AN IMPROVED METHOD OF DETERMINING THE ECCENTRICITY INCREMENT IN REINFORCED CONCRETE COLUMNS

By

K. SZALAI

Department of Reinforced Concrete Structures,
Technical University, Budapest

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1. Introduction

To determine the total eccentricity in r.c. members in compression, the Hungarian Standard MSz 15022/1—71 specifies an eccentricity increment:

$$\Delta e_t = 0.04 \left(\frac{l_0}{l_0 h} \right)^2 h \qquad (1)$$

where l_0 is the buckling length of the column and h the effective depth of the cross section. Implementation of this specification of the 1971 standard gave very advantageous experiences. Further theoretical analysis of the eccentricity increment value showed an eventual refinement of (1) to be feasible if a higher accuracy is needed [1].

In the following, recent research results will be recapitulated.

2. Fundamentals of the new analysis

The relevant comprehensive research has been described in [1]. Results concerning the eccentricity increment can be stated as:

a) Eccentricity increment vs. initial eccentricity e_0 is fairly approximated by the broken line in Fig. 1. In case of a compressive force of slight eccentricity, the increment depends on the initial eccentricity.

b) In ultimate condition, the buckled shape of the column may be considered as sinusoidal.

c) The eccentricity increment of the column is related to the rotation of the cross section in failure.

d) In addition to the bar flexibility, the ultimate strain ε_b of the extreme compressed concrete fibre of the cross section depends on the percentage of reinforcement, on the design stress of concrete, on the ability to creep of the concrete, on the cross section form. Thus, computation of the eccentricity increment can be reduced to the cross-sectional rotation, related, in turn, to the strain of the compressed extreme fibre.

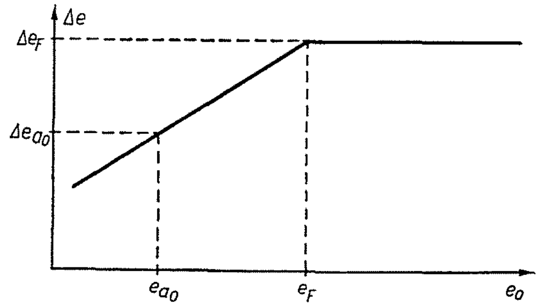

Fig. 1.

3. Ultimate strain of the compressed extreme fibre

Actual calculations have shown the ultimate strain (permillage) of the extreme fibre in compression of a symmetrically reinforced concrete cross section to be given by:

$$\varepsilon_b = \varepsilon_{b0} \frac{0.5}{\xi_s} k_d \tag{2}$$

involving

$$\varepsilon_{b0} = 2.45 + 3000 \frac{\mu}{\sigma_{bH}} - 0.02 \left(\frac{l_0}{h} - 10 \right) \tag{3}$$

where:

$\mu = \frac{F_a}{F_b}$ percentage of reinforcement (F_a being steel area in one side, F_b the overall concrete cross section area);

σ_{bH} design stress of concrete;

l_0/h flexibility of the column;

ξ_s relative value of the spacing between centroid S_{b0} of the concrete area F_{b0} and depth x_0 (Fig. 2);

$$k_d = 1.0 + \varphi_l (1 - e^{-0,2t}) \frac{Y_{\text{const}}}{Y_{\text{tot}}} \tag{4}$$

the ability to creep of the concrete,

where $$\varphi_l = 6 - 2 \log K_{\min} \tag{5}$$

coefficient of creep of the concrete at time $t = \infty$;

Y_{const} axial force from the permanent part of the effective load;

Y_{tot} axial force from the total effective load;

t number of days from applying the permanent load part to the time of testing.

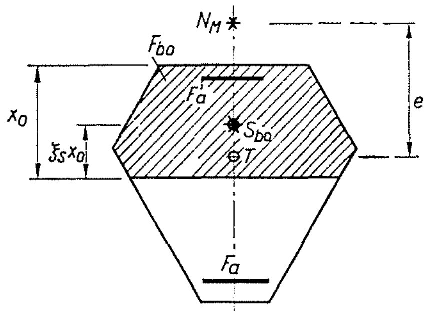

Fig. 2.

4. Improved value of the eccentricity increment

An improved value of the eccentricity increment is given by

$$\Delta e_{tt} = \Delta e_{a0} + \frac{\Delta e_F - \Delta e_{a0}}{e_r - e_{y0}} (e_0 - e_{a0}) \leq \Delta e_F \tag{6}$$

where

$e_0 = e_k + e_{sz}$ initial random eccentricity e_k (according to MSz 15022, $e_k = 0.03h + 0.01 \left(\frac{l_0}{l_o h}\right)^2 h$, and from the structural analysis eccentricity $e_{sz} = \frac{M_M}{N_M}$; M_M = effective moment; N_M = effective axial force);

e_{a0} eccentricity corresponding to the stress state $\sigma_a = 0$ of (tensile) reinforcement F_a in case of a symmetrically reinforced rectangular cross section:

$$e_{a0} = \frac{0.08 + 0.5\mu \frac{\sigma_{aH}}{\sigma_{bH}}}{0.80 + \mu \frac{\sigma_{aH}}{\sigma_{bH}}} h ; \tag{7}$$

σ_{aH} design tensile stress of steel;

σ_{bH} design compressive stress of concrete;

e_F eccentricity corresponding to the depth of neutral axis $x = x_0$, in case of a symmetrically reinforced rectangular cross section:

$$e_F = \left(0.25 + 2\mu \frac{\sigma_{aH}}{\sigma_{bH}}\right) h ; \tag{8}$$

Δe_{a0} the increment for the eccentricity e_{a0}:

$$\Delta e_{a0} = \frac{\varepsilon_b}{100}\left(\frac{l_0}{10h}\right)^2 h\,; \tag{9}$$

Δe_F the increment for the eccentricity e_F:

$$\Delta e_F = \frac{\varepsilon_b + \varepsilon_F}{100}\left(\frac{l_0}{10h}\right)^2 h \tag{10}$$

where

$$\varepsilon_F = \frac{\sigma_{aH}}{E_a} 1000\,, \tag{11}$$

yield strain of steel (per mille).

Summary

Recent research has led to an improved method of calculating the eccentricity increment in compressed r.c. columns. In addition to bar flexibility, the eccentricity increment depends on the initial eccentricity, the percentage of reinforcement, the ability to creep of the concrete and the form of the cross section.

References

[1] SZALAI, K.: A hajlékonyság szerepe a vasbetonoszlop teherbírásában. (The importance of flexibility for the load capacity of r.c. columns.) Műszaki Tudomány 52. 1976.

Prof. Dr. Kálmán SZALAI, H—1521 Budapest