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# ARGENTINA DOCUMENT

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# COMMENTARIES TO ACI DESIGN HANDBOOK SP-17(09) CHAPTERS 1 and 3


## ABSTRACT

With this presentation INTI-CIRSOC, which is the official institution in charge of national safety and structural codes in Argentina, intends to make a contribution to improve the examples in Chapter 3 of SP-17(09) related to short column design and a brief comment to Chapter 1 related to design for flexure.

Some mistakes and criteria issues have been detected in the examples presented in this Chapter 3, and we think that they should be overcome by errata or, most likely, new publications.


## INTRODUCTION

The ACI SP-17(09) is important to CIRSOC because:

1. CIRSOC 201-05 is a Structural Concrete Code based on ACI 318-05
2. There are two internationally recognized sources of fully developed examples based on ACI 318:
   - ACI Design Handbook SP-17
   - PCA Notes on ACI 318
3. CIRSOC 201-05 is a "metric" code (SI)
4. CIRSOC encourages the development of very solid and reliable sources of examples based on ACI 318 (better if they are "metric" versions)
5. There is only one internationally recognized source of fully developed examples based on ACI 318:
   - ACI Design Handbook SP-17(09)M

In the foreword of SP-17(09)[1], it is accepted the necessity of development of new design aids for the calculation to flexure due to the introduction, in ACI 318-02, of variable values for the strength reduction factor $\phi$. Actually, these design aids for calculation have been updated and included in Chapter 1.

On the contrary, this has not happened with design aids related to axial force and uniaxial bending, which carried out negative consequences for the development of the examples in Chapter 3.

The necessity of updating these design aids have been pointed out by CIRSOC to the ACI Committee 314 during the Fall 2008 Convention celebrated in the city of St. Louis. At that time, it was suggested the development of diagrams of the tipe shown in Figure 1. Later on, this same criteria was adopted in the last version of the text by Wight and MacGregor[2] where diagrams according to this concept are included. An example is presented in Figure 2 from Reference 2. Unfortunately, as it is observed in Figure 3, the last version of SP-17(09) reproduces the former diagrams in terms of nominal strength with no explicit limitations for the design axial strength, resulting in some mistakes in the calculation of the examples, which could induce users to mistake.

