Design of Beam Sections under Large Flexural Deformation

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ABSTRACT

The ACI 318 stress block parameters have been closely examined for validity of their values in evaluation of flexural strength and deformability. For this the conventional definition of stress block has been used. The comparison of parameter values between ACI stress blocks and the exact approach implies that an alternative idealization other than the rectangular stress block may be required.

1. INTRODUCTION

The flexure is considered the most comprehensive mechanism to handle and the design procedure in ACI 318 (2002) and KCI (2001) code provisions are rather simple and clear than any other force-transfer mechanism. Fig. 1 shows the idealized flexure model for section analysis. For convenience and simplicity, the code provisions employ several basic assumptions such as plane sections remaining plane before and after bending, maximum compressive fiber strain $\varepsilon_{cu} = 0.003$ at failure, no tensile strength in concrete, rectangular stress block idealization and steel yielding. These assumptions have been accepted to the engineering professionals for quite a long time without any resistance. However, with the advancement and refinement in engineering theory and practice, some of the assumptions should be reconsidered for rationale, even still in a simplified version.

In the seismic design and analysis, the structures and structural elements are likely subjected to large deformations. Accordingly, it is essential to take the effect of large deformation in the design and analysis into account. For this, the various ultimate compressive strains for the concrete extreme fiber beyond the prescribed value, 0.003, are suggested to consider by different researchers. Paulay and Priestley (1992) and Wallace (1995) suggested 0.004 and FEMA 273 (1997) suggested 0.005 for the maximum fiber strains in compression. This implies that the corresponding parameters for the rectangular stress block idealization should be modified, as well.

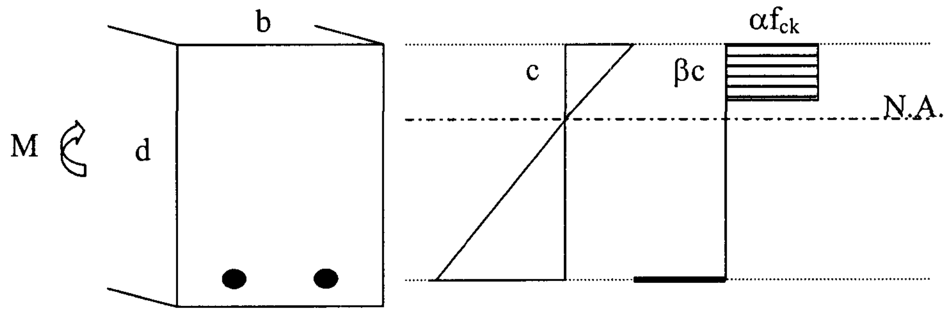

Fig. 1 Idealized flexural model for section analysis

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In the present paper, the conventional flexural theory is reviewed to include the effect of large deformation. Finally, ACI parameter values are examined for validity in evaluation of strength and deformability of flexural elements.

2. DEALIZED RECTANGULAR STRESS BLOCK

The signification of a rectangular stress block is two-fold: (1) the area of a rectangular stress block should be the same as the area under the concrete stress-strain curve at the considered maximum strains in compression; and (2) the first moment of area of a rectangular stress block taken about the neutral axis should be the same as that of the real concrete stress-strain curve.

3. STRESS BLOCK PARAMETERS

In ACI 318, the rectangular stress block parameters are selected to be $\alpha = 0.85$ and $\beta = 1.09 - 0.008 f_{ck}$ (in MPa) and $0.65 \le \beta \le 0.85$ based on $\varepsilon_{cu} = 0.003$.

In order to appropriately evaluate the values of α and β, the stress-strain curves of concrete in compression with maximum strength of 20MPa, 30MPa and 40MPa are considered shown in Fig. 2. The dashed rectangles represent the ACI idealized stress blocks. For this, the Tsai's model modified by Chang and Mander (1994) is utilized. Then the stress block parameters of α and β can be determined by for considered maximum strain

$$\alpha\beta = \frac{\int_0^{\varepsilon_c} f_c \, d\varepsilon_c}{f_{ck}\varepsilon_c} \tag{1}$$

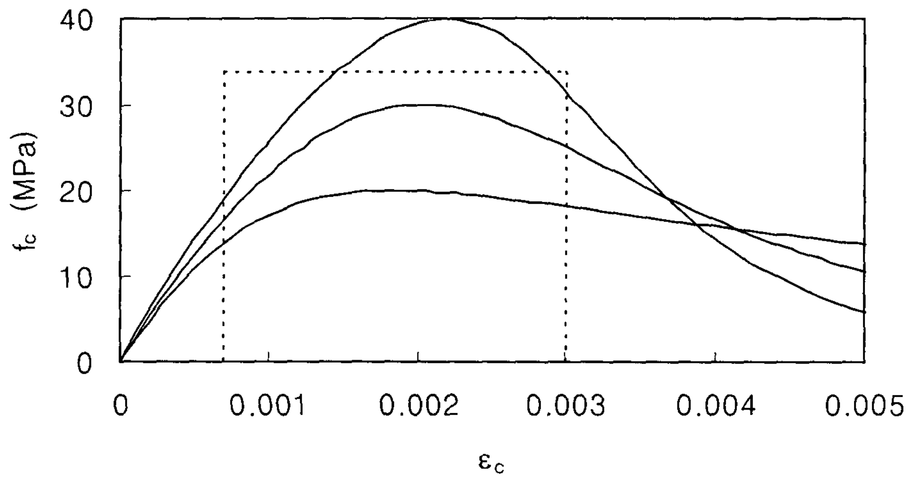

Fig. 2 Stress-strain curves of concrete in compression

$$\beta = 2\left(1 - \frac{\int_0^{\varepsilon_c} f_c \varepsilon_c \, d\varepsilon_c}{\varepsilon_c \int_0^{\varepsilon_c} f_c \, d\varepsilon_c}\right) \tag{2}$$

