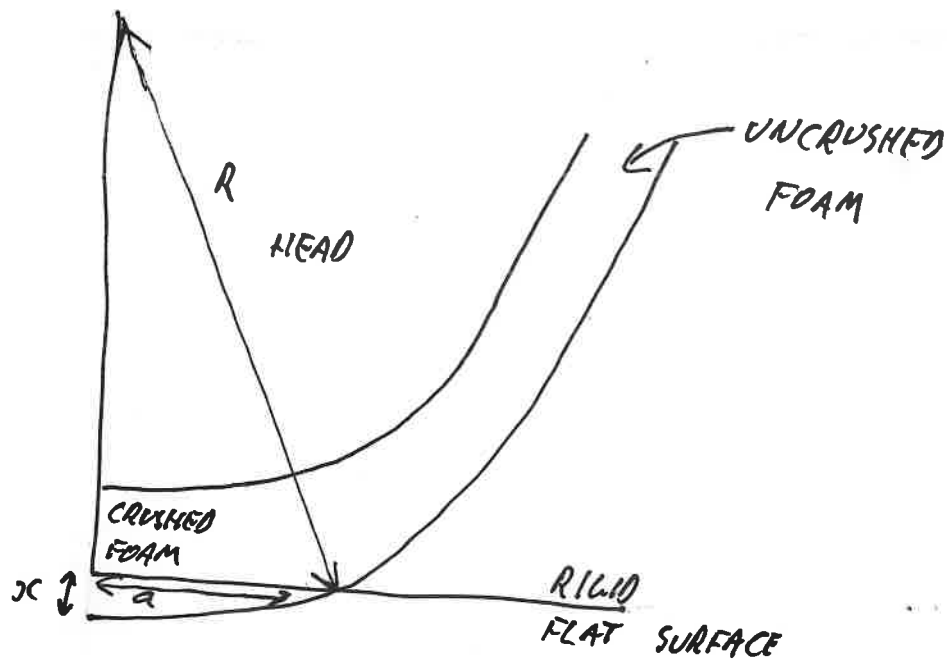


DESIGNING A HELMET

①



- HELMET RADIUS = R
- CRUSH DISTANCE = x
- FOAM CRUSHES OVER A DISC OF RADIUS, a

- FROM PYTHAGORAS $R^2 = (R-x)^2 + a^2$
 $R^2 = R^2 + x^2 - 2Rx + a^2$ ($x^2 \approx 0$)
 $\therefore a^2 = 2Rx$

- CONTACT AREA $A = \pi a^2$
 $\therefore A = 2\pi Rx$

- $\sigma = \frac{F}{A}$
 $\therefore F = \sigma A$
 $= \sigma_y A$
 $= \sigma_y \times 2\pi Rx$

TYPICAL
VALUES

$R = 140 \text{ mm}$
 $\sigma_y = 0.7 \text{ MPa}$

$$F = 27 \times 140 \times 10^{-3} \times 0.7 \times 10^6 x$$

$$F \approx 600,000 x$$

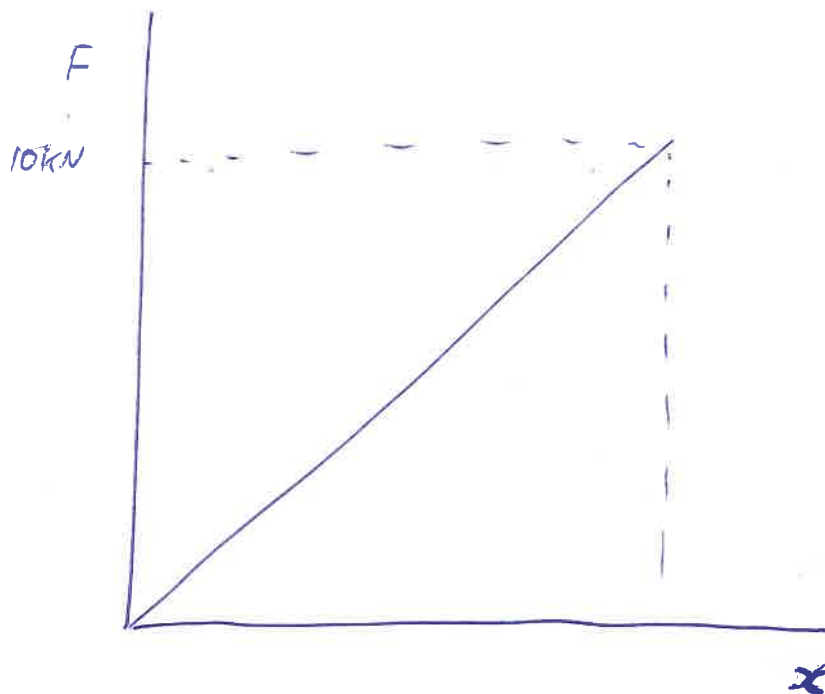
$$\leftarrow F = Kx$$

$$\frac{F}{x} = \text{STIFFNESS}$$

$$= 600,000 \text{ N/m}$$

$$= 600 \text{ N/mm}$$

$\Rightarrow$ STIFFNESS OF FOAM



TO LIMIT F TO $10,000 \text{ N}$ $\leftarrow$ ELSE RISK OF CONCUSSION OR MINOR HEAD INJURY.

$$x = \frac{F}{K} = \frac{10,000}{600,000} = \underline{\underline{16.7 \text{ mm}}}$$

$$\text{ENERGY ABSORBED} = \frac{1}{2} Fx$$

$$= \frac{1}{2} \times 10,000 \times 16.7 \times 10^{-3}$$

$$= \underline{\underline{83.5 \text{ J}}}$$

$$\frac{16.7}{x} = 0.8$$

FOAM "BOTTOMS OUT" WHEN STRAIN = 80%

$$\frac{16.7}{16.7} = 0.8$$

$$\frac{16.7}{x} = 0.8$$

$$\therefore x = \underline{\underline{20.9 \text{ mm}}}$$

WHAT ABOUT HIGHER ENERGY IMPACTS?

