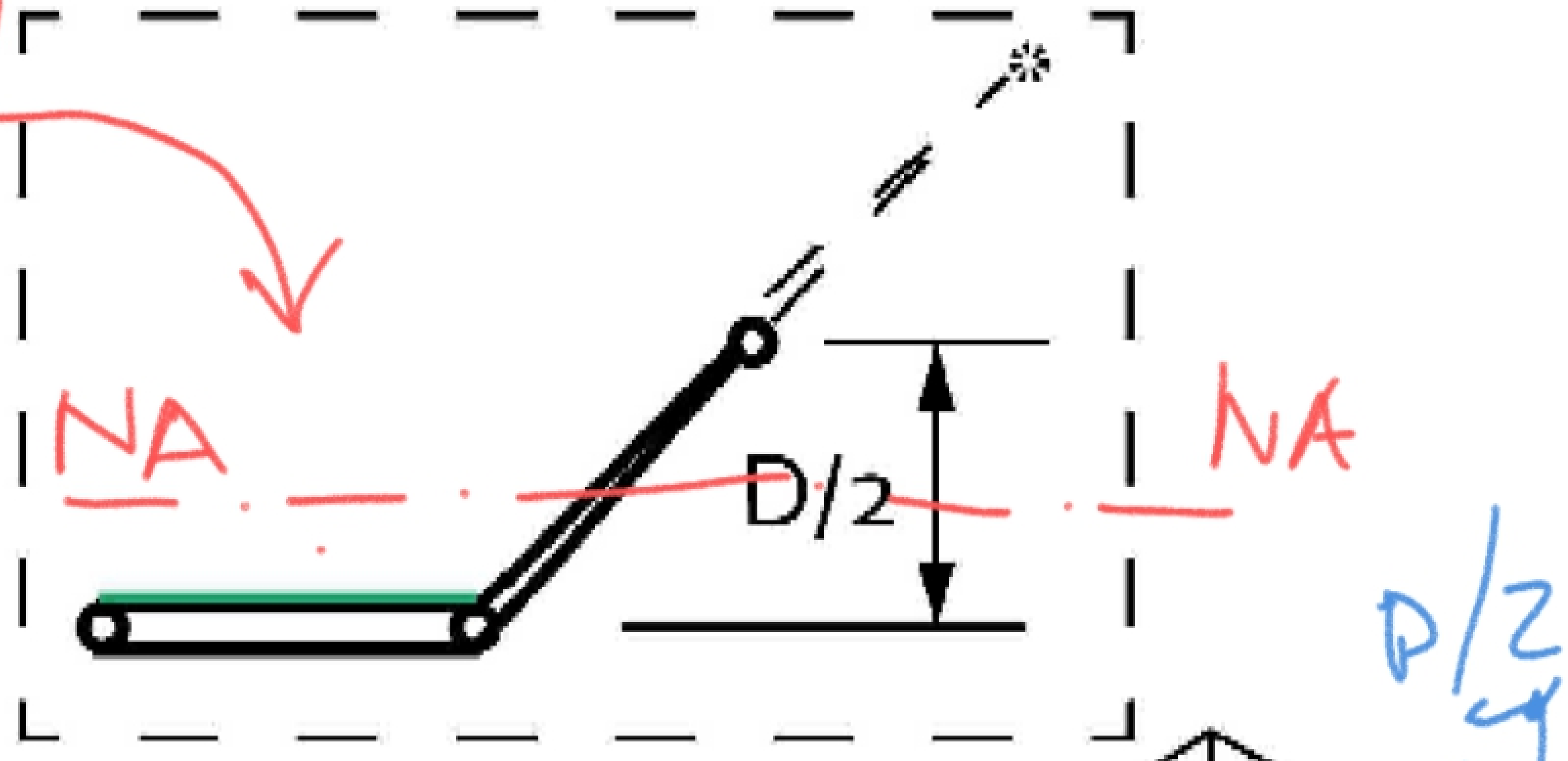
Merchants' Bridge Castlefield Approximate Analysis Hints

Check for two conditions:

