Nonlinear bond slip behavior modeled using plasticity

Assume that a bond behavior is governed purely by plasticity model with the following parameters:

$$\mathrm{E_b} = 100\ \mathrm{MPa/mm},\ \tau_0 = 10\ \mathrm{MPa},\ K = 10\ \mathrm{MPa/mm},\ \gamma = 5\ \mathrm{MPa/mm}$$

a) Plot the bond-slip law for a monotonic loading up to $s = 1.0$ mm, and determine the slope of the hardening range.

b) Calculate the total slip at the state with the bond stress $\tau = 15.0$ MPa.

c) Calculate the plastic slip at the states with the total slip $s = 0.1$ mm, and $s = 0.6$ mm.

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a) Plot the bond-slip law for a monotonic loading up to $s = 1.0$ mm, and determine the slope of the hardening range.

Solution:

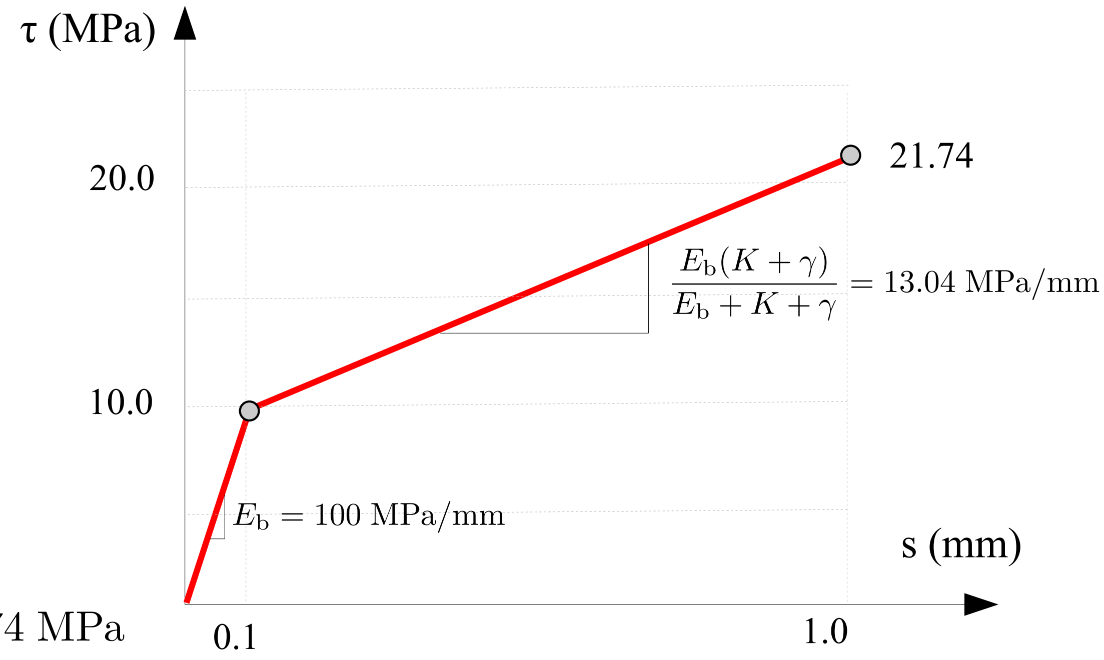
The slope of the hardening range

$$\frac{E_\mathrm{b}(K+\gamma)}{E_\mathrm{b}+K+\gamma} = \frac{100\ (10+5)}{100+10+5} = 13.04\ \mathrm{MPa/mm}$$

The bond stress at $s = 1.0$ mm

$$\tau(s=1.0) = \tau_0 + \frac{E_\mathrm{b}(K+\gamma)}{E_\mathrm{b}+K+\gamma} \times (1.0 - s_0)$$

$$\tau(s=1.0) = 10 + \frac{100(10+5)}{100+10+5} \times (1.0-0.1) = 21.74\ \mathrm{MPa}$$



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b) Calculate the total slip at the state with the bond stress $\tau = 15.0$ MPa.

Solution:

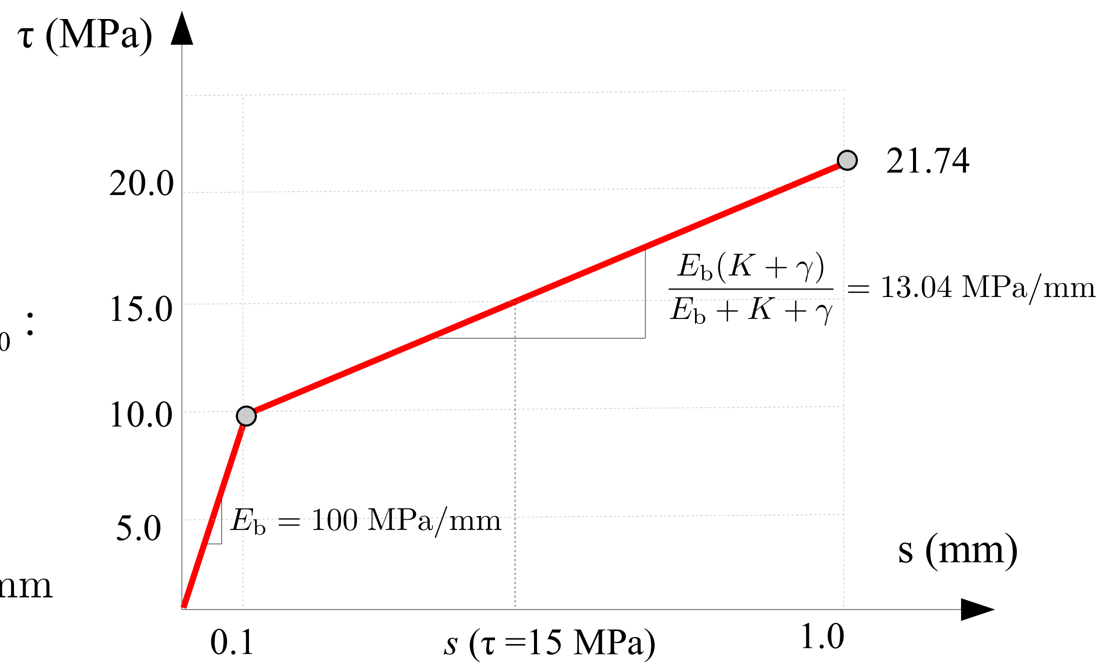
The bond stress in the range $s \geq s_0$:

$$\tau(s) = \tau_0 + \frac{E_\mathrm{b}(K+\gamma)}{E_\mathrm{b}+K+\gamma} \times (s - s_0)$$

The total slip for a given bond stress in the range $s \geq s_0$:

$$s(\tau) = s_0 + (\tau - \tau_0) \times \frac{E_\mathrm{b}+K+\gamma}{E_\mathrm{b}(K+\gamma)}$$

$$s(\tau = 15) = 0.1 + (15 - 10) \times \frac{100+10+5}{100(10+5)} = 0.483\ \mathrm{mm}$$



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c) Calculate the plastic slip at the states with the total slip $s = 0.1$ mm, and $s = 0.6$ mm.

Solution:

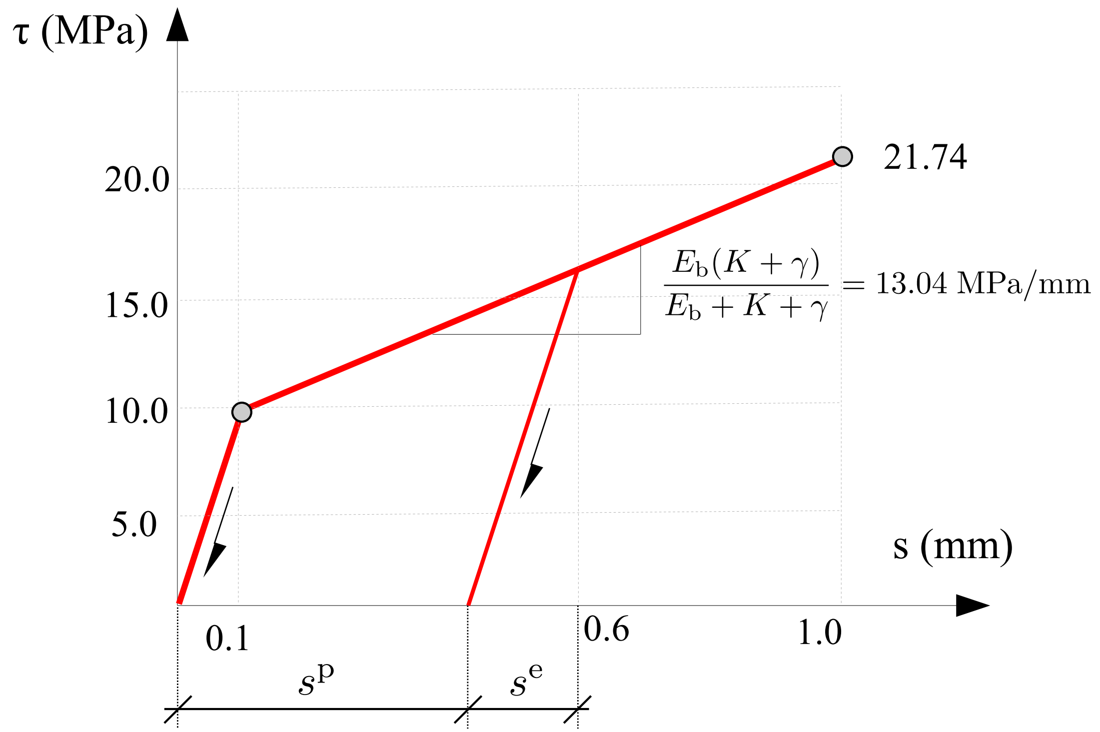
- at the slip $s = 0.1$ ⟶ The plastic slip $s^p = 0.0$

- at the slip $s = 0.6$

$$\tau(s) = \tau_0 + \frac{E_b(K+\gamma)}{E_b + K + \gamma} \times (s - s_0) = 16.52\ \mathrm{MPa}$$

$$\mathrm{s^e}(s = 0.6) = \frac{\tau(s=0.6)}{E_b} = \frac{16.52}{100} = 0.165\ \mathrm{mm}$$

$$s^p(s = 0.6) = s - s^e(s = 0.6)$$
$$= 0.6 - 0.165 = 0.435\ \mathrm{mm}$$



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