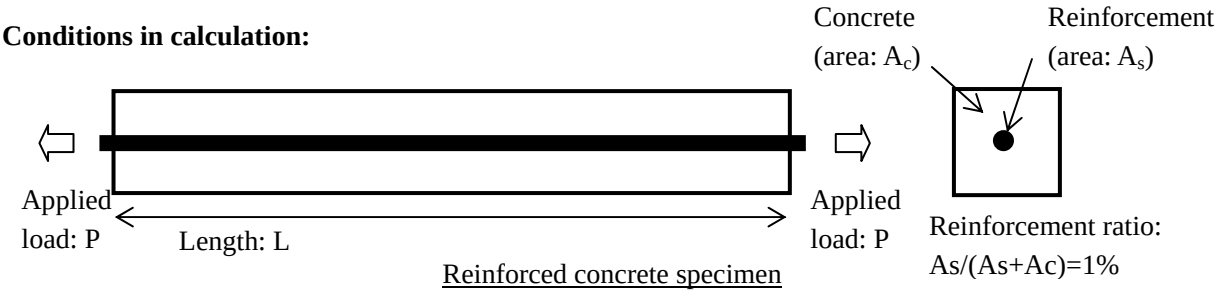
Numerical simulation of stress-strain curve of reinforcement in RC

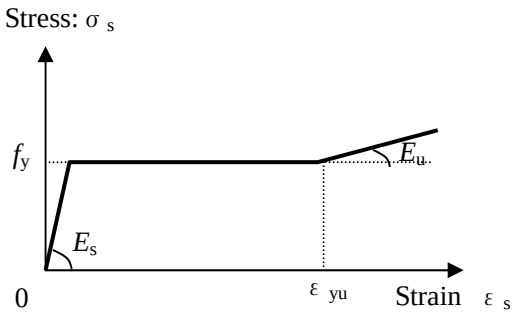
Stress-strain curve of reinforcement in RC (reinforced concrete) member – exactly speaking, stress and strain of reinforcement that are averaged in a control volume of concrete having several cracks – is different from that of bare reinforcement. A procedure to obtain this curve through experimental work has been already explained in the previous lecture.

The stress-strain curve of reinforcement in RC can be also evaluated by numerical simulation, in which 'stress distribution of reinforcement and concrete in RC' and '(average) stress-strain curve of concrete in RC' are assumed.

Conditions in calculation:



Reinforced concrete specimen



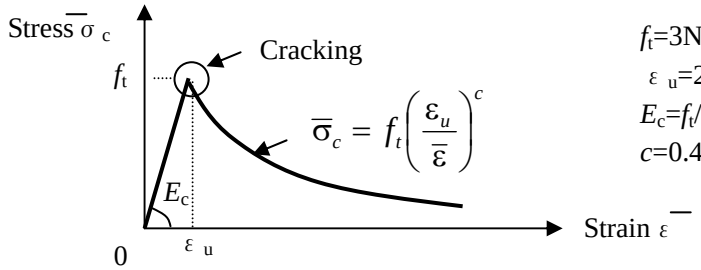
f_y=400N/mm^2
E_s=2×10^{5}N/mm^2
ε_{yu}=20000 μ
E_u=2×10^{4}N/mm^2

Stress-strain curve of bare reinforcement

Assumption for stress distribution of reinforcement and concrete:

- Stress gradient within cross-section is not considered: i.e., ideal uniaxial member
- Slip between reinforcement and concrete is not considered: i.e.. strains of reinforcement and concrete are the same value.
- Cracks are developed in constant intervals: i.e., smeared crack assumption
- Stress distribution of reinforcement after cracking can be expressed by cosine function with respect to longitudinal direction.

Stress-strain curve of concrete in RC:



f_t=3N/mm^2
ε_u=200×10^{-6}
E_c=f_t/ε_u
c=0.4

Average stress-strain curve (tension-stiffening model) of concrete in RC:

Assignment:

(1) Express σ_{smax} (stress of reinforcement at crack section) in terms of $\overline{\sigma}_c$ (average stress of concrete) and $\overline{\sigma}_s$ (average stress of reinforcement). Using σ_{smax}, express the yield stress of reinforcement in RC (the average stress of reinforcement when it yields at crack section) under the given condition.

(2) After yielding of reinforcement, average stress of reinforcement can be calculated as a function of average strain by following procedure:

① give average strain
② calculate average stress of concrete from ①
③ assume average stress of reinforcement
④ obtain stress distribution of reinforcement from ② and ③
⑤ obtain strain distribution of reinforcement from ④ and stress-strain relationship of bare reinforcement
⑥ calculate average strain from ⑤ by means of either numerical or analytical integration
⑦ Compare ① and ⑥. If ⑥ is equal to ①, assumed stress (③) is correct. If not, assume new average strain (③) and iterate the procedures ④⑤⑥ and ⑦.

By the above method, calculate average stress-strain curve of reinforcement in RC from the strain is zero up to about 20000 μ.

(3) Calculate average stress-strain curves of reinforcement in RC under the conditions that tensile strength of concrete f_t=1～3N/mm^2, reinforcement ratio 1～5% and parameter for bonding characteristic c=0.2～0.8. Based on the obtained results, discuss the effectiveness or sensitivity of these factors on average stress-strain curve of reinforcement in RC.

Note:

Computational results of (3) will be as shown below.
Of course, calculate by yourself!!