1. Straight Span (Pure Bending) as idealised beam (Beam depth *overall = 0.5 arch rise*).

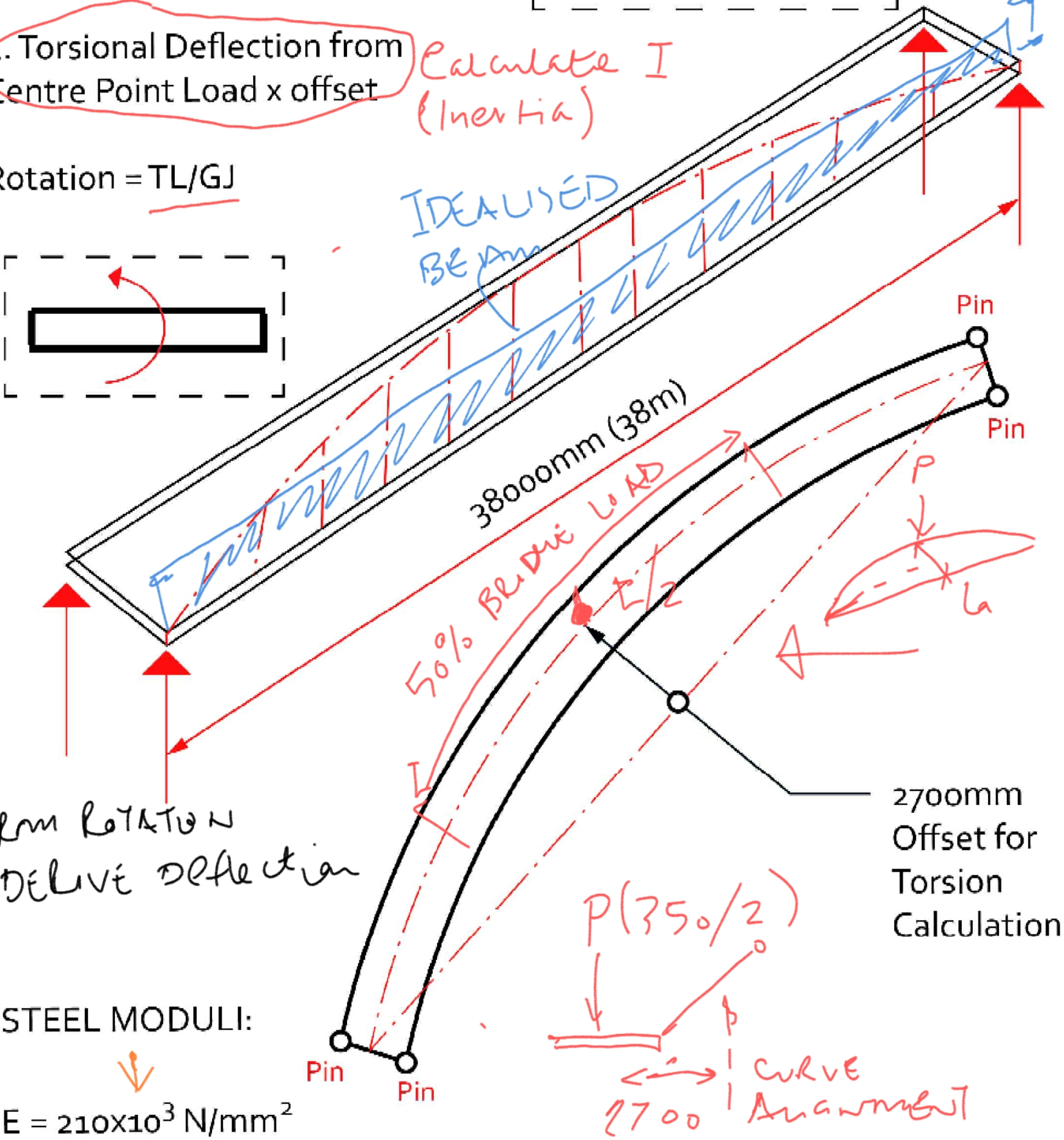


Bending Deflection = $5wL^4/384EI$

2. Torsional Deflection from Centre Point Load x offset

Calculate I (Inertia)

Rotation = TL/GJ



FROM ROTATION DERIVE DEFLECTION

STEEL MODULI:

