Essential Requirements for Reinforced Concrete Buildings

A New Generation of Reinforced Concrete Standards

By Luis E. Garcia

There is a worldwide criticism that current structural design standards and codes might be unnecessarily complex for many applications. A recent publication by the Portland Cement Association indicates that 93% of all floor area constructed in the United States during 2002 corresponds to low-rise buildings (1 to 3 stories). The criticism might be right on the mark if we take into account that many of the building code requirements for reinforced concrete contained in the design standard adopted by the US model codes — ACI 318 Code — are aimed at high-rise buildings that require considerations that are not critical for low-rise buildings.

There is no doubt that modern structural engineering has been affected by improvements and developments that took place in the last decades. The use of computers in analysis, design, and drafting, the introduction and wide-spread use of improvements in traditional structural materials aimed at better performance and higher strengths, along with important developments in building and construction procedures, have brought corresponding changes in design procedures and requirements developed initially for a different situation. Complexity in building code requirements are just a consequence of these changes.

From an international perspective, there are many regions and countries of the world that don't have the resources or personnel to develop a local building code. This situation is solved by adopting world class documents, in many cases without any attempt of adaptation to the local situation. The ACI building code has been the model of choice adopted by many countries where the main structural material is reinforced concrete. The reality is that the full use of the code is limited to the larger cities where most well trained engineers reside. Other less developed regions use a document far too complex for the type of construction used, and where no advanced technology is available and engineering expertise is either not available, nonexistent, or of low quality.

With this in mind, an attempt to bridge the gap was worked as an international agreement between the American Concrete Institute (ACI), and two Colombian Institutions: the Instituto Colombiano de Normas Técnicas y Certificación (Colombian Institute for Technical Standards and Certification – ICONTEC) and the Asociación Colombiana de Ingeniería Sísmica (Colombian Association for Earthquake Engineering – AIS). As a result of this agreement the document IPS-1, *Essential Requirements for Reinforced Concrete Buildings* was developed (*see Figure 1*). The document is published in English and Spanish. There are SI and US Customary units versions for the English document. Current knowledge on reinforced concrete behavior obtained through experimentation and experience, and its status and dissemination as a structural material used worldwide, made the task of developing a simplified design and construction document not only feasible, but challenging.

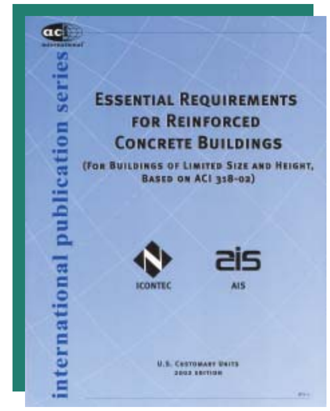

Figure 1: IPS-1 – Essential Requirements for Reinforced Concrete Buildings

Document IPS-1 is based on the 2002 *Building Code Requirements for Structural Concrete* (ACI 318-02) and *Commentary* (ACI 318R-02), the 1998 Minimum Design Loads for Buildings and Other Structures (ASCE 7-98) developed by the American Society of Civil Engineers, and the year 2000 *International Building Code* (IBC 2000), developed by the International Code Council. The quality and testing of materials used in construction are covered by reference to the appropriate ASTM (American Society for Testing and Materials) standard specifications.

The first question would be: what is the legal status of a document of this nature? The document is a vehicle to meet the requirements of the code in an easy, conservative, and simplified manner. Therefore, it doesn't constitute an alternative standard and it does not compete with the adopted code, just helps complying with it. The document presents the material in an order that follows the design procedure with requirements introduced when the designer will need them in the course of the design. This is evident from the Table of Contents of the document (*see Table 1*).

Table 1 - Table of Content of IPS-1

Introduction	
1	General Requirements
2	Definitions and Nomenclature
3	Layout of the Structural System
4	Loads
5	General Reinforced Concrete Requirements
6	Floor System
7	Solid Slabs Supported on Girders, Beams, Joists, or Reinforced Concrete Walls
8	Girders, Beams, and Joists
9	Slab-Column Systems
10	Columns
11	Lateral-Force Resistance
12	Reinforced Concrete Walls
13	Other Structural Members
14	Foundations
15	Drawings and Specifications
16	Construction
17	Referenced Standards and Reports
Appendix	Comparison of Essential Requirements to ACI 318-02, IBC 2000, and ASCE 7-98