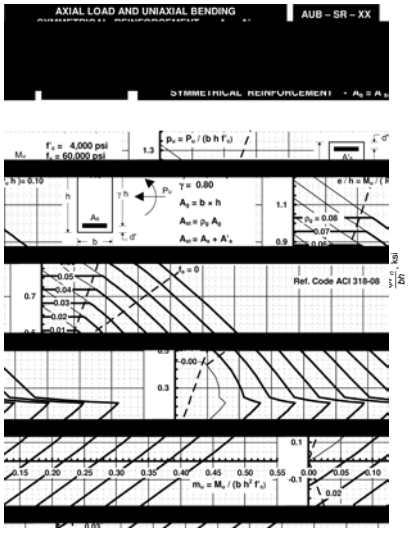



Figure 1

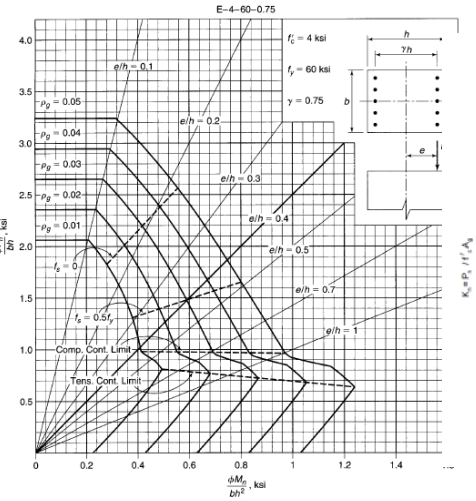



Figure 2

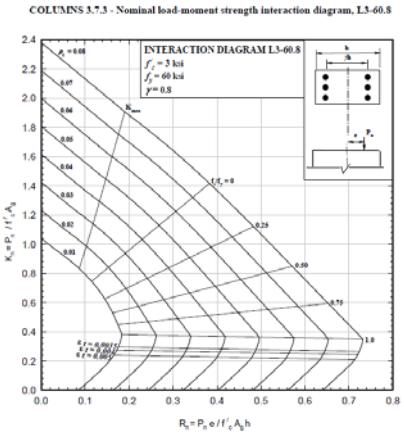
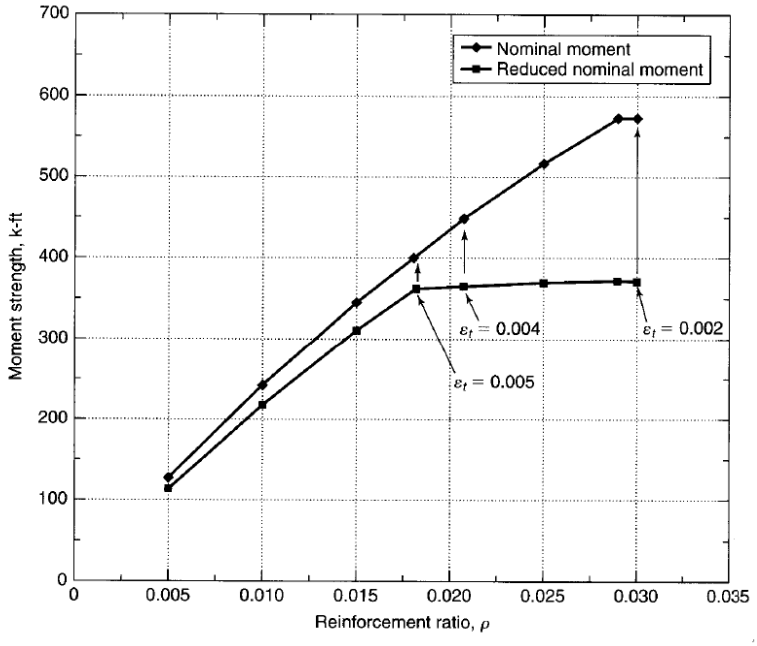



Figure 3

In Chapter 1, for flexure with low levels of compression, the SP-17(09) adopted the 0.004 limit for $\varepsilon_t$ in accordance to ACI Code Section 10.3.5. In our presentation in St. Louis we suggested that this limit should be moved to 0.005. Wight and MacGregor[2] (2009) arrived to the same conclusion (see next figure).




*This figure belongs to Wight and MacGregor[2], clearly shows that for $\varepsilon_t$ smaller than 0.004 it is not economical to add more tension steel to the section.*

This is not a mistake in Chapter 1 but using a limit of 0.005 sections will be a little bit more economical, a little bit more ductile and a little bit less congested.

**EXAMPLE 1**

This example is related to columns with ordinary ties.

It was supposed $\phi$ = 0,70 for the calculation, which means the column is within the transition zone; also, diagrams COLUMNS 3.2.2 and 3.2.3 were used, which are reproduced in Figures 4 and 5.