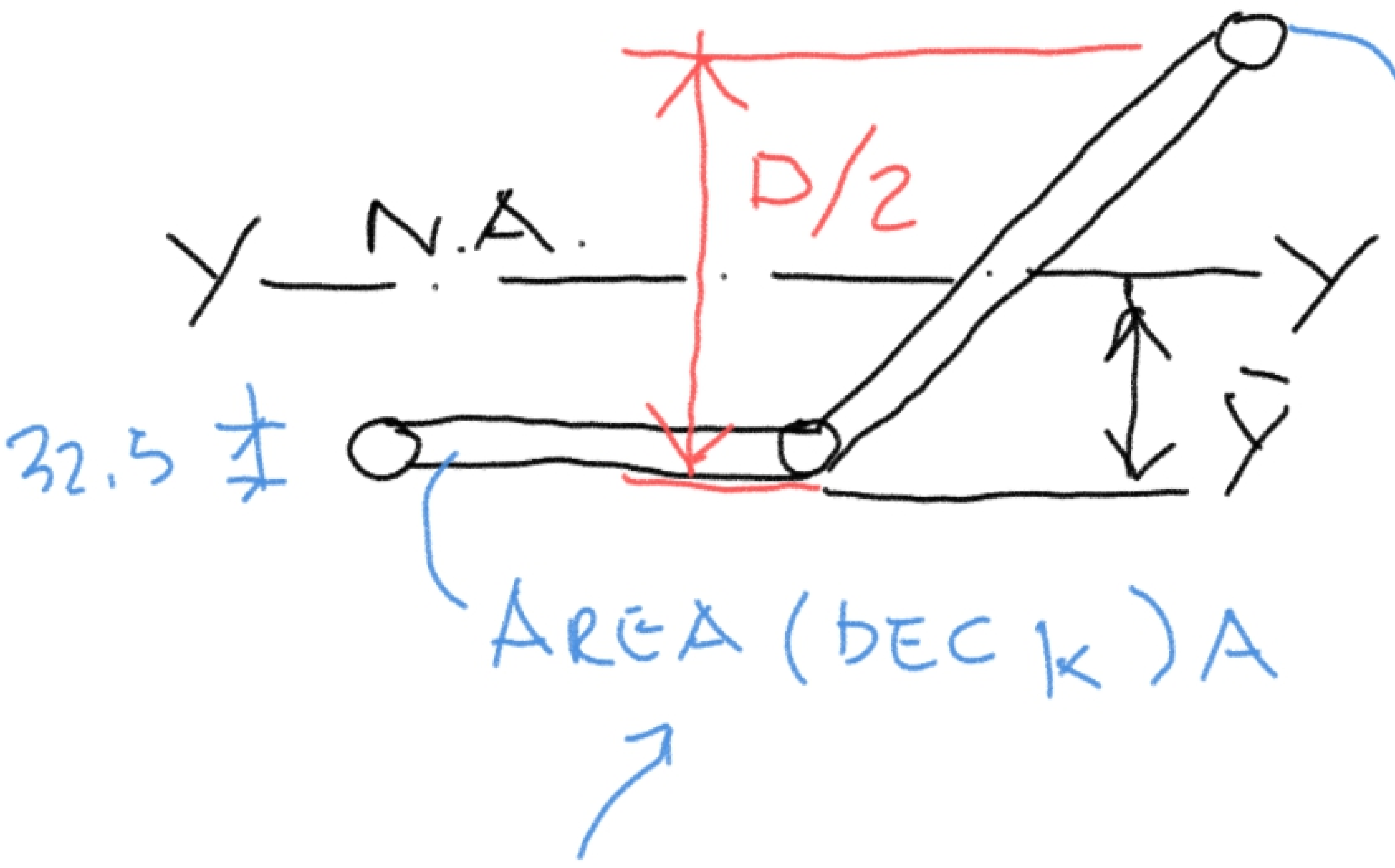
$E = 210 \times 10^3 \ N/mm^2$

$G = 78 \times 10^3 \ N/mm^2$

Merchants' Bridge

ROUGH CALCULATIONS

1. Assess deflection (assume srraight bridge)



- WORKOUT I_y (INERTIA)
- ASSUME BEAM DEPTH D/2 (D = ARCH RISE)

FIND $\bar{y}$ ... $A = 2000 \times 1.0 \times 2 + 122 \times 2 = 644\,cm^2$

$$\bar{y} = \frac{644 \times 32.5/2 + 122 \times (365/2)}{(644 + 122)} = 42.7\,cm \sim 430\,mm$$

(D/2 = 365/2)

$\therefore I_y = [644 + (43 - 32.5)^2 + 122\,(365/2 - 43)^2]$
$= 2.42 \times 10^6\,cm^4$
$= 24.2 \times 10^9\,mm^4$ ($\times 10^4$ conversion)

Simply supported Deflection $= 5wL^4/384EI$

where $w = 350/38/2$
$= 4.6\,kN/m$

. . . .

Merchants' Bridge

ROUGH CALCULATIONS

Deflection (bending) continued . . . .

