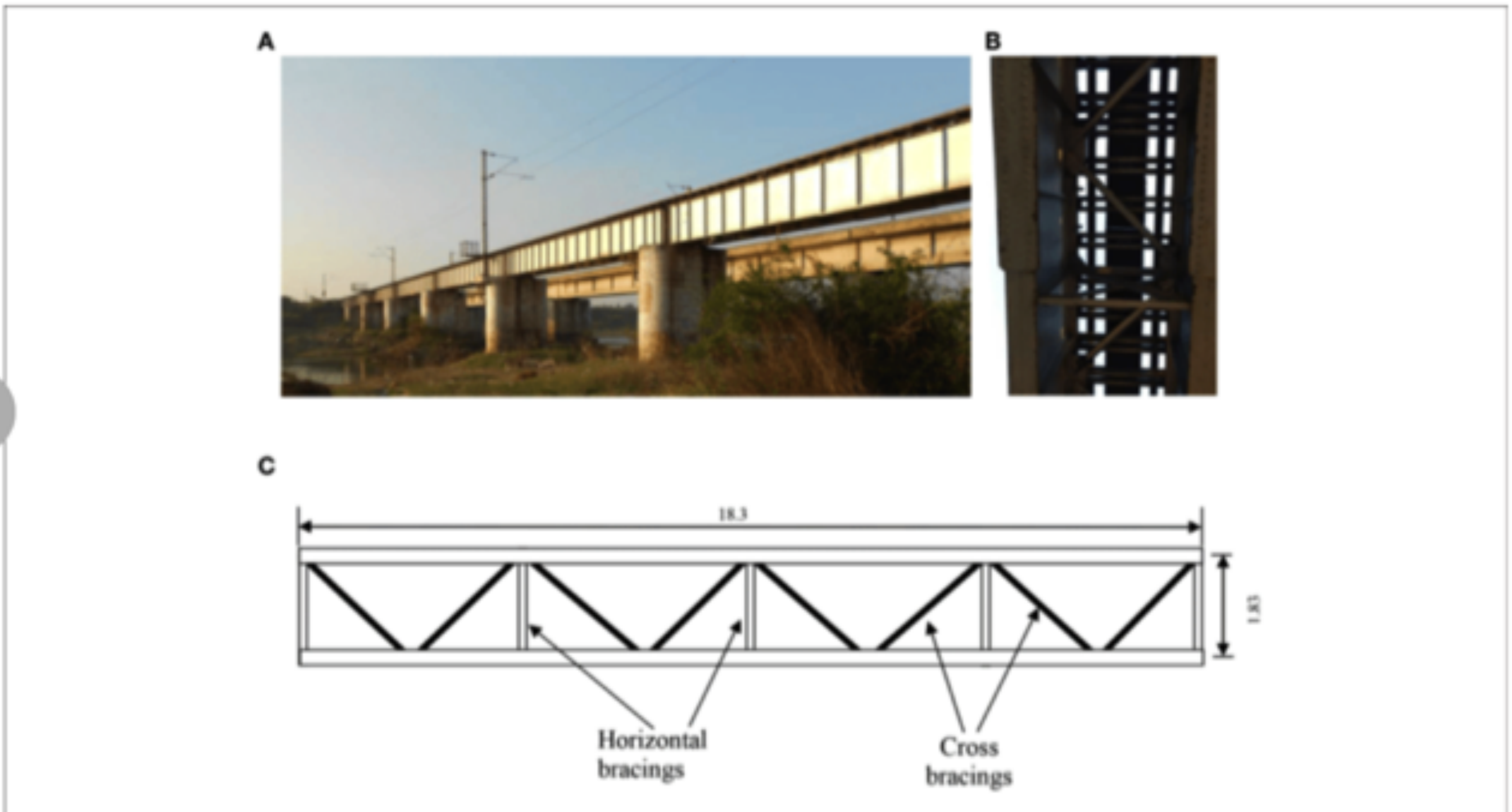