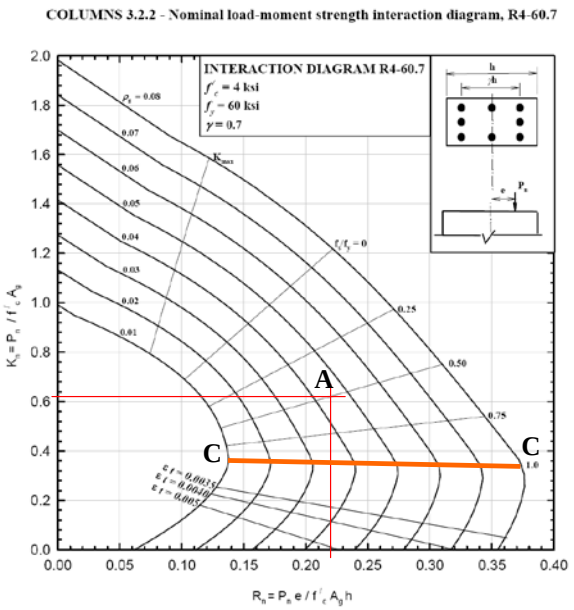



Figure 4

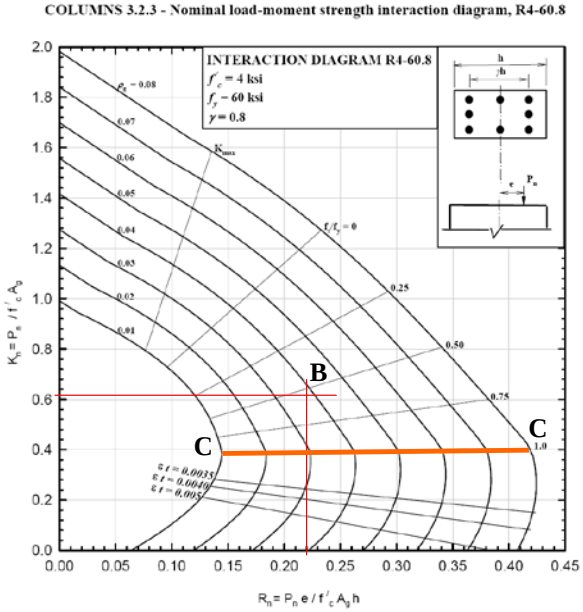



Figure 5

It can be seen that the dots “A” and “B” are situated over the straight line “C-C “ which represents the net tensile strain $\varepsilon_t$ = 0,002, that is to say $\phi$ = 0,65 should have been used, resulting in an unsafe solution. This mistake should not have happened if the related $\phi$ values would have been included in the graphics. Anyway, the problem could have been solved by iteration, in this case, just once. The error is approximately 12% on the unsafe side.

Figure 6 presents the diagram produced by the free program for design and verification, CIRSOC-FLEX, which was presented to the ACI Committee 314 in the ACI Convention 2009, in New Orleans.

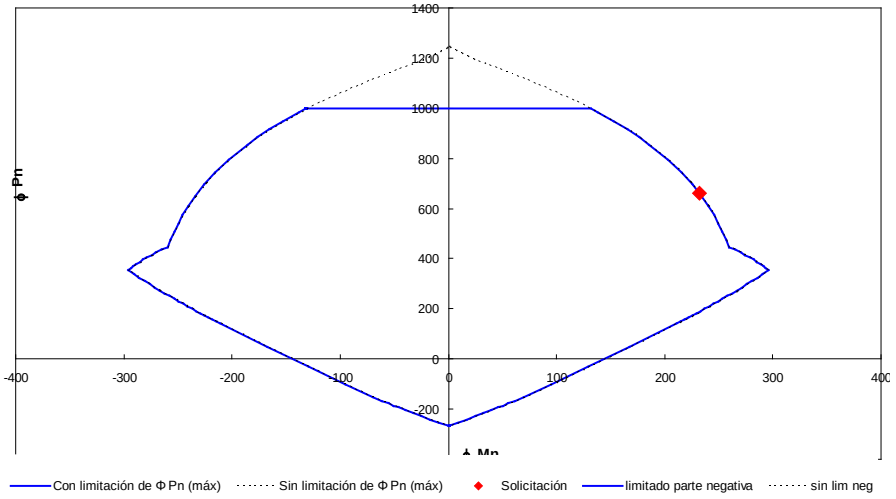



Figure 6

**EXAMPLE 2**

This example is related to columns with ordinary ties. It was assumed $\phi$ = 0,70 for the calculation, which means the column is within the transition zone.

The situation of Example 1 is repeated. $\phi$ = 0,65 should have been used. In this example the error is smaller, but the conceptual mistake exists.

Also, there is a numerical mistake in the exercise. In Figure 7 is reproduced the sector in page 65 where the mistake was found.

| | | | |
|---|---|---|---|
| B) Compute $K_n = \frac{P_n}{f'_c A_g}$ | $\frac{943}{(4)(384)} = 0.61$ | $\frac{943}{(4)(416)} = 0.57$ | $\frac{943}{(4)(448)} = 0.53$ |
| C) Compute $R_n = \frac{M_n}{f'_c A_g h}$ | $\frac{3986}{(4)(384)(16)} = 0.16$ | $\frac{3986}{(4)(416)(16)} = 0.14$ | $\frac{3986}{(4)(448)(16)} = 0.14$ |

Figure 7

0.15

**EXAMPLE 3**

This example is related to a square section column with spiral reinforcement. Although the same procedure of the precedent examples is repeated, in this case the required strength produces $\phi$ = 0,70 and the result is correct. Differences exist on how to read the values in the diagrams, but that is a common stuff in these procedures and they are within the allowable tolerances.