The following features were the general guidelines for the development of IPS-1:

- The aim of the document is to provide rules for the design and construction of common, low-rise structures of small to medium floor areas.
- The design rules are based on simplified accepted strength models; other limit states are accounted for by specified dimensional requirements. The minimum dimensional requirements contained in the document are intended to replace the need for more-sophisticated analysis and design procedures.
- Material and construction requirements are aimed at available steel grades and concrete of medium strength that could be site mixed.
- The document is self-contained; therefore, loads and simplified analysis procedures are included, as well as geotechnical exploration requirements to be used in defining a soil bearing capacity and minimum acceptable construction practice guidelines.
- Earthquake-resistant requirements are based on the use of structural concrete walls (shear walls) that limit the lateral deformations of the structure and provide lateral strength.
- The document is written in mandatory language to remind the user that the document has to be followed as a whole. Where explanatory material was required, this material was included using a cursive type font to indicate the non-mandatory character.
- In a departure from traditional code related publications, the document contains abundant figures and graphical explanations.
- The design can be carried out using solely the document and a hand calculator without need for a computer.

To give an idea of the way the reinforced concrete design requirements are presented, *Figure 2* shows the way the development length, lap splice length, and standard hook anchorage distance are presented. When these requirements are compared with the corresponding requirements of ACI 318-02, it is noticeable that the requirements are conservative for all reinforcing bar diameters less and equal to one-inch. This is covered by setting a maximum one-inch diameter on reinforcing bars that may be employed in designs made using the document. This type of approach is used throughout the document.

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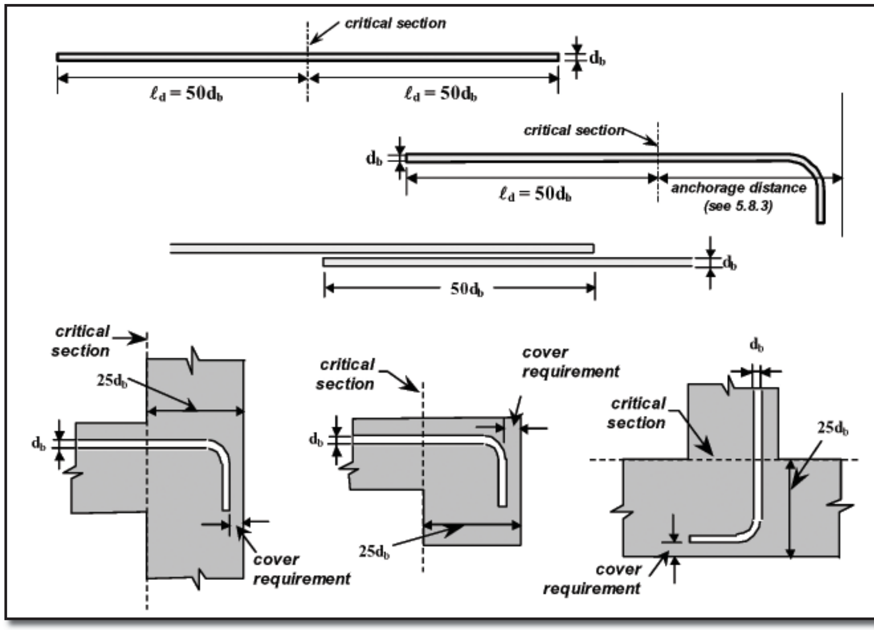

Figure 2: Development length, lap splice length, and standard hook anchorage distance requirements