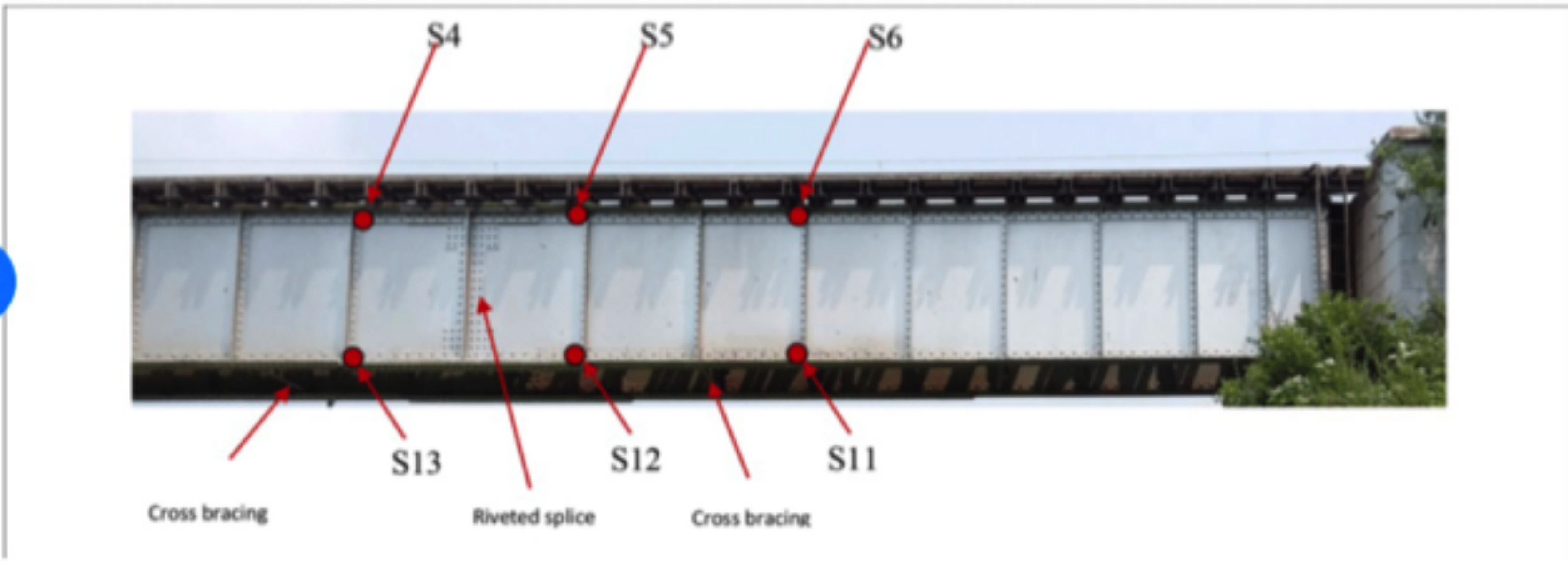
AS3520

