H4.1 Moment-Curvature (M-φ) **Diagram**

The stress-strain curves of **M25** grade *unconfined* concrete and the associated *confined* concrete are shown in **Figure H4.1(a)**, and that of **Fe500** grade reinforcing steel in **Figure H4.1(b)**. The values of salient points of the stress-strain curves are given in **Table H4.1**. The expressions of stress-strain curves of concrete follows *parabolic-linear* path (Eq.(H4.1)), and of reinforcing steel follows *elasto-plastic* path (Eq.(H4.2)).

Using these material constitutive laws, write a computer program to obtain the **Moment-Curvature** (M-φ) **Diagrams** of the RC pier section shown in **Figure H4.2**. The following cases need to be studied:

(a) The concrete in the entire cross-section is *unconfined*, and
   (i) P_D=2,000 kN, (ii) P_D=4,000 kN, (iii) P_D=8,000 kN, (iv) P_D=12,000 kN, and (v) P_D=16,000kN; and

(b) The concrete in the cover region of the cross-section is *unconfined*, and in the core region is *confined*, and
   (i) P_D=2,000 kN, (ii) P_D=4,000 kN, (iii) P_D=8,000 kN, (iv) P_D=12,000 kN, and (v) P_D=16,000kN; and

Draw the M-φ Curves of the said cases on a single graph.

