Homework No. 3.1

Consider a steel bar of diameter d_{bL} and assume that the buckling length is half the stirrup spacing, s_w:

(a) Find the ratio s_w/ d_{bL} beyond which the bar will buckle before it yields.

(b) According to Shanley's theory for inelastic buckling (i.e. buckling after yielding), Euler's expression for the critical buckling load still applies, if one uses in it the tangent modulus, $E_t = d\sigma/d\varepsilon$, instead of the elastic modulus, E. Assuming that a bar in the compression zone of a concrete member, being under displacement-control conditions, can go through the yield plateau of its σ-ε law without buckling, please relate the s_w/d_{bL} ratio of the bar to its stress level at buckling, if the hardening range of the monotonic σ-ε law can be described by the following relation:

$$\sigma = f_t - (f_t - f_y)\left(\frac{\varepsilon_{su} - \varepsilon}{\varepsilon_{su} - \varepsilon_{sh}}\right)^{\frac{E_{sh}}{E_{sec}}}$$

where:

ε_{sh}: tensile strain at the end of the yield plateau and at the beginning of strain-hardening;

E_{sh}: tangent modulus at the onset of strain-hardening;

E_{sec}: secant modulus from the onset of strain hardening at $\sigma = f_y$, $\varepsilon = \varepsilon_{sh}$, till tensile strength at $\sigma = f_t$, $\varepsilon = \varepsilon_{su}$;

You may use the following values, as typical of European Tempore S500s steel: f_y=575MPa, f_t=650MPa, ε_{sh}=1%, ε_{su}=8%, E_{sh}=3500MPa.

Homework No. 3.2

Please estimate the increase in yield stress of S500 steel due to strain rate at a cross-section where the bars are expected to reach a strain equal to 7-times their nominal yield strain (measured under quasi-static conditions). You may assume that the period of the response at the time when the peak strain demand takes place in equal to 0.8sec.

Homework No. 3.3

Reinforcing steel with nominal yield stress $f_{y,nom}$=500MPa is checked for fulfillment of the Eurocode 8 requirements for the steel of Ductility Class (DC), Low (L), Medium (M) or High (H) buildings. Measurements of the yield stress in a large number of samples gave the following values of the mean, *m*, and the standard deviation, *s*, of the yield stress, of the strain at maximum stress and of the hardening ratio of steel:

	f_y (MPa)	ε_{su} (%)	f_t/f_y
Mean, *m*	560	10.2	1.24
Standard deviation, *s*	42	2.2	0.065

Please check whether this steel meets the requirements of Eurocode 8 for S500 steel to be used in DC H, M or L buildings. You may assume that the number of samples is sufficient for the probability distribution of the material properties to be considered as Normal (Gaussian), in which case the 5%-, 10%- and 90%-fractiles of material property *x* are equal to:

$x_{k,0.05}= m-1.645s$, $x_{k,0,10}= m-1.282s$, $x_{k,0.90}= m+1.282s$

Homework No. 3.4

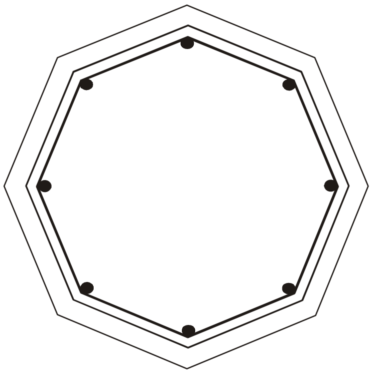
Please use Eqs. (3.2), (3.3) to compare the chord rotation capacity of a beam that fails due to rupture of the tension steel, for the following parameter values: shear span L_s=2.8 m, effective depth d=0.5m, compression zone depth at yielding, or at ultimate, normalized to d, equal to ξ_y=0.22 and ξ_u=0.17, respectively, S500 steel having ε_{su}=8.5% and f_t/f_y= 1.09. What would be the difference if f_t/f_y= 1.16?