**EXAMPLE 4**

This example is about a square section column, with symmetric reinforcement in the four faces subject to axial load and biaxial bending.

The procedure used consists of transforming the biaxial bending into uniaxial bending by means of vectorial addition of the acting moments and, in the end, to arbitrarily increase 15% to the obtained reinforcement. The procedure does not result in a very big error for this combination of actions, but it is not wise_to use it in an ACI Handbook without previous warning about its restrictions for the general use. Once again, a value of $\phi$ is adopted without further verification, which would have been absolutely necessary, since the required strength lead to the variable $\phi$ zone.

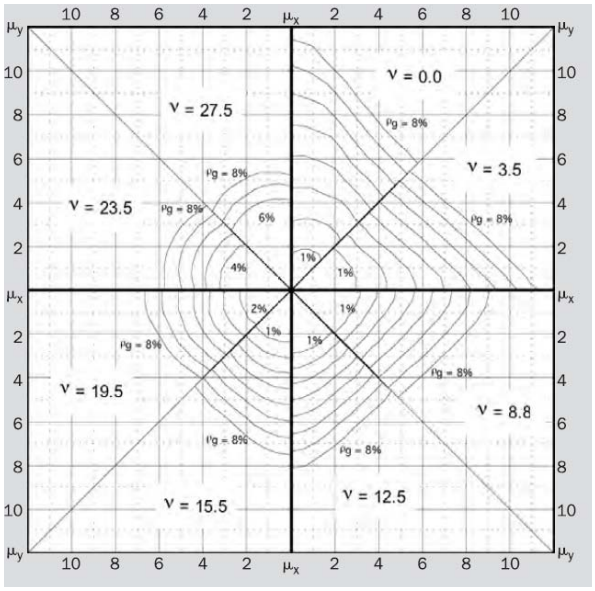



Figure 8

There are no developed examples using procedures accepted by ACI 318.

If this same square section column is subjected to other sets of actions, the solutions obtained by using this procedure will be highly unsafe and consequently unacceptable. Warning should be given to prevent the use of this procedure as a general procedure.

It is reasonable to discuss procedures in ACI 318, considering that they are not design procedures. They are

Procedures in ACI 318 are slow because they do not permit the design of sections.

Validated procedures for direct design are presented in many texts and papers (although they have been validated for nominal stresses with no consideration to the variable $\phi$ value effects).

Some “rosetta kind” graphs exist, which allow direct reading of reinforcement[4]. This quoted reference is free of charge and should be easily obtained in the Internet.
Figure 8 presents a rosetta graphic obtained from Reference 4. It is possible to observe that the hypothesis presented in the example supposing horizontal cuts as elliptical can be wrong and on the unsafe side depending on the level of acting axial force. It is pretty dangerous to present an example of a method of calculation supposed to be of general use without any warning about its scope and limitations.

Figure 9 presents the solution using software CIRSOC-FLEX.