Lecture 2

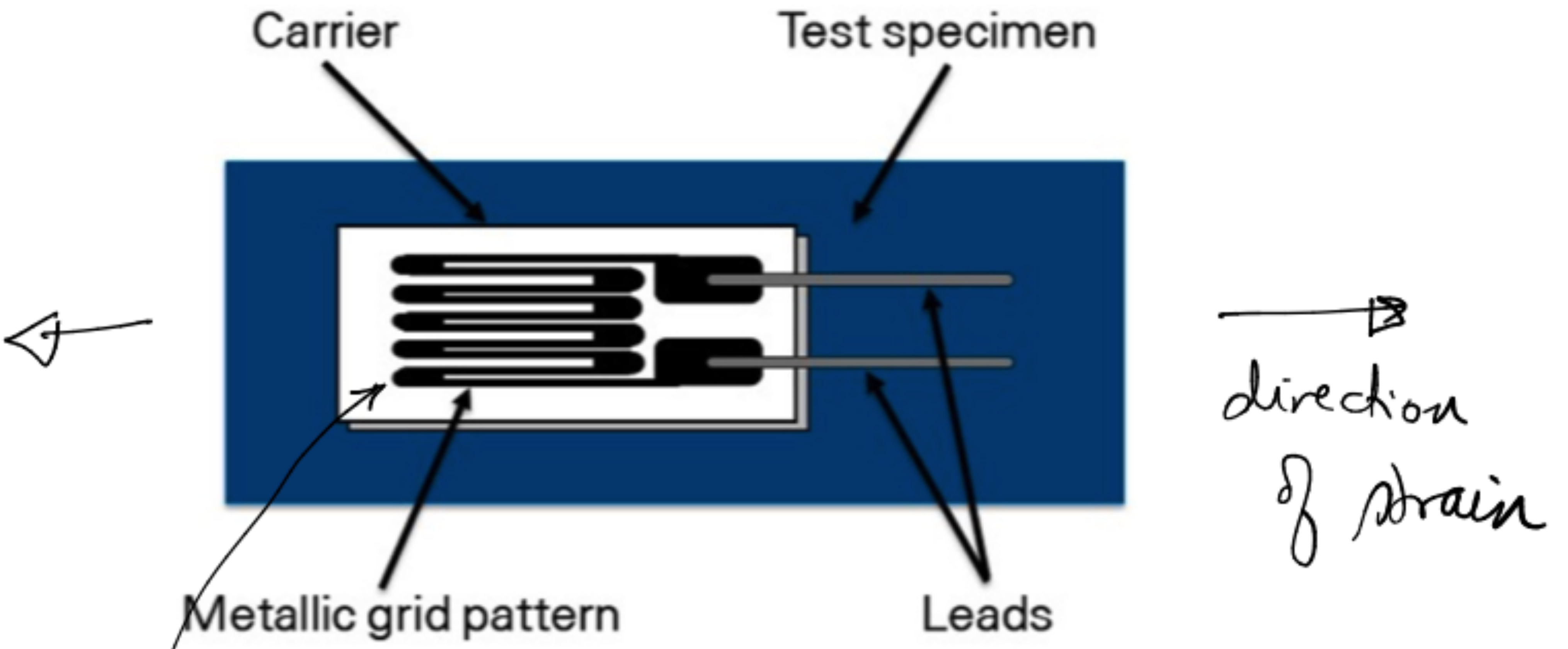
Applications of strain gauges



| Ponneri railway bridge. (A) Photo of the bridge. (B) View from bottom. (C) Plan.



| Ponneri bridge-connection details.



$$R = \frac{\rho l}{A}$$

when the base (blue) strains,
polyimide strains,
metal grid pattern strains.
l changes $\Rightarrow$ R changes.

Greater $l \Rightarrow$ greater $\Delta l \Rightarrow$
greater $\Delta R \Rightarrow$ a more sensitive guage.

Wires produced by photoengraving.

↳ to minimize A

| thickness : 3.8 μm to 5 μm.
| breadth : 13 μm.

$R = 120\,\Omega$

For typical values of strain,

$$2 \times 10^{-4}\,\Omega \le \Delta R \le 2.4\,\Omega$$

The external circuitry which measures resistance should have a sensitivity of $\sim 10^{-4}\,\Omega$.

Temperature Effect on ΔR

$$R = \frac{\rho l}{A}$$

Temperature induces an "apparent" strain in the strain guage measurement.

$$-\frac{\Delta A}{A^2}$$

$$\Delta R = \frac{\Delta \rho\, l}{A} + \frac{\rho\, \Delta l}{A} + \underbrace{\rho l \Delta (A^{-1})}_{\text{neglected.}}$$

Additionally the base / substrate may expand thermally.

$$l_f = l_0 (1 + \alpha \Delta T)$$

coeff. thermal expansion.

