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We are thankful to Dr. Andor Windisch for raising important comments and questions regarding the Axial-Shear-Flexure Interaction methodology presented in the paper. These remarks have been reviewed and following the explanations are provided for clarification of the methodology, accordingly.

DERIVATION OF ANALYTICAL MODEL

The stress and strain relations, expressed in a Mohr's circle in the MCFT and the ASFI methods, correspond to the average stress and strain condition of the shear element. They are employed for compatibility and equilibrium conditions by assuming unit dimensions for the element, as shown in Fig. 5 and 6 of the article. In other words, equilibrium and compatibility conditions are derived for the entire element; however, they are converted and expressed in the stress and strain fields.

The correct form of Eq. (7) and Eq. (8), respectively, are

$$\sigma_x = f_{cx} + \rho_x f_{sx} \tag{1}$$

$$\sigma_y = f_{cy} + \rho_y f_{sy} \tag{2}$$

The crack angle θ is determined in the stress field by solving Eq. (9) and Eq. (10), which is incorporated in Eq. (14) and (15):

$$tan^2\theta = \frac{f_{c1}-f_{cy}}{f_{c1}-f_{cx}} \tag{1}$$

Fig. 4 (a) was drawn for the assumption related to Eq. (6). It illustrates the pattern of the principal compression stress, and therefore strain, along the entire column. It shows that the principal compression stress and strain at the points along the curve are very close to the value of the compression stress and strain obtained from a section analysis. Therefore, Eq. (6) could represent the maximum compression strain or assume to provide the principal compression strain of the element between the two flexure sections. Eq. (3), above, provides an average value for the entire pattern shown in this figure when only two flexure sections have been selected: one at the end and one at the inflection point.

The approach presented in this article can be used only to estimate the point of the ultimate capacity, which is the ultimate deformation and load of the column, however, the equations have been derived from a monotonic loading approach. Therefore, although the method presents suitable agreement for the column specimens in Fig. 11, the attempt was not to assess and include the effect of cycling loading. Therefore, for specimens with heavily cyclic loading, the corresponding effects need to be included in the analysis.

In the ASFI method, the crack spacing in the longitudinal direction of the column, S_x, is the same as the hoop spacing. Crack spacing in the transverse direction, $S_{y,}$ is the maximum distance between the longitudinal bars. These are the average smeared crack spacings and not the maximum values. For specimen No. 12, S_x= 150 mm and S_y= 60 mm, which yields to S_{cr} = 72 mm, derived from the analysis at the maximum load stage. Based on the specimen dimension perpendicular to the crack, this means that about four cracks could appear on the columns; as it is the case for the column specimen in Fig. 8.

Eq. (19) provides a maximum limit for shear stress. As mentioned earlier, the method proposed in this article only estimates the load and deformation of the column at the ultimate stage. For specimens containing transverse reinforcement, the lateral load drops as soon as the transverse bars yield and the analysis ends (defining the ultimate load stage).

FLEXURE MECHANISM

Both the flexural and shear models, as well as the MCFT, use a secant stiffness approach for the analysis. The values for Young's Modulus of concrete in equations (20), (21a) and (21b) are the inelastic values. They are determined by dividing value of the concrete compressive stress by the concrete compressive strain at the corresponding loading stage.

PROCEDURES FOR ESTIMATION OF ULTIMATE DEFOMATION

The value of d_f affects the magnitude of the lateral load. In the case of columns with dominant flexural response, due to the effect of support confinement, a plastic hinge will be formed a small distance away from the support. This will result in increasing the overall lateral load capacity of the column. This resulted in up to about a 20% lateral load reduction for flexure column specimens studied in this paper. Therefore, the authors believe that this adjustment needs to be employed in the analysis.

NUMERICAL EXAMPLES

The analytical results in Fig. (11) are the ultimate points of deformations and loads for the column specimens. As mentioned above, the ultimate deformation capacity approach presented in this paper can be implemented only for evaluation of the load and deformation of the columns at the ultimate stage. Although, one may try to estimate pre- or post-peak response of the column by implementing a small modification in the current method, it has not been verified for full load deformation response analysis. This method is a simplification of the original ASFI method, which is a method capable of doing full load deformation analysis (Mostafaei and Kabeyasawa 2007). As mentioned in the paper, for columns with very low shear stress, those are columns with very high shear capacity and very low flexure load, compression softening factor, β, is limited to 0.15. This means the method overestimates the ultimate deformation for these columns. Further studies and modifications are needed for the method in this regard.

It is important to note that a comprehensive analysis software has been developed at the University of Toronto, based on the MCFT, which is capable of predicting the entire load deformation response including under cycling loading regimes (Palermo and Vecchio 2004).

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