Short communication

Proportioning of reinforced concrete column sections

Mark Aschheim \(^a,\star\), Luisa María Gil-Martín \(^b,1\), Enrique Hernández-Montes \(^b,2\)

\(^a\) Department of Civil Engineering, Santa Clara University, 500 El Camino Real, Santa Clara, CA 95053, USA
\(^b\) Department of Structural Mechanics, University of Granada, E.T.S. Ingenieros de Caminos, Campus Universitario de Fuentenueva, E-18072 Granada, Spain

**Article history:**
Received 16 November 2009
Accepted 4 October 2010
Available online 20 November 2010

**Keywords:**
Reinforced concrete
Columns
Cross-section design

**Abstract**
Relatively simplistic recommendations are widely available for the preliminary sizing of reinforced concrete columns. A simple, more precise approach is developed herein. The neutral axis depth and reinforcement required to provide a desired resistance to axial load and moment was determined analytically for the common case of symmetrically distributed reinforcement. Readily available solver routines are used to determine section dimensions required to provide the desired axial and flexural strength, for a desired reinforcement ratio. The approach is illustrated for two examples, including a case in which independent load combinations cause bending about each principal axis of the section.

© 2010 Elsevier Ltd. All rights reserved.

1. Introduction

The design of longitudinal reinforcement in reinforced concrete beams and columns is restricted by various code provisions. Beams may readily be proportioned to achieve a desired reinforcement ratio, selected between minimum and maximum limits. However, the initial proportioning of column sections has been less precise, with intuition or various formulas recommended to obtain trial sections, such as those found in [1, p. 512]. A significant number of iterations may be required when beginning with a trial section, particularly when conventional \(P–M\) interaction diagrams are used.

The authors have recently advanced methods for determining optimal reinforcement for reinforced concrete sections. In general, optimal reinforcement is not symmetric; that is, significant savings in reinforcement quantities can be achieved if the top and bottom reinforcement quantities are selected optimally. The notion of optimal domains for column reinforcement [2] was established using the method of Reinforcement Sizing Diagrams [3]. A mathematical theorem of optimal reinforcement of rectangular sections was put forward by Hernández-Montes et al. [4]. Optimization under multiple load combinations was described by Lee et al. [5]. Finally, optimal reinforcing of rectangular sections under biaxial loading was described by Aschheim et al. [6].

These developments in reinforcement optimization provided the basis for developing the simple procedure described in this paper for the proportioning and design of rectangular column sections having symmetric (non-optimal) reinforcement for a desired reinforcement ratio for load combinations applied independently about one or both principal axes of the cross section. The procedure is developed for the ultimate strength analysis assumptions of ACI 318 [7], although simple adjustments would allow other strength analysis hypotheses to be used.

2. Flexural analysis assumptions

Equilibrium, compatibility, and the constitutive relations of the steel and concrete materials are considered at the section level. The compatibility conditions make use of Bernoulli’s hypothesis that plane sections remain plane after deformation, and assume no slip of reinforcement at the critical section. Thus, the distribution of strain over the cross section (Fig. 1(a)) may be defined by the strain at the extreme compression fiber of the section, \(\varepsilon_{c,max}\), and the depth of the neutral axis, \(c\), as illustrated in Fig. 1(b).

For the demonstration of the procedure, assumptions of ACI 318 were adopted, as follows: (1) plane sections remain plane; (2) the maximum usable strain for concrete compression is given by \(\varepsilon_{c,max} = 0.003\); there is no limitation on the maximum usable strain for steel in tension; (3) a rectangular stress block is used having depth equal to the product of a coefficient, \(\beta_1\), and the depth of the neutral axis, where \(\beta_1\) varies between 0.85 and 0.65 as a function of the specified compressive strength of the concrete; and (4) the stress–strain relation for the steel is elastic–perfectly plastic, with symmetric behaviour in tension and compression.

3. Equilibrium solutions

Integration of the stresses shown in Fig. 1(c) over the areas on which they act produces the stress resultants shown in Fig. 1(d).