temp change

$$\Delta l = l_0 \alpha \Delta T$$

$$\Delta R = \frac{\Delta \rho\, l}{A} + \frac{\rho_0 l_0 \alpha \Delta T}{A}$$

$\Delta \rho$ = change in resistivity due to change in temperature.

$$\rho_f = \rho_0 (1 + \gamma \underbrace{\Delta T})$$

change in temperature.

for Constantan

$\gamma = 40 \times 10^{-6} / {}^\circ C$

$$\frac{\Delta \rho}{\rho_0} = \gamma \Delta T$$

$$\frac{\Delta R}{R} = \frac{\frac{\cancel{\rho_0} \gamma \Delta T \cancel{l_0}}{\cancel{A}} + \frac{\cancel{\rho_0} \cancel{l_0} \alpha \Delta T}{\cancel{A}}}{\frac{\cancel{\rho_0} \cancel{l_0}}{\cancel{A}}}$$

$$\frac{\Delta R}{R_T} = (\gamma + \alpha)\,\Delta T.$$

From lecture 1, we know:

$$\frac{\Delta R}{R} = S\,\varepsilon$$

sensitivity or gage factor.

$$S\,\varepsilon = (\gamma + \alpha)\,\Delta T$$

$$\varepsilon_{apparent} = (\gamma + \alpha)\,\Delta T$$

For constantan $\gamma + \alpha \approx 0$.

"self-temperature compensating material".

Tranverse Strains.