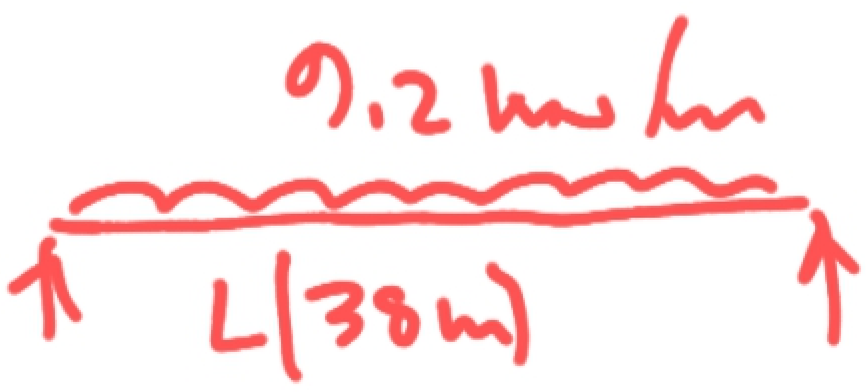
Deflection

$\Delta_n(DL) = 5wL^4/384EI \rightarrow w = 4.6\,kN/m^2$

$= 4.6 \times 2$

$= 9.2\,kN/m$

Line load



$$\therefore \Delta_n = \frac{5 \times 9.2 \times 38000^4}{384 \times 210E3 \times 24.2 \times 10^9} = 49\,mm$$

Live ($\Delta_n(LL)$) Pro-Rata from DEAD

$$\Delta_n(\text{Live } 10\%)_{LL} \sim \left(\frac{3}{4.6} \times 49\right) / 10 = 3\,mm$$

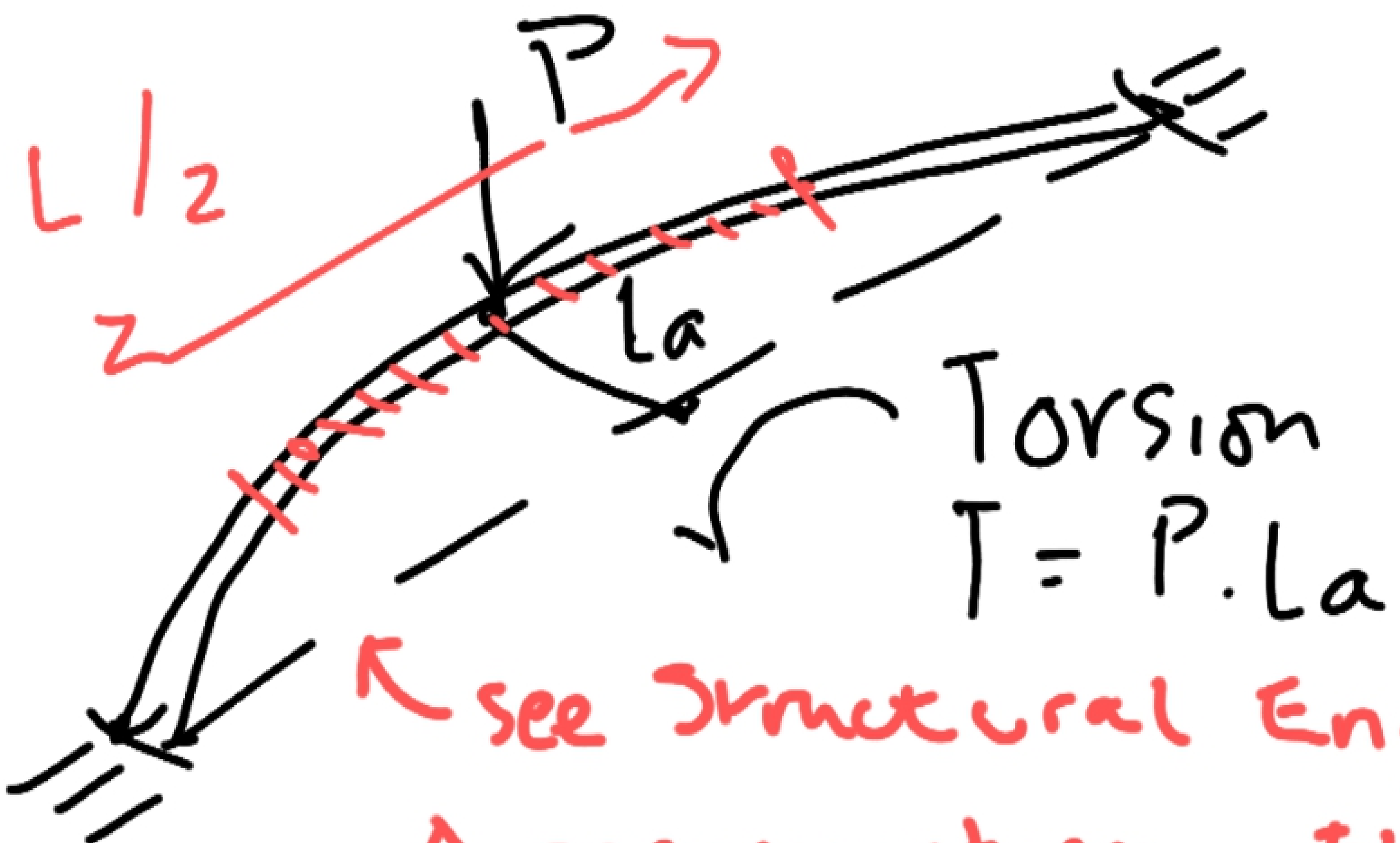
$$\text{TOTAL }(DL + 10\% LL)\ \Delta_n = 49 + 3$$