Homework 3.5

The predominant period of the seismic response of a typical concrete building is of the order of 1 sec. The design ground motion has strong motion duration of around 10 sec. The amplitude of the seismic response is expected to exceed 15 to 30% of the peak response only during 50% of the strong motion duration, in total. Would you expect that concrete will suffer from low-cycle fatigue under such conditions?

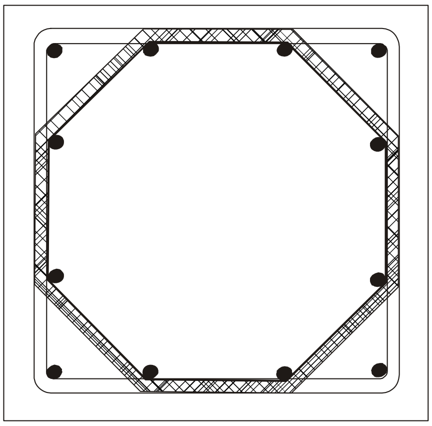
Homework No. 3.6

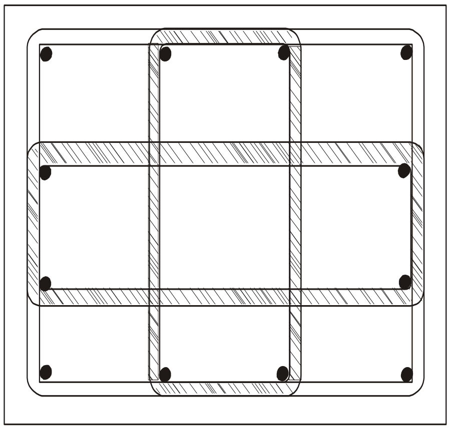
Please calculate the factor a_n for confinement effectiveness within the cross section of a tie, for octagonal concrete columns with a single octagonal tie engaging the corner bars along the perimeter.



Homework No. 3.7

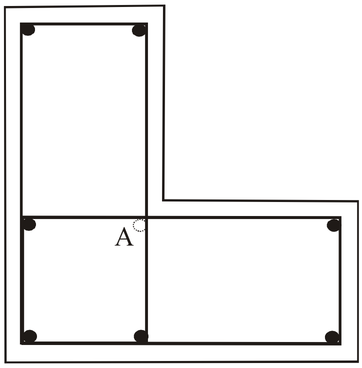
A square column section has two intermediate longitudinal bars along each side. Compare the cost-effectiveness of a single octagonal tie engaging all eight intermediate bars, to that of two rectangular interior ties, each one extending from one side of the section to the opposite and engaging just the two pairs of intermediate bars of these two sides.