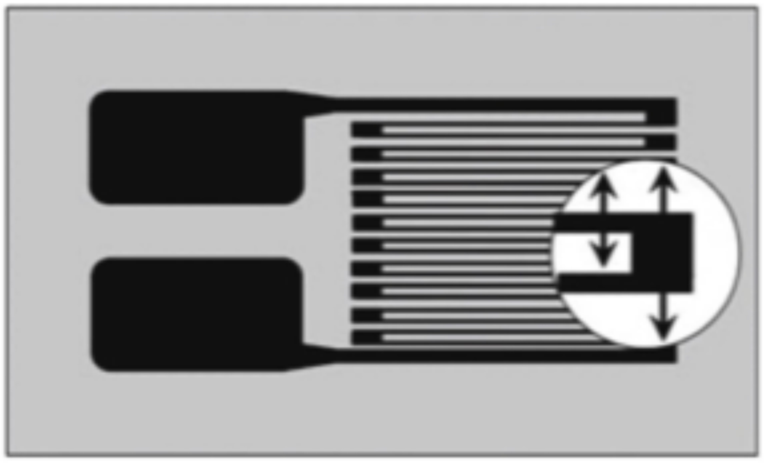


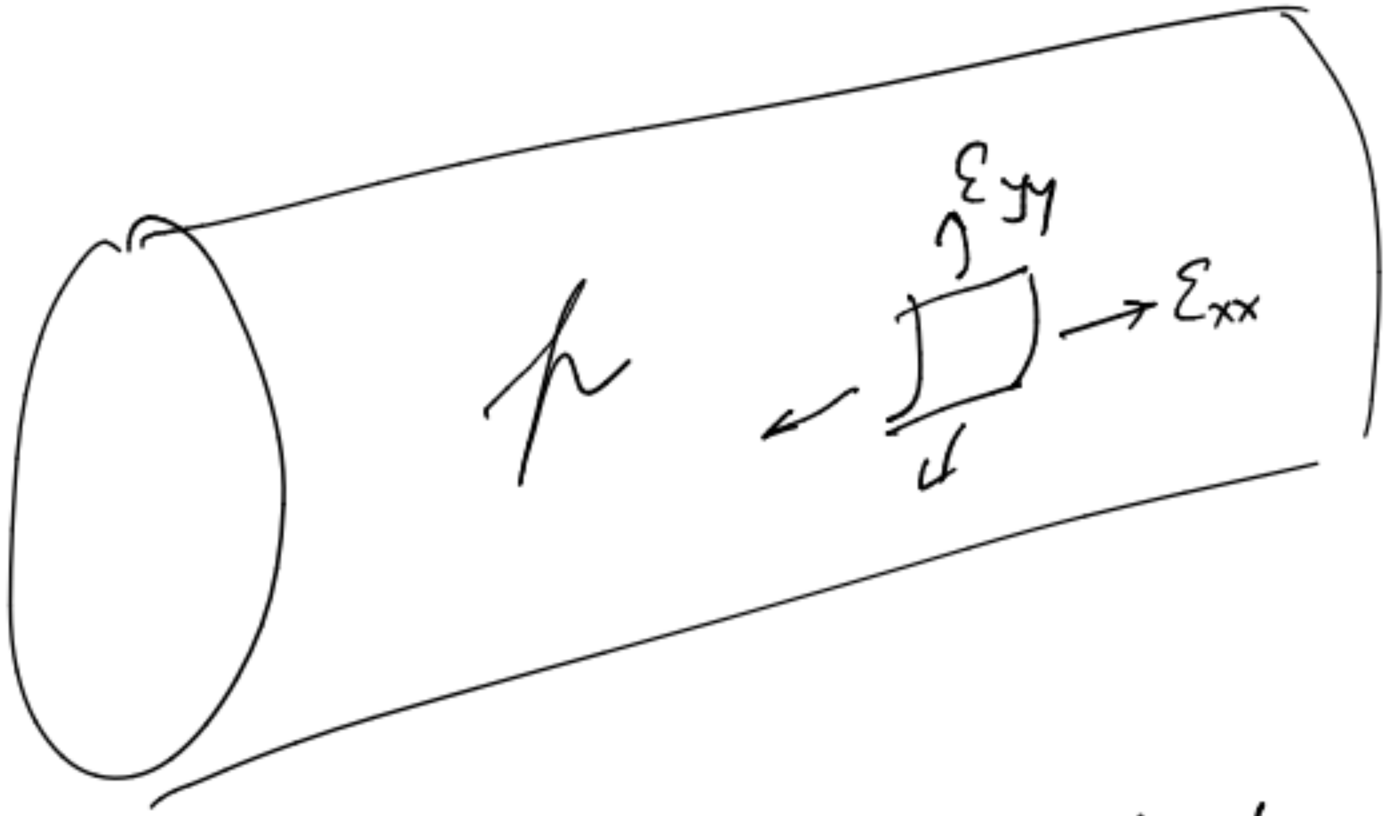
Fig. 2.4 Transversal strain on longitudinal grid elements and on the inversion portions of the conductor

uniaxial strain

Tranverse strain thru' Poisson's effect

'S' for a guage already accounts for tranverse strain.