in which $\beta \le 1.0$.

Parameters $\alpha\beta$ and β are plotted in Fig. 3 in terms of strains normalized by the strain at peak, ε_c', for comparison between different concrete compressive strengths. Since ε_c' differs from each other, values of ε_c' for different concrete strengths are summarized in Table 1.

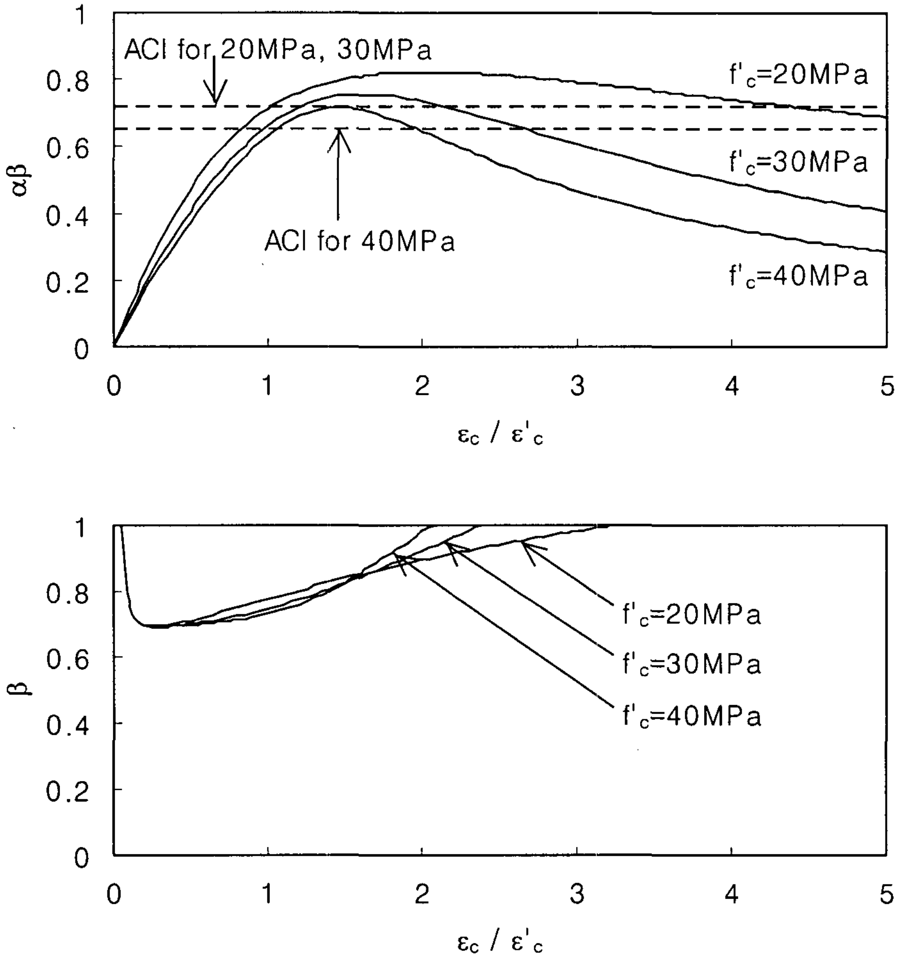

Fig. 3 Stress block parameters for various concrete strengths

Table 1 Strains at peak and normalized strains under considerations

f_{ck} (MPa)		20	30	40
ε_c'		0.001834	0.00203	0.002181
$\frac{\varepsilon_{cu}}{\varepsilon_c'}$	$\varepsilon_{cu} = 0.003$	1.6357	1.478	1.3754
	$\varepsilon_{cu} = 0.004$	2.1809	1.9706	1.8339
	$\varepsilon_{cu} = 0.005$	2.7261	2.4633	2.2924

4. DISCUSSION

Plots in Fig. 3 implies that the exact values for $\alpha\beta$ are quite much deviated from the ACI prescribed values with the exception of strains around 0.003 for concrete strength of 30MPa and higher. For concrete strength of 20MPa, the degree of deviation is larger than stronger ones. Values of β are underestimated by ACI for strains greater than 0.003.

5. CONCLUSIONS

The stress block parameters are quite significant because they determine the flexural strength and deformability of reinforced concrete members. The deviation in values of stress block parameters between ACI 318 and the exact approach implies that an alternative idealization other than the rectangular stress block may be required.

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