$$= 52\,mm$$

. . . .

Merchants' Bridge
ROUGH CALCULATIONS

1. TORSION – See hint sheet



from hint sheet

– $L_a = 2.7$ m (2700 mm)

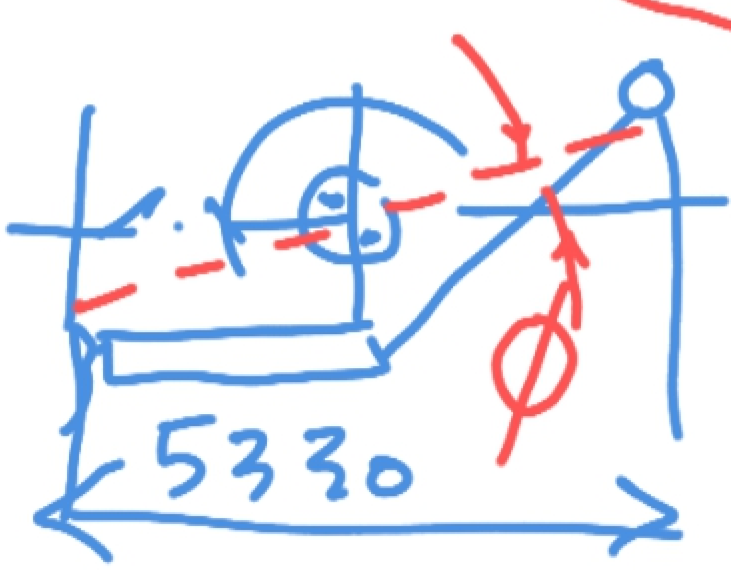
↖ see Structural Engineering Art & Approximation – FIGURE 2.9.17, pg. 109

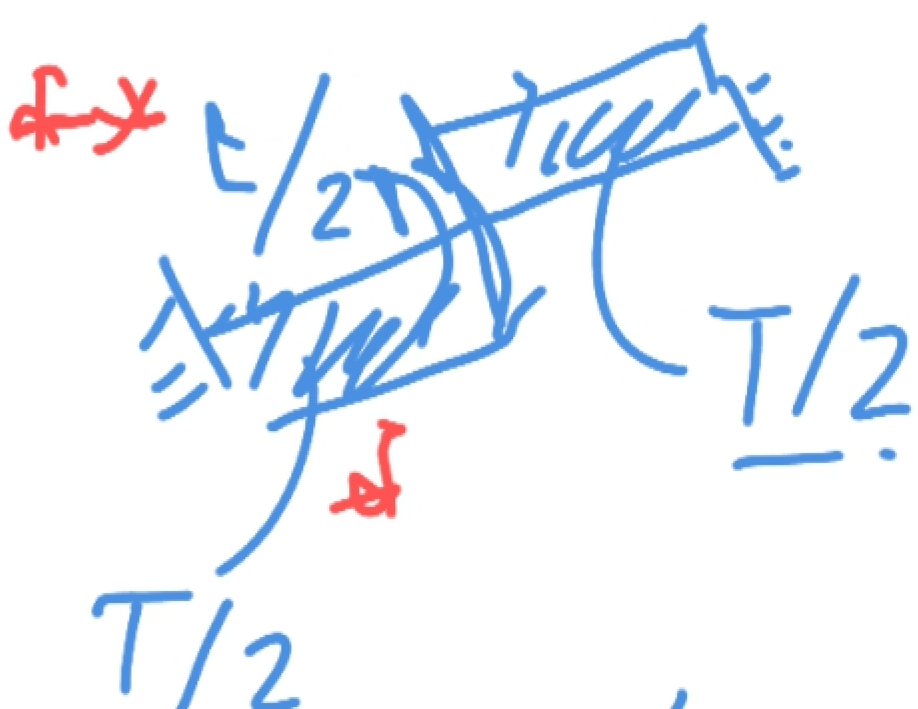
P – take Dead load over ½ span

i.e. $P = (350/2) \approx 175$ kN
kN

$\therefore T = P.L_a = 175 \times 2.7 = 473$ kNm

Rotation (ϕ)