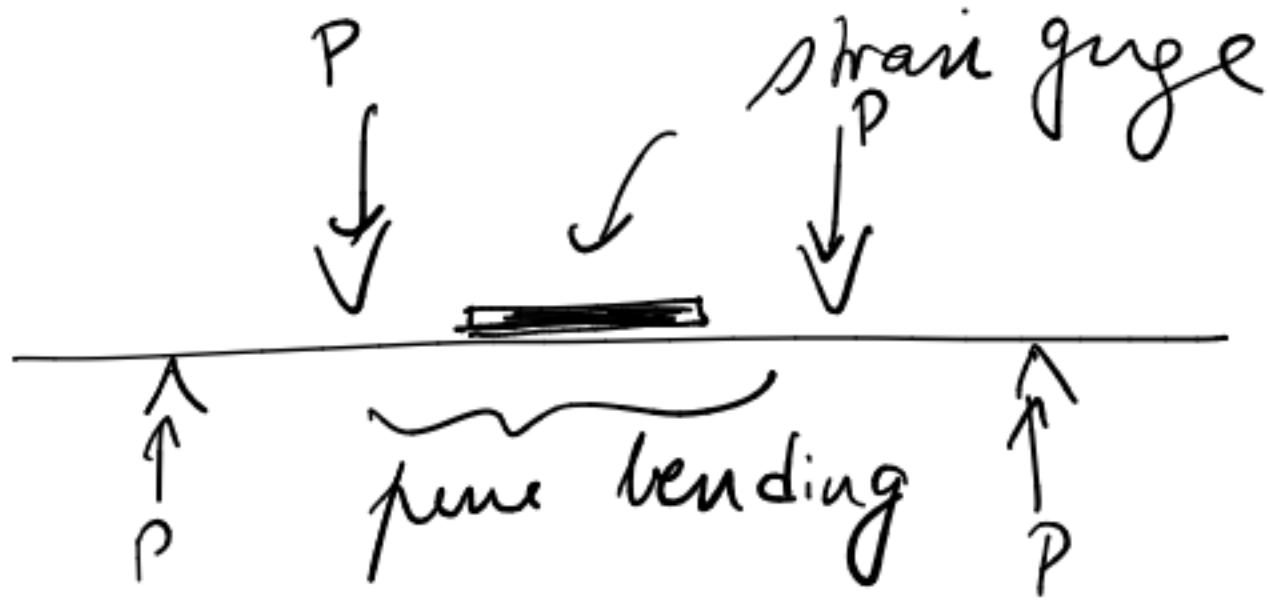
'S' is determined under uniaxial loading only.



often strain conditions tend to be biaxial.

Q: How to correctly measure longitudinal strain under biaxial loading conditions?

process of find S / calibration:



$$R = R_l + R_t$$

$$\Rightarrow \Delta R = S\varepsilon_l R_l + S\varepsilon_t R_t$$

$$\Rightarrow \frac{\Delta R}{R} = \underbrace{\frac{S R_l}{R}}_{S_l} \varepsilon_l + \underbrace{\frac{S R_t}{R}}_{S_t} \varepsilon_t$$

longitudinal sensitivity

transverse sensitivity

$$\Rightarrow \frac{\Delta R}{R} = S_l \left(\varepsilon_l + K_t \varepsilon_t \right)$$

$$K_t = \frac{S_t}{S_l}$$

under uniaxial condns.