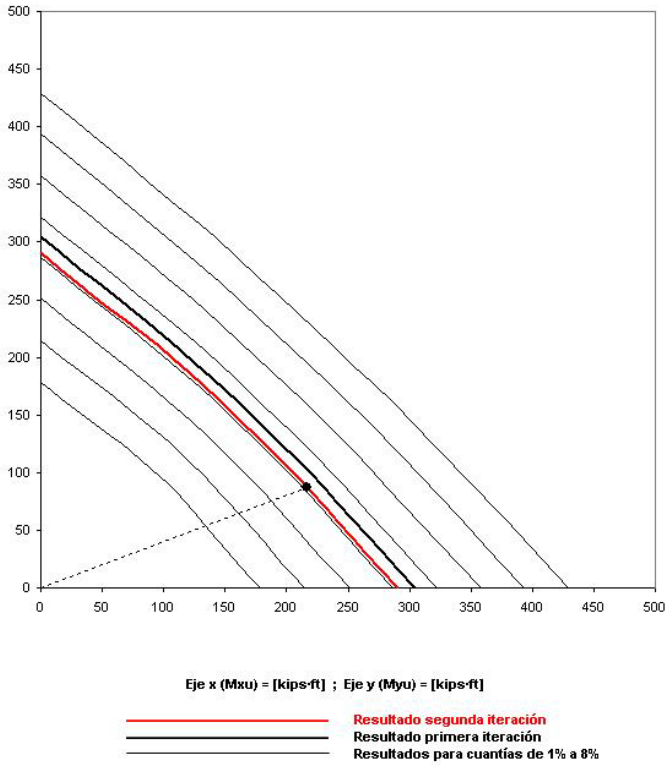



Figure 9

**EXAMPLE 5**
This example is related to a column with circular section and spiral reinforcement. For this case, SP-17(09) graphs do not take into account the ACI 318 limitation related to axial force, as a consequence, it was not noticed that dot A is located in the zone where the horizontal straight lines should have replaced to the curved lines. This mistake, located on the unsafe side, is almost 18% considering that the interpolation should be done between horizontal straight lines, not curved lines.

Figure 11 shows a graph obtained from Reference 2, to observe the general configuration of the diagrams, also, notice that the straight line “e/h = 0,1”, should not be taken as reference to design the horizontal lines.