TORSION DISTRIBUTION

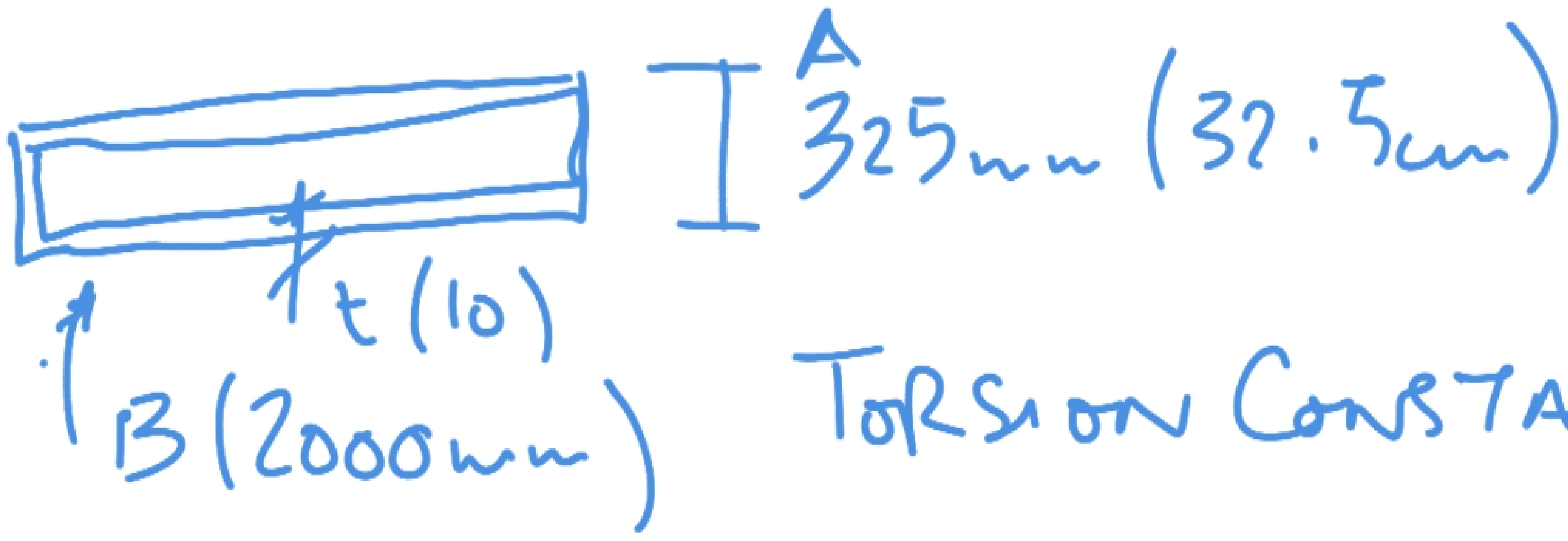
$$\phi = TL/GJ = \frac{(473E6)/2 \times 38000/2}{78000 \times J}$$

see overleaf

Merchants' Bridge

ROUGH CALCULATIONS

Torsion continued . . . .



TORSION CONSTANT (J)