③

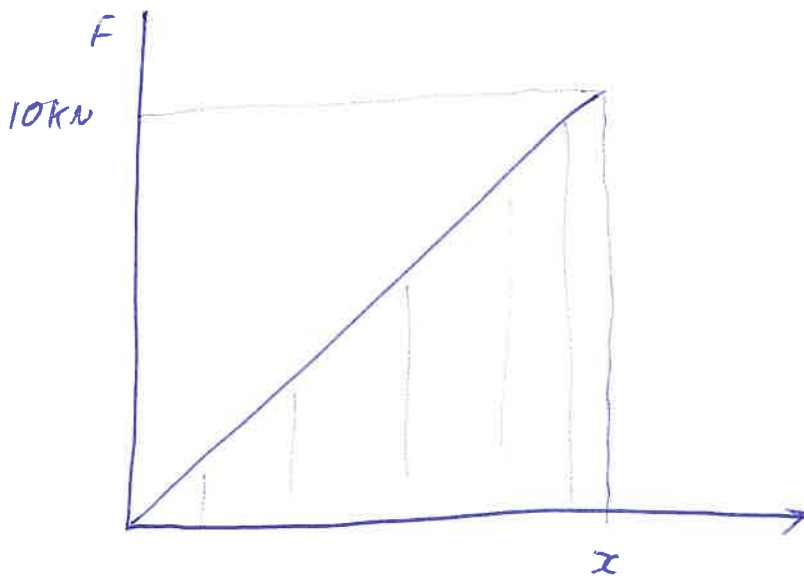
• FALLING FROM 5m WHILST BOULDERING.

$$K.E. = \frac{1}{2}mv^2$$

$$v^2 = u^2 + 2as$$

$$v = \sqrt{0^2 + 2 \times 9.81 \times 5}$$
$$\approx \underline{\underline{10 \text{ m s}^{-1}}}$$

$$K.E. = \frac{1}{2}mv^2$$
$$= \frac{1}{2} \times 5 \times 10^2$$
$$= \underline{\underline{250 \text{ J}}}$$



$$S.E. = \frac{1}{2}Fx$$

$$x = \frac{2 \times S.E.}{F} = \frac{2 \times 250}{10,000} = 0.05 = \underline{\underline{50 \text{ mm}}}$$

~~STIFFNESS~~ STIFFNESS $F = Kx \therefore K = \frac{F}{x} = \frac{10,000}{50 \times 10^{-3}} = \underline{\underline{200 \text{ N/mm}}}$

LOWER STIFFNESS FOAM :

~~FOAM~~ THICKNESS = $1.25x$ TO STOP BOITDING. OUT

$$= 1.25 \times 50 = \underline{\underline{62.5 \text{ mm}}} \quad \text{OR } \frac{50}{0.8} = 62.5 \text{ mm}$$

STATIC FOAMS : CRASH MATS

①

(INFO ONLY)

$$v^2 = u^2 + 2as$$

CLIMBING WALL = 5m

$$\begin{aligned} v &= \sqrt{u^2 + 2as} \\ &= \sqrt{0^2 + 2 \times 9.81 \times 5} \\ &= \underline{\underline{9.9 \text{ ms}^{-1}}} \end{aligned}$$

LET $v = 10 \text{ ms}^{-1}$

IF $m = 5 \text{ kg}$ (NECK SEPARATES BODY MASS)

$$\begin{aligned} \text{K.E.} &= \frac{1}{2} m v^2 \\ &= \frac{1}{2} \times 5 \times 10^2 \\ &= \underline{\underline{250 \text{ J}}} \end{aligned}$$

~~RISK OF CONCUSSION OR MINOR HEAD INJURY~~

~~FORCE > 10 kN~~

• AT END OF IMPACT

$$\text{K.E.} = \text{S.E.}$$

IF LIVER

$$250 = \frac{1}{2} K x^2$$

①

IF USING CLOSED

~~FLAT MATS USE CLOSE~~ CELL FOAMS : $K > 100 \text{ kPa}$

$$\begin{aligned} x &= \sqrt{\frac{2 \times 250}{100 \times 10^3}} \\ &= 71 \times 10^{-3} \text{ m} = \underline{\underline{71 \text{ mm}}} \end{aligned}$$

(E.G. JUNE CRASH MATS)

THESE MATS TEND TO BE $\sim 75 \text{ mm}$

• NOW

$$F = Kx$$

(2)

$$= 100 \times 10^3 \times 71 \times 10^{-5}$$

$$= \underline{\underline{7.1 \text{ kN}}}$$

• RISK OF CONCUSSION OR MINOR HEAD INJURY
IF FORCE $> 10 \text{ kN}$.