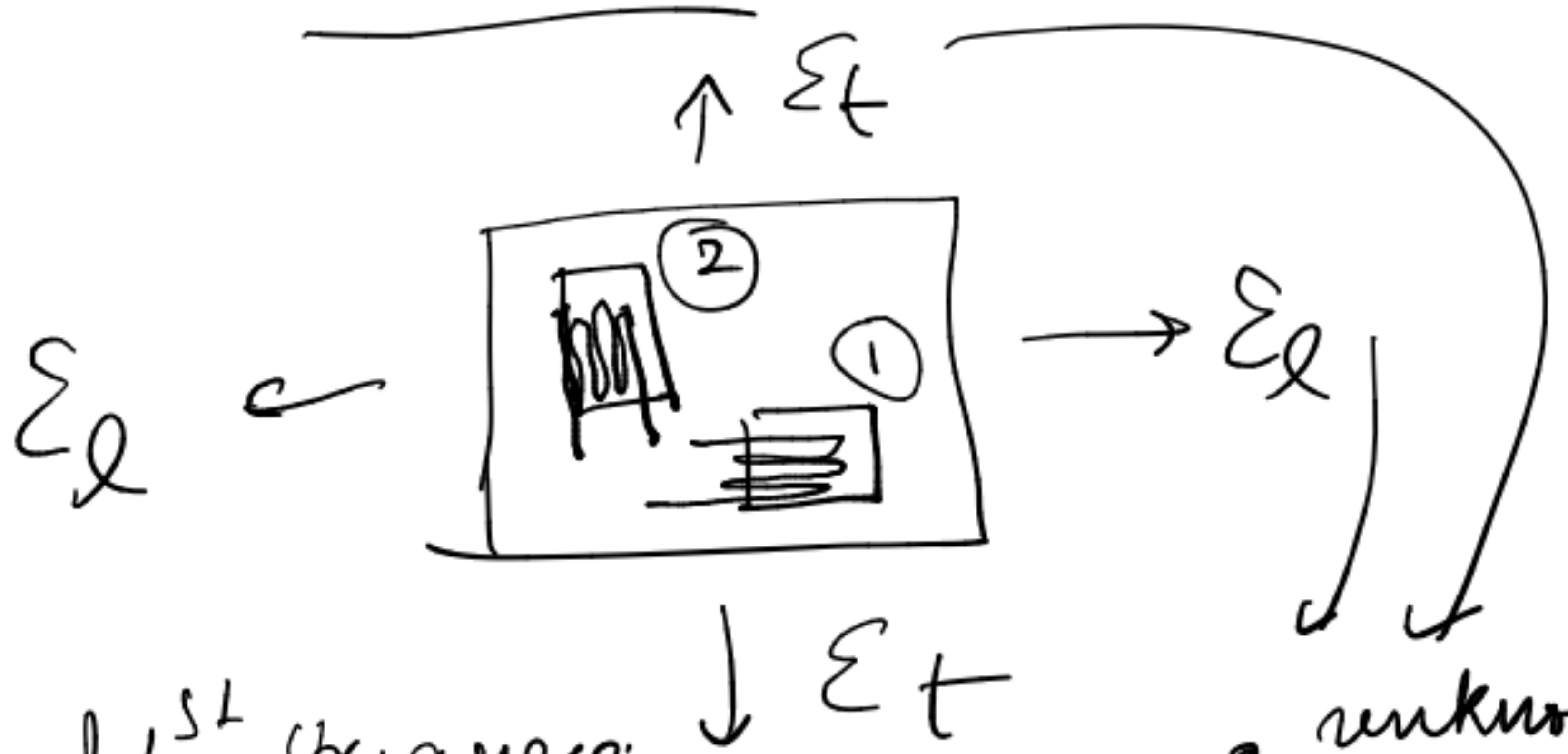
$$\varepsilon_t = -\nu \varepsilon_l$$

$$\frac{\Delta R}{R} = \underbrace{S_l}_{} \varepsilon_l \underbrace{(1 - \nu K_t)}_{} = K \varepsilon_l$$

$$S_l (1 - \nu K_t) = K$$

K = accounts for Poisson contraction also under uniaxi loading.
= is affected by the Substrate on which calibration is done.

Actual Biaxial Strain State



Measure of 1st str. guage:

$$\frac{\Delta R_1}{R_1} = S_l \varepsilon_l + S_t \varepsilon_t = K \hat{\varepsilon}_1$$

measured

known

$$\frac{\Delta R_2}{R_2} = S_l \varepsilon_t + S_t \varepsilon_l = K \hat{\varepsilon}_2.$$

$\hat{\varepsilon}_1$, $\hat{\varepsilon}_2$ are not the actual longl & transverse strains.

$$\begin{cases} S_l\,\varepsilon_l + S_t\,\varepsilon_t = K\hat{\varepsilon}_1 \\ S_t\,\varepsilon_t + S_l\,\varepsilon_l = K\hat{\varepsilon}_2 \end{cases}$$

$$S_l\left(\varepsilon_l + K_t\,\varepsilon_t\right) = S_l(1-\nu K_t)\,\hat{\varepsilon}_1$$

$$S_l\left(\varepsilon_t + K_t\,\varepsilon_l\right) = S_l(1-\nu K_t)\,\hat{\varepsilon}_2$$

unknowns

measured.

$$\boxed{\begin{aligned} \varepsilon_l &= \frac{1-\nu K_t}{1-K_t^2}\left(\hat{\varepsilon}_1 - K_t\,\hat{\varepsilon}_2\right) \\ \varepsilon_t &= \frac{1-\nu K_t}{1-K_t^2}\left(\hat{\varepsilon}_2 - K_t\,\hat{\varepsilon}_1\right) \end{aligned}}$$