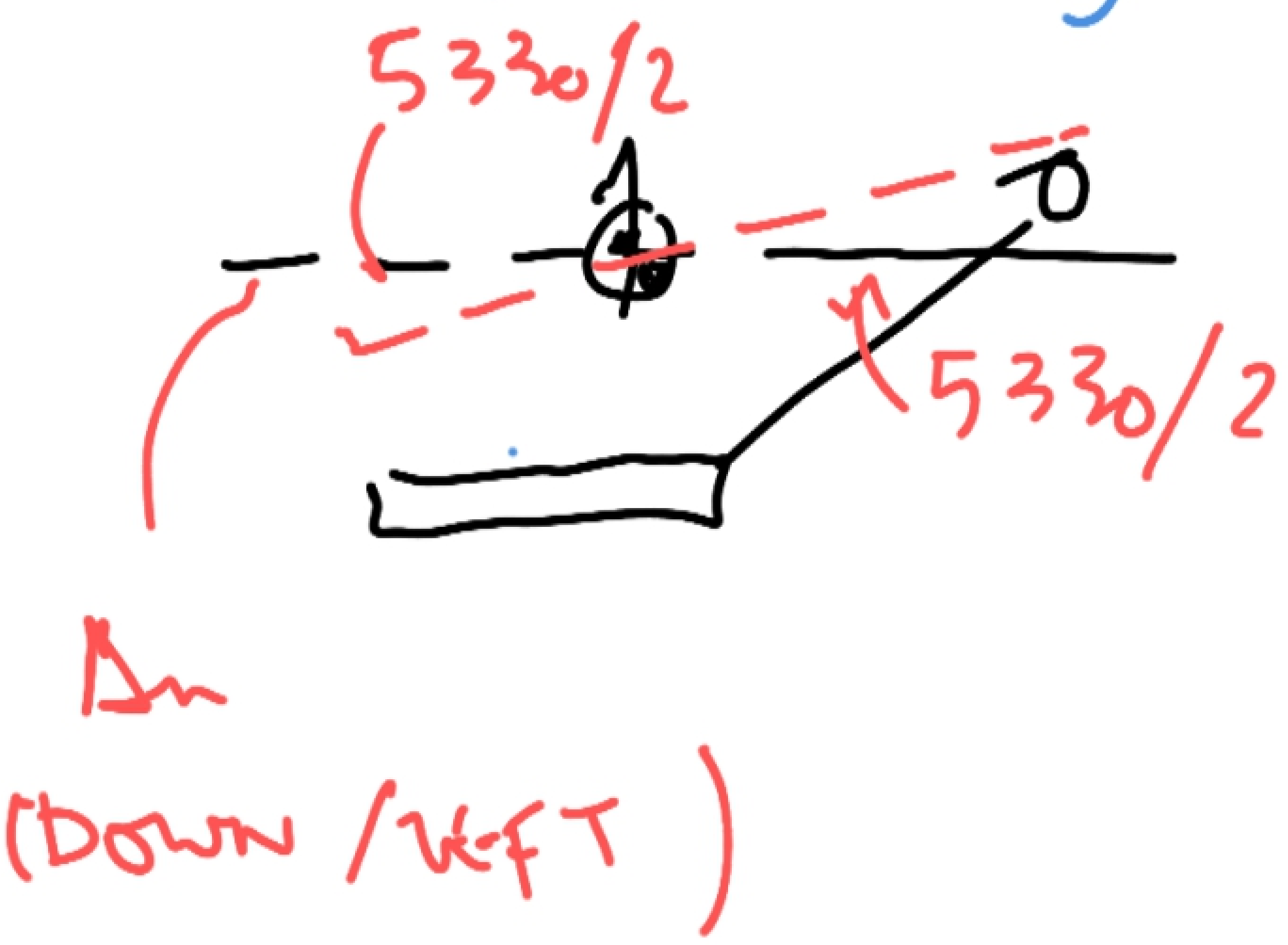
FOR HOLLOW (THIN WALL) BOX :

$$J \approx \frac{2t^2A^2B^2}{t(A+B)} = \frac{2\times10^2\times325^2\times2000^2}{10\,(2000+325)}$$

$$= 3.63E9\ mm^4\ (363\times10^3\ cm^4)$$

$\therefore$ from previous sheet

$$\phi = TL/GJ = \frac{(473E6/2\times38000/2)}{78E3\times3.63E9} = 0.015\ \text{radians}$$



Δ_n = WIDTH/2 × ϕ

= 5330/2 × 0.015

= 40mm (DEAD)

Merchants' Bridge

ROUGH CALCULATIONS

TORSION CONTINUED . . . .

TORSION Δ_n (10% LL) obtain PRO-RATA . . .

Δ_n (10% LL) $\sim (3/4.6 \times 40)/10 = 2.6$ mm ~ 3

TOTAL TORSION COMPONENT Δ_n =

$= \Delta_n$ (DL + 10% LL) $= 40 + 3 = 43$ mm

ADD (FROM PREVIOUSLY) BENDING Δ_n . . . .

TOTAL COMBINED DEFLECTION $= 51 + 43$
$= 94$ mm

FUNDAMENTAL NATURAL FREQUENCY
from briefing sheet

$f_n \sim 18/\sqrt{\delta} = 18/\sqrt{94} = 1.9$ Hz (HERTZ) cycles/second

In situ reading (vibrate-it App)
SIMILAR (See website)

CLOSE TO ESTIMATE

. . . .