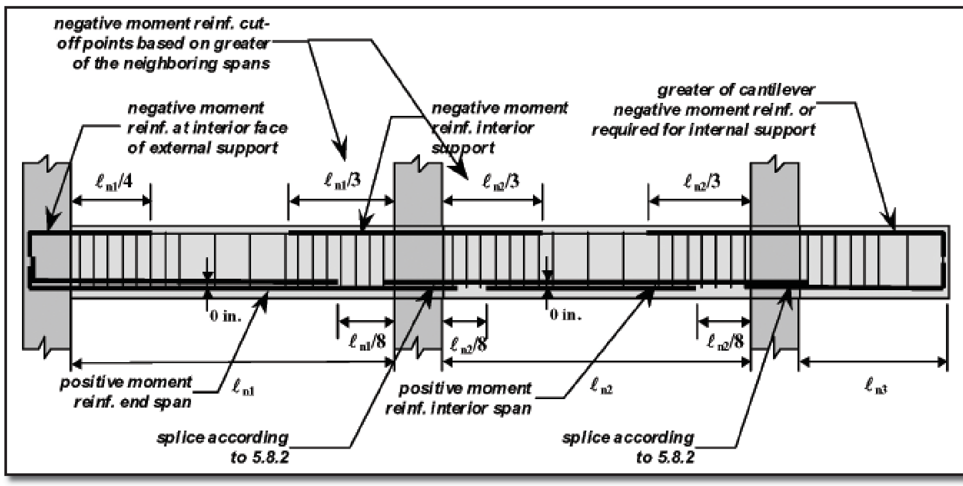

Fig. 3 – Reinforcement in girders that are part of a moment resisting frame supported by columns or reinforced concrete walls

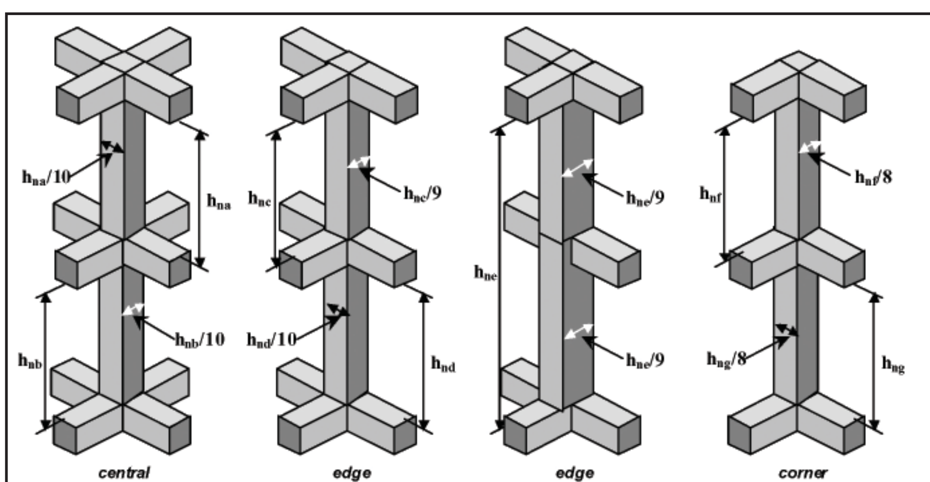

Fig. 4 – Lateral restrain and minimum section dimension for columns

Typical reinforcement details are presented for many elements. *Figure 3* shows the reinforce-ment layout for girders that are part of a frame. *Figure 4* shows the minimum section dimension for columns that replace all the slenderness computations and checks.

Foundation requirements include how to conduct a limited scope geotechnical invest-igation, recommend the type of foundation, and define allowable soil stresses. The doc-ument includes general guidelines for drawings, specifications, and construction, including minimum inspection and quality control re-quirements. A great effort was made to include self-explanatory tables, graphics, and design aids to simplify the use of the document and provide foolproof procedures.

Although the IPS-1 document was developed for employment in situations different from the classroom, the potential of its use in teaching basic reinforced concrete can not be underestimated. Several features of the document make its employment by students useful:

- The document gives a whole perspective of the design process from initial planning of the structure layout to the production of construction drawings.
- The document describes the different alternatives of structural systems, and lists the advantages and disadvantages of each system.
- Although simplified procedures are employed, they are based on the same requirements of the Code. Therefore, the Code is met but with a higher degree of conservatism.
- The document doesn't rely on sophisticated analysis tools, therefore the student can determine the load and forces acted upon the structural elements in a reliable form that leads to appropriate dimensions in a logical process.
- The document asks for final check of the results that precludes results that are not realistic.
- The document integrates related fields, such as foundation engineering and construction supervision, and instructs the student on their importance.▪

In 1980, Luis Enrique Garcia founded Proyectos y Diseños Ltda., a consulting firm engaged in design of structures. He is a member of ACI, ASCE, AIS (Asociación Colombiana de Ingeniería Sísmica), CRSI, EERI, fib, IABSE, and TMS. He was Chairman of the Committee that developed the Colombian Seismic Code, enacted in 1984 after the March 1983 Popayán Earthquake. He has been a member of Committee ACI 318 and numerous other codes & standards committees.

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