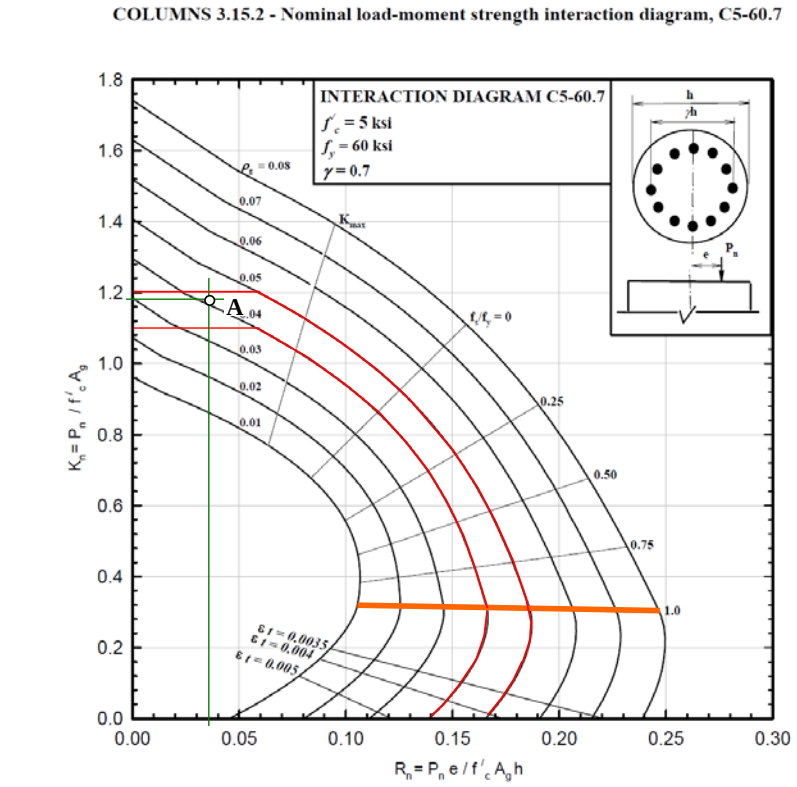



Figure 10

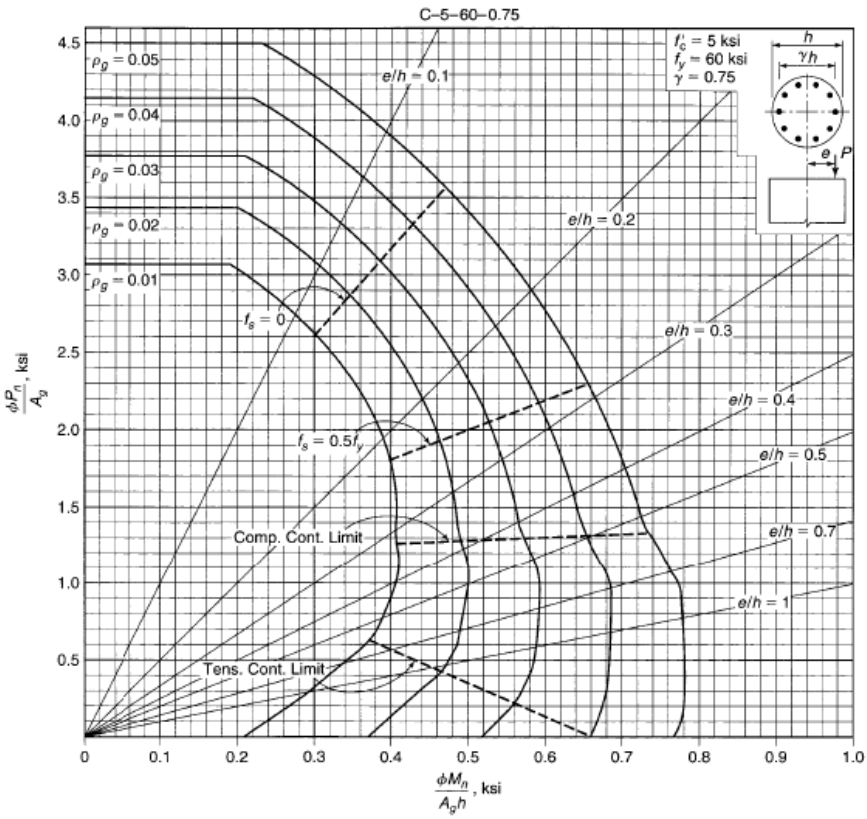



Figure 11

In this example there is also a numerical mistake which has been corrected by the errata already published.

## CONCLUSIONS

1. Most of the mistakes observed in the examples are a consequence of SP-17(09) lacking of design aids including variable $\phi$ values and axial force limits established by ACI 318
2. Procedures which are not of general use, and/or not validated by ACI, should not be included.
3. Procedures presented by ACI 318-08 for verification of sections subject to axial force and biaxial bending, were not calibrated considering $\phi$ variable influence. A high complexity geometry is displayed by the strength surfaces obtained under this new conditions, even for symmetrical sections, (Figure 12) and there could be no correspondence between horizontal cuts and constant $\phi$ values, which means that a generalization of the expressions historically used could be rather complicated.

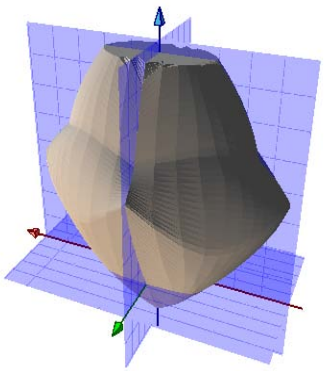


Figure 12

4. "Rosetta" type diagrams could be included in a new edition of SP-17 or in some specific handbook, in order to bring direct solutions to axial force and biaxial bending, such as presented in Reference 4, or the 2008 presentation by CIRSOC to this Convention.
5. The metric version, SP-17(09)-M, includes the conversion of all units to the system SI. Examples and also procedures are the same so the commentaries are still valid. Rounding some of the magnitudes, particularly the transverse dimensions of the sections and the strength of materials have changed the input values to the diagrams, but the same readings remained so some minor additional errors have been introduced.
6. Free software CIRSOC-FLEX allows solving most problems related to flexure and flexure and axial loads.

## REFERENCES


1. Saatcioglu, M, ACI DESIGN HANDBOOK, SP-17(09), American Concrete Institute, Farmington Hills, Mich, 2009, pp. 59-166
2. Wight, J.K. and MacGregor, J. G., Reinforced Concrete: Mechanics and Design, 5th Edition, Prentice- Hall, Upper Saddle River, N.J., 2009
3. Furlong R.W, Hsu C.T.T and Mirza S.A., "Analysis and Design of Concrete Columns for Biaxial Bending-Overview", ACI Structural Journal, May-June 2004, pp. 413-423
4. Larraín Vial A., Yáñez Uribe, F. and Verdugo Arnold Ch., "Manual de Cálculo de Hormigón Armado-Segunda Edición en Base al Código ACI 318-05", GERDAU AZA S.A., 2006