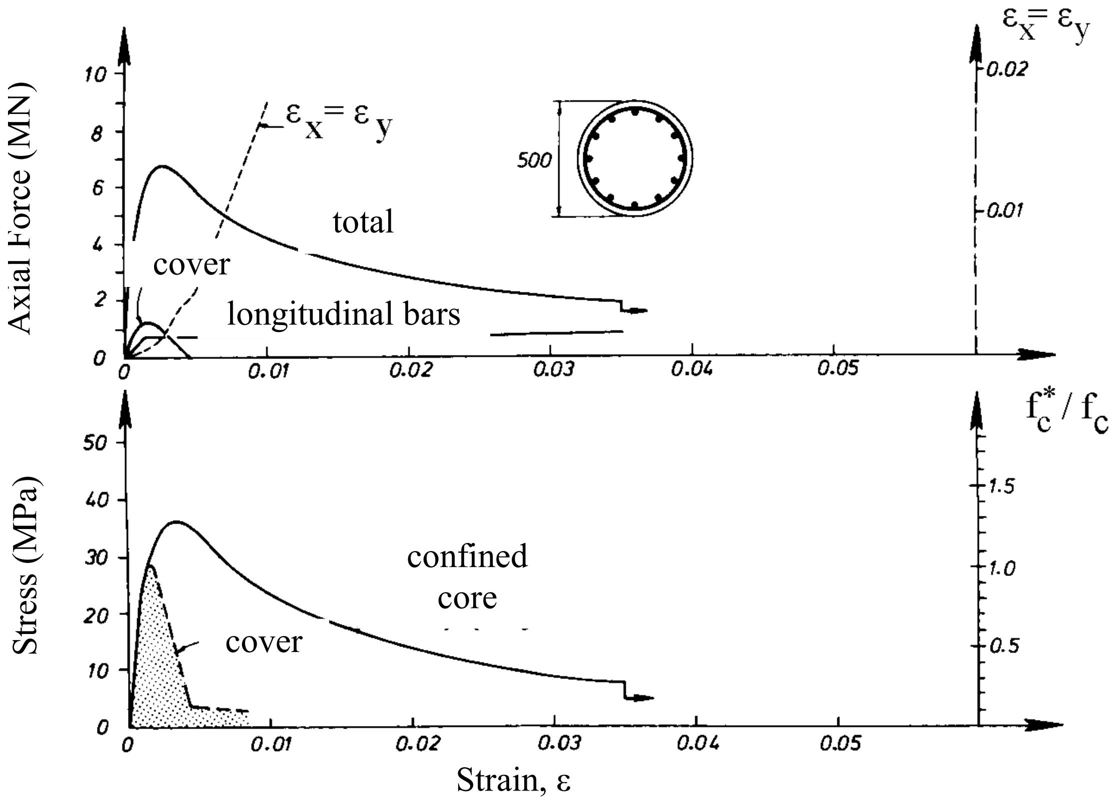
Homework No. 3.8

Consider an L-shaped column section, with one closed rectangular tie extending all along each leg of the L and overlapping over the common part of these two legs next to the corner of the section. Please calculate the factor a_n for confinement effectiveness within the section, assuming that there is a longitudinal bar at each corner of these two stirrups (a total of seven bars, considering that the two stirrups share the external corner of the L). Would the value of a_n change, if an 8^{th} bar is added at the inside corner at the intersection of the tie interior legs at the re-entrant corner of the section (point A) and how?



Homework No. 3.9

Compare the cost-effectiveness of transverse reinforcement to that of the longitudinal, with respect to enhancement of the axial load capacity (in terms of the same steel ratio needed to increase the axial force capacity by the same percentage), for a column that has factor *a* for confinement effectiveness equal to *a* = 0.4, as a function of ω_w, using the confinement model of the CEB/FIP Model Code 90. You may assume that the longitudinal and the transverse reinforcement have the same yield stress value.



Section of circular concrete element and results of concentric compression test from Mander et al: axial force and normal stress, σ_1, confined and unconfined concrete in terms of the axial strain, ε_1.

Homework No. 3.10

The section in the figure above has diameter 0.5m, longitudinal reinforcement consisting of twelve 14mm bars with f_y=400MPa and spiral reinforcement having 8mm diameter, pitch equal to 120mm, f_y=625MPa and ε_{su}=0.10. The unconfined concrete properties are: f_c=29MPa, ε_{co}=0.2% and ε_{cu}=0.4%. Concrete cover to the outside of the spiral is c=28mm. Please calculate:

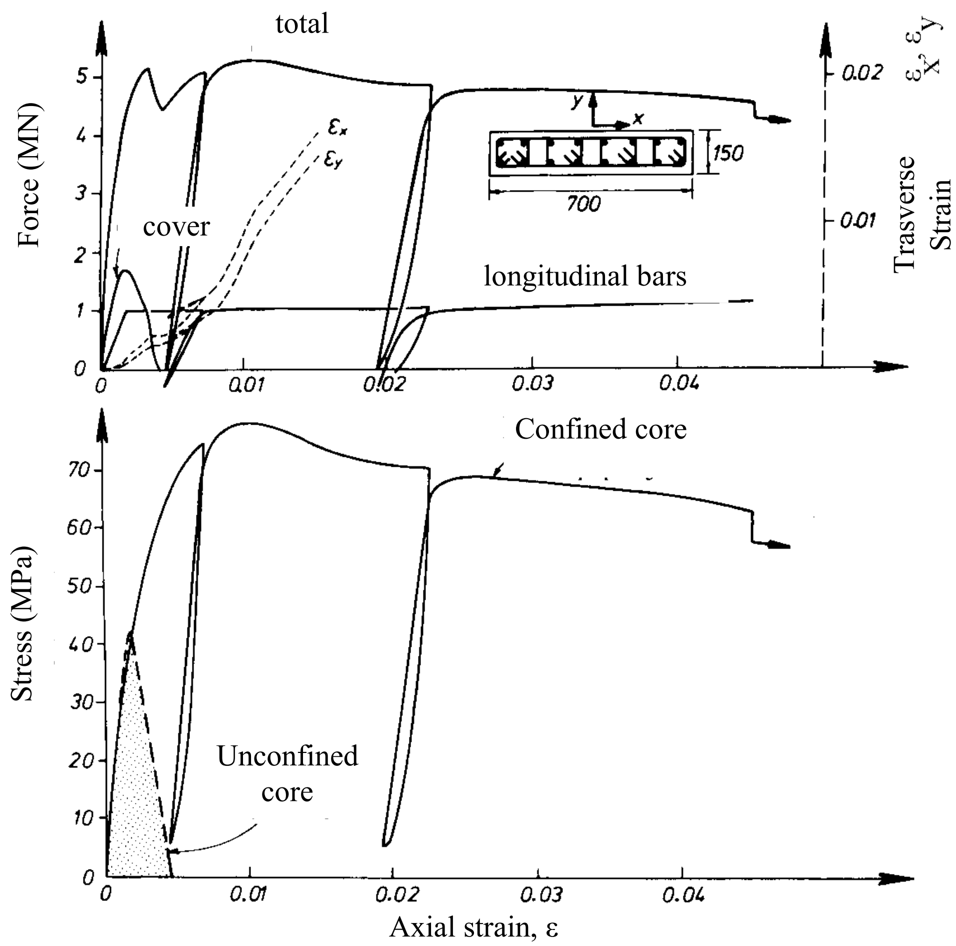
a) the mechanical volumetric ratio of stirrups;

b) the confinement effectiveness factor, a;

c) the properties f_c^*, ε_{co}^* and ε_{cu}^* of confined concrete and the ultimate load of the element in concentric compression, according to all the confinement models in Sections 3.1.2.2, 3.1.2.3.

d) the ultimate load of the element in concentric compression

Homework No. 3.11



The cross-section shown in the Figure above (from Mander et al) has dimensions 0.15mx0.7m and sixteen 14mm diameter bars having f_y=430MPa. These longitudinal bars are uniformly distributed along the two long sides of the section and are engaged by the perimeter stirrup and by four square interior stirrups. All stirrups have 8mm diameter, f_{yw}=515MPa and ε_{su}=0.13, and are placed at a spacing of 42mm on centres along the axis of the member. Concrete cover is c=28mm to the exterior of the stirrups. The properties of unconfined concrete are: f_c=43MPa, ε_{co}=0.2% and ε_{cu}=0.4%.

Please calculate:

a) the mechanical volumetric ratio of stirrups;

b) the confinement effectiveness factor, a;

c) the properties f_c^*, ε_{co}^* and ε_{cu}^* of confined concrete and the ultimate load of the element in concentric compression, according to all the confinement models presented in Section 3.1.2.2, 3.1.2.3.

d) the yield moment and yield curvature in the strong direction of the section (bending about the strong axis, y, in a plane parallel to axis x), for axial compression N=750kN.

<u>Homework No. 3.12</u>

Please derive Eqs. (3.34), (3.35), (3.37), assuming linear material behaviour.