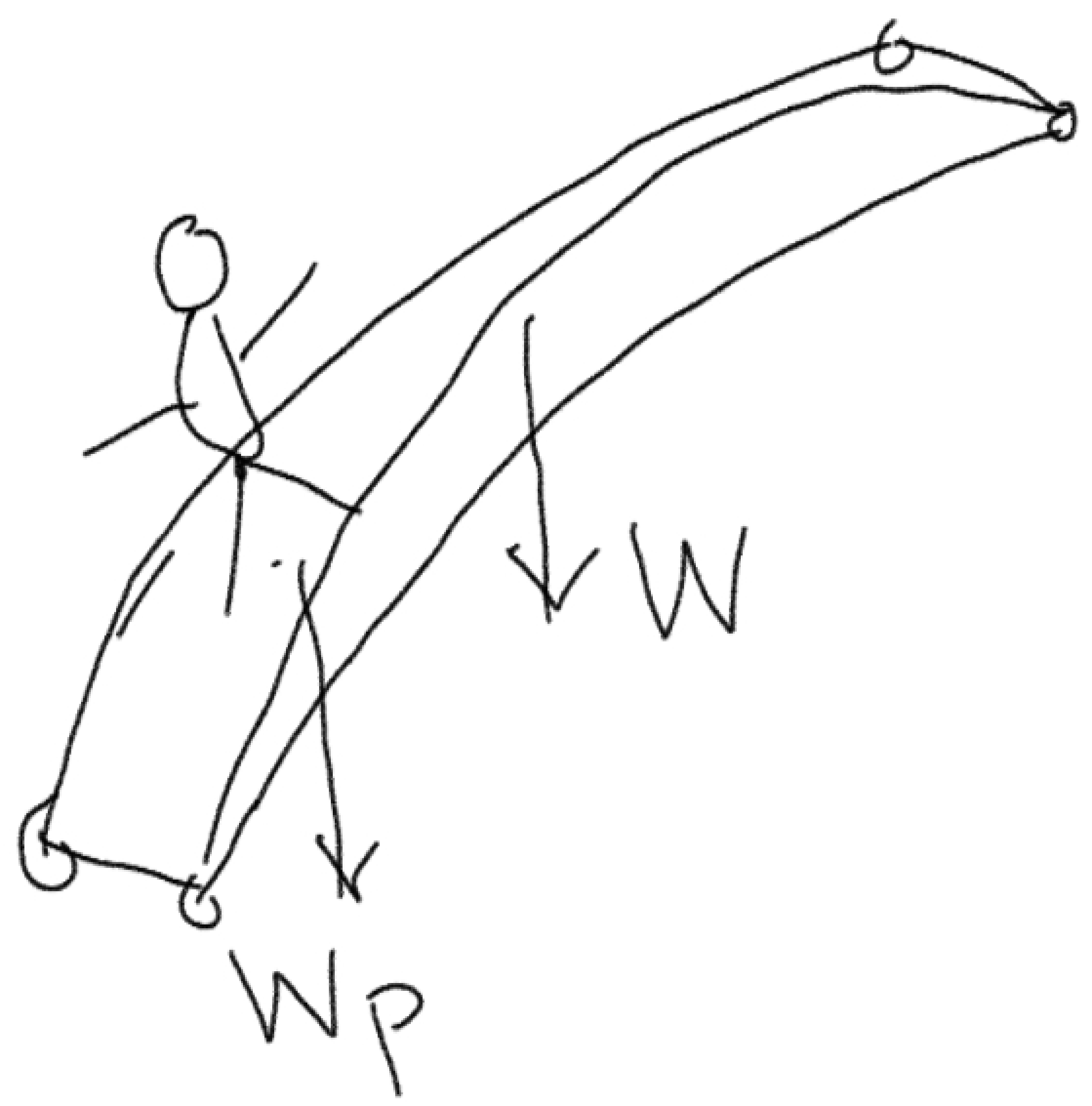
Merchants' Bridge

ROUGH CALCULATIONS

APPROXIMATE PEAK EXCITATION

Response excitation (acceleration) as a comparative measure of DYNAMIC RESPONSE

REFERENCE - STRUCTURAL ENGINEERING ART & APPROXIMATION (P. 136-7 / CHP 2.12)



WEIGHT (MODAL MASS or MASS effective in response)

- W (BRIDGE) - 350 kN (3500 kg)
- Mass forcing the resonant response wp (person) - 0.75 kN (75 kg)

Peak ACCELERATION RATIO (a/g) To be found

occurs at resonance → $a/g \approx \frac{1.3 \alpha w_p}{2 \rho \; W}$

α - factor depending on activity (0.5 WALKING)

ρ - DAMPING RATIO ≈ 0.02 (2%)

$\approx \frac{1.3 \times 0.5 \times 0.75}{2 \times 0.02 \times 350} = 0.034$

If $g \approx 10\,m/s^2$ $a = 3.4\%\,g$ **OK FOR PEDESTRIANS**