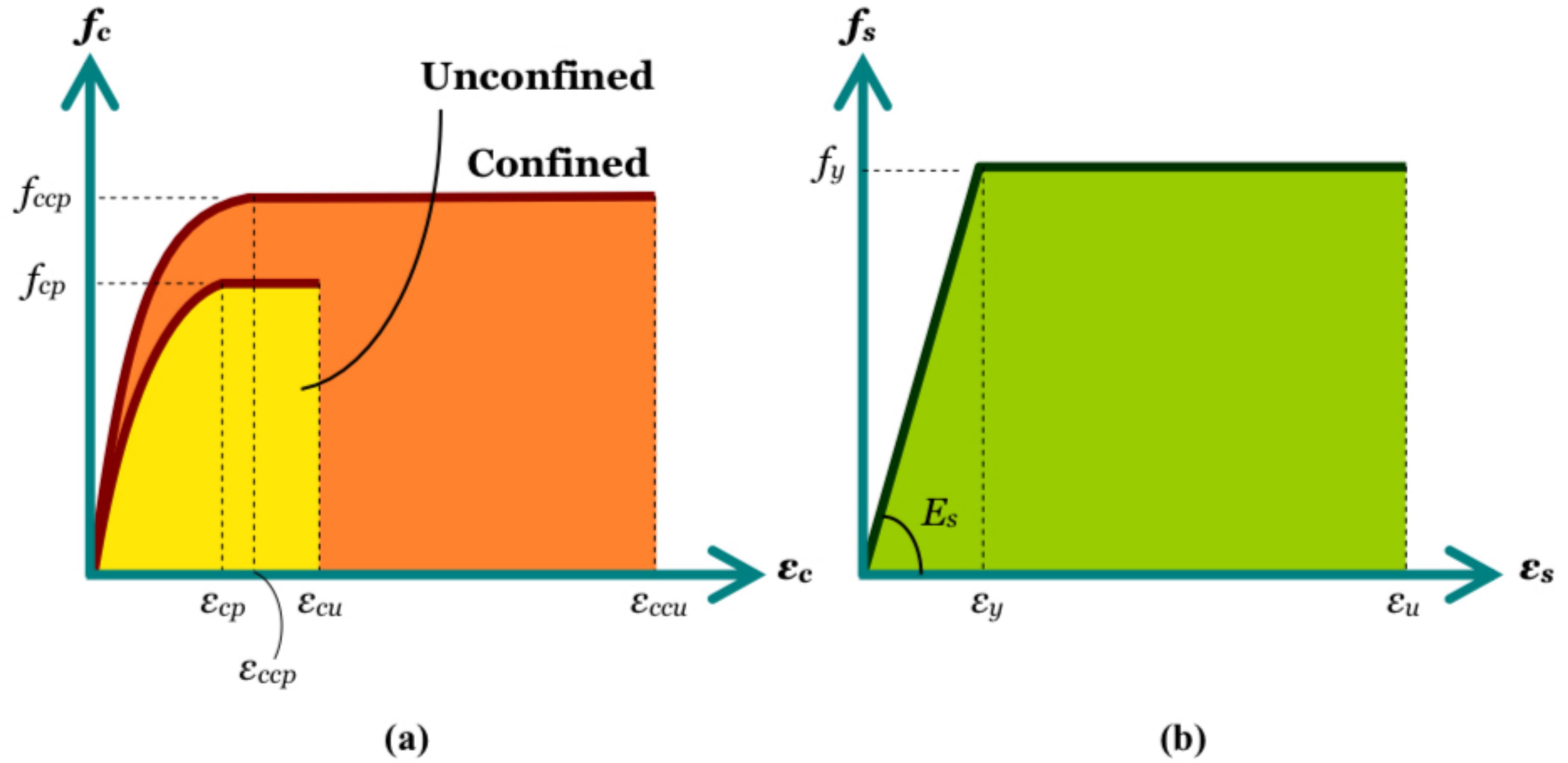

Figure H4.1: Stress-strain curve of: (a) concrete and (b) reinforcing steel

Table H4.1: Values of salient points of stress-strain curves

Concrete	***f_c at peak (MPa)***	***ε_c at peak f_c***	***ε_c at ultimate***
Unconfined	25.0	0.0020	0.0035
Confined	32.5	0.0025	0.0100
Steel	***f_y (MPa)***	***ε_y***	***ε_u***
Longitudinal	500	0.0025	0.1200

Unconfined concrete: $$f_c = \begin{cases} f_{cp}\left[2\left(\dfrac{\varepsilon_c}{\varepsilon_{cp}}\right)-\left(\dfrac{\varepsilon_c}{\varepsilon_{cp}}\right)^2\right] & : 0 \le \varepsilon_c \le \varepsilon_{cp} \\ f_{cp} & : \varepsilon_{cp} < \varepsilon_c \le \varepsilon_{cu} \end{cases} \quad \text{(H4.1(a))}$$

Confined concrete: $$f_c = \begin{cases} f_{ccp}\left[2\left(\dfrac{\varepsilon_c}{\varepsilon_{ccp}}\right)-\left(\dfrac{\varepsilon_c}{\varepsilon_{ccp}}\right)^2\right] & : 0 \le \varepsilon_c \le \varepsilon_{ccp} \\ f_{ccp} & : \varepsilon_{ccp} < \varepsilon_c \le \varepsilon_{ccu} \end{cases} \quad \text{(H4.1(b))}$$

Reinforcing steel: $$f_s = \begin{cases} E_s\varepsilon_s & : 0 \le \varepsilon_s \le \varepsilon_y \\ f_y & : \varepsilon_y \le \varepsilon_s \le \varepsilon_u \end{cases} \quad \text{(H4.2)}$$

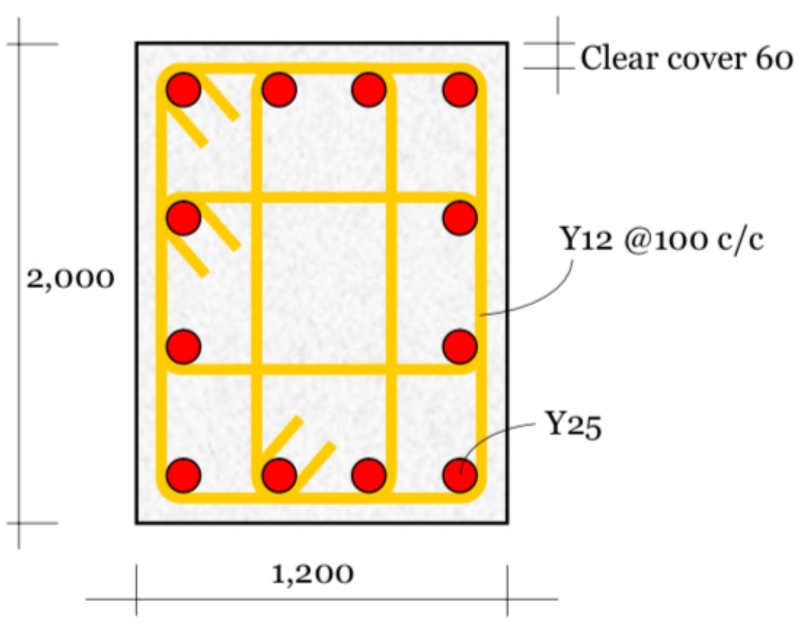

Figure H4.2: Cross-section geometry of RC pier (all dimensions are in mm)

20 Marks

H4.2 Axial Force – Bending Moment (P-M) **Interaction Diagram**

Write a computer program to draw the **Axial Force – Bending Moment** (P-M) **Interaction Diagram** for *case (a)* and *case (b)* given in **H4.1**. Mark the *axial force (P)* and *bending moment (M)* values obtained from the *moment-curvature analysis* of **H4.1** in the corresponding P-M interaction diagram. **Comment** on the results obtained.

10 Marks

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