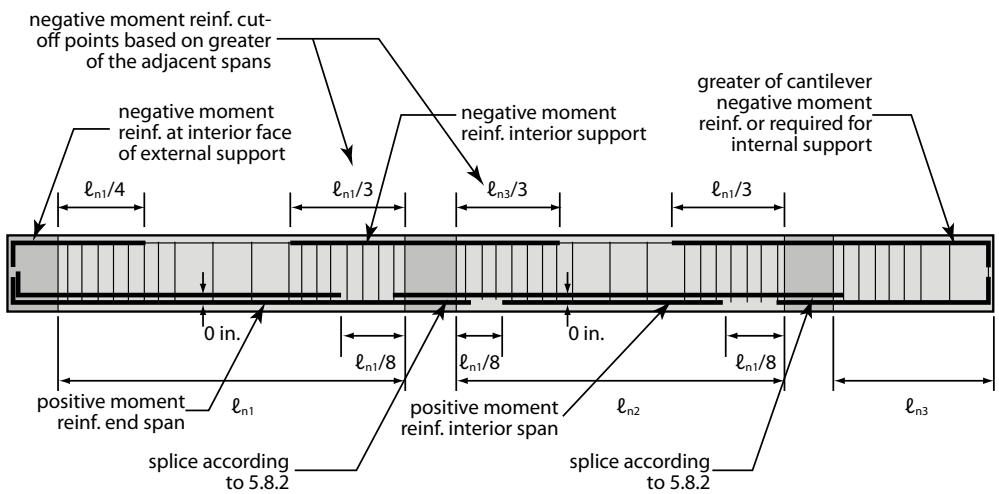

Figure 1: Reinforcement for beams and joists supported by beams or girders.

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low-rise buildings. A survey of the construction industry conducted by the Portland Cement Association in the early 1990s showed that approximately 90% of structures in the U.S. are five stories or less and, as a result, the design can be simplified through a small amount of conservatism without impacting the overall economy of the structure.

The design guidelines in IPS-1 were tested in Latin America where reinforced concrete is the framing system most commonly used. IPS-1 was also successfully tested at Purdue University, where the students found it extremely useful as a design aid in the completion of homework assignments.

To properly use the *Guide*, it is important to understand the limitations associated with scope. Low-rise buildings within this scope are expected to have a normal rectangular footprint, with simple geometries and member dimensions in both the plan and vertical directions.

Other limitations include:

- Maximum number of stories must be five or less above ground and no more than one basement level.
- Maximum area per floor not to exceed 10,000 square feet (1000 square meters).
- Story height, measured from floor finish to floor finish, should not exceed 13 feet (4 m).
- The span length for girders, beams, and slab-column systems, measured from center-to-center of the supports, should not exceed 30 feet (10 m).
- Spans should be approximately equal, and the shorter of two adjacent spans should be at least 80% of the larger span, except in elevator and stair cores.
  - There should be at least two spans in each of the two principal directions of the building in plan. Single spans may be permitted in one- and two-story buildings if the span length does not exceed 15 feet (5 m).
  - For girders, beams, and slabs with overhangs, the length of the overhang should not exceed ⅓ of the length of the first interior span of the member.
  - Buildings with offsets, reentrant corners, and vertical and/or horizontal irregularities are considered outside the scope of this *Guide*.
  - Additional limitations, including use and occupancy, can be found in Chapter 1 of the *Guide*.

Simplicity in the design process, along with practical construction considerations, have been implemented throughout the *Guide*. An example of this is the limitations of bar sizes from #3 to #8 (⅜-inch to 1-inch nominal diameter) for both ASTM A615 and A706 (weldable reinforcement) grades. In addition, issues such as minimum development lengths and lap-splices are simplified to consist of one value equal to $50d_b$. Given the simple types of structures considered in the *Guide*, this simplification also facilitates field installation without significantly impacting overall economy.

One of the main features displayed throughout the document is the ability to convey the guidelines through well-conceived graphics. A sample graphic (*Figure 1*) shows that short descriptions have been inserted to explain the reasoning behind the drawing. Although this may be viewed as redundant to seasoned engineers, this information has been found extremely useful by young engineers and students.

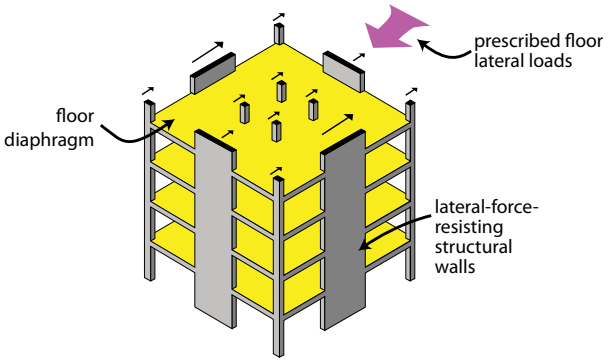

Figure 2: Lateral-force-resisting structural system.

Brief Overview of Lateral-Force Resisting System Guidelines

Within the scope of the *Guide* and in zones of low and no seismic risk, the total lateral story shear at any story should be distributed to the frames through the columns, and reinforced concrete walls are not required to resist lateral forces.

In Moderate or High seismic risk zones, the *Guide* requires that 100% of factored lateral loads are resisted by reinforced concrete walls. These elements are proportioned through simple design guidelines that preclude the need for special analyses, including slenderness and second order effects. Additionally, frames should be proportioned to resist a minimum lateral force equal to 25% of the factored lateral force in each direction in plan, to account for effects such as base rotation of the walls or a decrease in stiffness and strength due to inelastic response (*Figure 2*).

Brief Overview of Floor Systems Guidelines

Several types of common concrete floor systems are covered in the *Guide*. These include both one and two-way systems as follow:

- Flat plate and Flat slab,
- Slab-on-girder system with and without intermediate beams,
- One-way joist systems, and
- Waffle slab system.

Guidelines are also included for structural integrity for both perimeter and non-perimeter beams. Guidelines for minimum member thicknesses are included for deflection sensitive elements associated with the different types of floor systems mentioned above.

Design Case Studies Developed By ACI 314

In order to assist engineers in the design of typical structures, ACI 314 developed three case studies based on actual designs. The case studies include a 16-level hotel in Illinois, a post-tensioned 6-level parking garage in California, and a 5-level post-tensioned parking garage located in Maryland.

The case studies consist of five sections that discuss: project information, structural analysis, member design and detailing, miscellaneous design and detailing, and sample drawings. The information presented in these sections is referenced to the provisions of ACI 318-05, and is organized to include detailed calculations with explanations intended to offer designers insight into the design of the particular structure.

The case studies can be found in the Concrete Knowledge Center of the ACI website (**www.concrete.org**) where many other excellent technical resources on a variety of topics can be found.

As current Chair of ACI Committee 314, I would like to thank the many volunteer members of this committee that have helped create and review the design aids produced to date. I would also like to recognize prior Committee Chairs, Luis Garcia and JoAnn Browning, for their leadership.▪

REFERENCES

1. *Guide to a Simplified Design for Reinforced Concrete Buildings*, ACI 314R11 (For Buildings of Limited Size and Height, based on ACI 318-11 and IPS-1, *Essential Requirements for Reinforced Concrete Buildings*), ACI Committee 314, (ACI) American Concrete Institute, Farmington Hills, MI

2. Novak, L. and Kamara, M., *Simplified Design Reinforced Concrete Buildings of Moderate Size and Height*, Fourth Edition, (PCA) Portland Cement Association, Skokie, IL